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REPAIR TECHNOLOGY OF MACHINERY AND EQUIPMENT

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LECTURE COURSE

Kharkiv 2017

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While preparing the lectures, it was used domestic and foreign experience in machinery repair, relevant research and developments and results of basic research carried out and implemented in the educational process by the authors. The lectures were published in Ukrainian and English in separate books.

This lecture course can be useful for students and teachers of engineering specialties of higher educational institutions of III-IV accreditation levels, masters, graduate students, and a wide range of engineering and technical personnel of machine building and repair companies and technical service workshops of various forms of property both in Ukraine and foreign English-speaking countries.

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Content

INTRODUCTION

Repair Technology of Machinery and Equipment – a complex discipline, which embraces a major area of scientific knowledge, each section having an independent significance.

The subject of the discipline "Repair Technology of Machinery and Equipment" (RTME) is a set of functionally related means of technological equipment, objects of production and workers to influence broken parts of machinery, appropriate means of production to restore proper operation of machines with the lowest costs of labor and money.

RTME is based on the knowledge of general technical and general theoretical and professional subjects that must be taught after studying courses "Higher Mathematics", "Chemistry", "Physics", "Material Science and Technology of Constructive Materials", "Machine Parts and Design Principles", "Tractors and Cars, "Agricultural Machinery", "Cattle-breeding Machinery and Equipment", "Machine Reliability".

Repair Technology of Machinery and Equipment is closely connected with engineering technologies, including tractor and farming machine building. However, if the machine building technology is a branch of science that deals with the study of laws that occur while producing machines, the repair technology is a branch of science that deals with the study of laws in the process of deterioration and restoration of their properties on-stream and being repaired.

The content of the discipline is to solve practical and theoretical issues while using the repair information for effective impacts on machines production and provide their working capacity on-stream. To improve machine reliability and equipment it is necessary to combine all the effects in one powerful system that provides a set of technologies, based on modern science and international experience when repair is carried out.

The essence of the discipline is to study a general technological process of repair and characteristics of production, basic technological means used while machinery parts are repaired or restored.

While preparing the lectures, it was used domestic and foreign experience in machinery repair, relevant research and developments and results of basic research carried out and implemented in the educational process by the authors. The material presented in accordance with the curriculum will promote high-quality and focused training of specialists on repair of machinery and equipment.

The lecture course was published in Ukrainian and English in separate books for students studying in English at institutes of higher education, and English-speaking students studying the appropriate educational direction in Ukraine. The structure of the course includes 17 lectures that allow teachers of the discipline to maneuver a number of lectures under the specific educational program. These English lectures allow foreign specialists to learn the structure, technology and expertise of repair production in Ukraine.

This lecture course can be useful for students and teachers of engineering specialties of higher educational institutions of III-IV accreditation levels, masters, graduate students, and a wide range of engineering and technical personnel of machine building and repair companies and technical service workshops of various forms of property both in Ukraine.

Lecture № 1
Introduction to RTME. Theoretical bases of production technology and machinery repair

Change of technical state of machines and occurrence of component defects

In any car, regardless of whether it works, stands idle or is transported, physical and mechanical and geometric parameters of its parts change. At the same time technical and economic indicators of the construction in general decrease, and there comes the moment when its further operation is impossible or inefficient. Therefore, during operation any car requires maintenance to keep up its technical state and repair to restore technical and economic parameters when operation becomes impossible.

However, when a car (or other equipment) has failed, it does not mean that all parts and couplings lost their parameters and characteristics. As parts are made of materials with different physical and mechanical properties and intensity of wear varies, application of tolerances for dimensions, errors of shape and roughness of surfaces, indicators of thermal processing and other parameters cause randomness of favorable and unfavorable combinations of these parameters in the coupling and, as a result – different life cycle; varying tension of parts and components; durability of machinery elements have significant differences due to different working conditions.

As studies and practice show, repair of agricultural machinery cannot be avoided technically, on the one hand, it is economically reasonable, on the other hand. The majority of worn parts has a high depreciable value: metal and materials are spent 20-30 times less during restoration than during production of new ones.

The process of qualitative change of nature objects is called a technological process. <u>Technology</u> is a set of processing methods, production, change of a state, properties and a form of raw materials, materials or a semi-finished product to receive finished products.

The machinery repair technology is closely related to engineering technology, including automobile, tractor and farm machine building. However, if the engineering technology is a branch of science that deals with the study of patterns that occur in machine production, then the repair technology is a branch of science that deals with the study of patterns during repair. The technology of repair production differs from production technology in a number of significant features that allow it to sort out a number of independent scientific disciplines.

The main feature of the repair production technology is that the initial object under repair is not raw materials and semi-finished products, as in the production process, but components of vehicles that have changed during operation and, therefore, exhausted their resource or have some reserve. Repair production is associated with partially or completely worn out and disabled machine parts. Therefore, the science of repair technology should be based on recognition of the state of machines and parts that come to repair. The machinery repair technology has such features as availability of operations for disassembly, cleaning, washing and checking operation in the technological process, as well operations associated with restoration of initial properties of disabled parts. When machinery repair is carried out, we use not only new parts, but also partly worn and restored parts (suitable without repair).

Thus, <u>the subject of the scientific discipline</u> "Technological systems of repair production" is a set of functionally connected means of technological equipment, production items and performers to influence on faulty machinery parts of appropriate production tools to use of their residual life and machine operability restoration with the least labour inputs and costs. Based on the subject definition, main tasks of the machinery repair technology as a science are the study of regularities of changing the state of machinery parts in use and their impact on residual life, regularities of performance – technological processes during machinery repair and identification of parameters. It is possible to increase quality and efficiency of repair influencing on those parameters.

<u>The purpose of the discipline</u> "Technological systems of repair production" is to form scientific understanding about principles of designing progressive technological processes with the use of effective methods of production and worn-part reclamation on the basis of using repair and technological classification of machinery parts; to provide skills in development of standard and group technological production processes and worn-part reclamation using mechanization and automation.

<u>The content of the discipline</u> is solving practical and theoretical issues using repair information for effective influence on machine production, and also ensuring working capacity of machines with modern technological means during operation. To study the course, the following types of training are used: lectures, laboratory works, independent work and examinations.

The subject of the discipline is the means of influence on machinery worn parts of appropriate tools to provide resources and durability of machines with the least labour inputs and costs.

The machinery repair technology belongs to applied sciences, the object of which is machines, industrial machines, mechanisms and other technical devices. It is based on the theory of friction, lubrication, wear, aging and reliability of machines.

Harmful phenomena and destructive processes affect machinery elements (couplings and parts) on-stream. It leads to worsening functional properties, changing a technical state. The level of machine technical state characterizes its ability (or inability) to carry out specified functions and is estimated by the comparison of the actual values of parameters specified in the technical documentation.

Destructive processes are related to the working process which is carried out by the machine, external environment, material nature etc. The main types of destructive processes include: friction and part wear, plastic deformation, fatigue phenomenon, corrosion. Acting on the part, destructive processes change its size, shape and physical and mechanical properties; they form various defects resulting in malfunction of assemblies, units and machines. (Fig. 1).

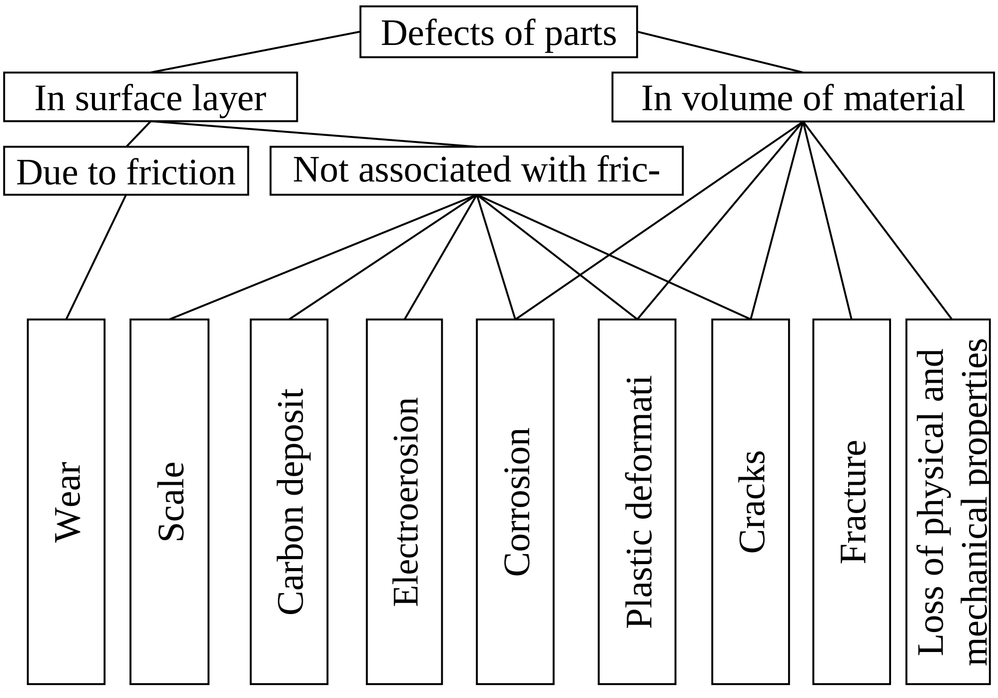


Fig. 1 – Classification of defects of machine parts

Wear of rubbing bodies should be considered as a total result of simultaneous course of elementary acts of destruction and a change of material properties whose nature is various. It defines variety of wear modes that take place on the same contact platform in any set timepoint and is the reason of development of a large number of classification of wear modes, each of which differs in the principle, taken as the basis.

Classification of wear modes

According to State Standards of Ukraine (DSTU), all wear modes can be divided into four groups: mechanical; mechanochemical, fretting-corrosion and electrosparking. The feature of the classification is a wear mode (Fig. 2).

Mechanical wear is a result of mechanical action due to friction.

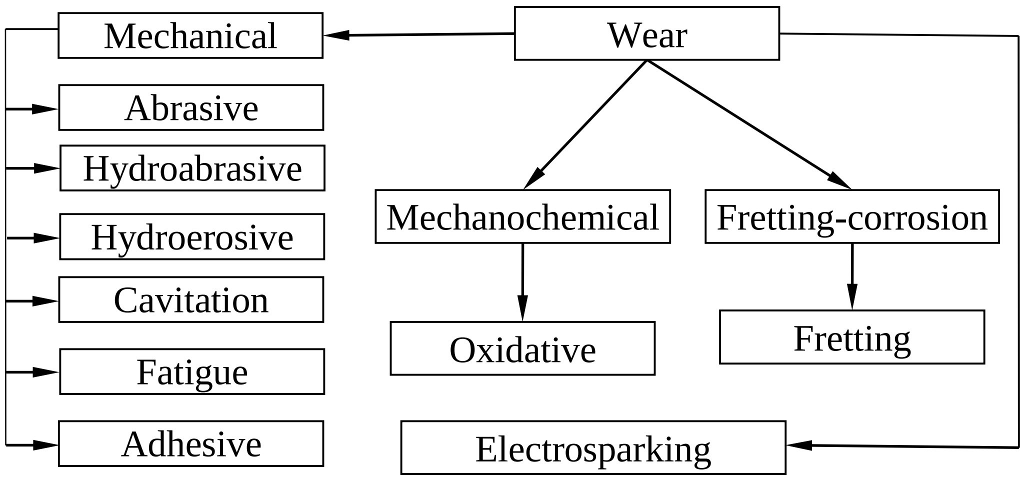


Fig. 2 – Classification of wear modes

Abrasive wear is the mechanical wear due to cutting or scratching actions of solid bodies or parts which is the most common mode of agricultural machinery wear.

This wear mode is realized due to:

- ➢ unfixed parts which transmit the pressure of mass (abrasive particles in soil, rocks, bulk cargoes during transportation) which deforms;
- ➢ free particles that fall in the contact zone of rubbing bodies (oxide films, wear particles, dust)
- ➢ firmly fixed solid grains on the rubbing surface of one of the bodies which are coupled. They are structural components of elements' material of friction pair, parts of abrasive, bars and other tools, particles of carbon deposit on internal combustion engine sidewalls.

In the abrasive environment the process of wear is characterized by microcutting and repeated plastic deformation of the same metal microvolumes as a result fatigue destructions of the upper layer take place.

Hydroabrasive and gasoabrasive wear is abrasive wear as a result of actions of solid bodies or solid particles which are collected by the liquid stream (for example, wear of pump blades supplying water which contains sand) or gas. During hydroabrasive and gasoabrasive wear the mechanism of the abrasive wear described above acts but with less intensity due to lower specific loads on the material.

Hydroerosive wear is mechanical wear of the surface as a result of fluid flow.

Gasoerosive wear is mechanical wear of the surface as a result of gas flow. Hydroerosive and gasoerosive wear are often combined with other wear modes.

Cavitation wear is mechanical wear when solids move relative to the liquid and gas bubbles burst at the surface, creating high local specific pressure or high temperature. Imposing a large number of such impacts on a metal surface, cavities with a diameter of 0,2-1,5 mm are formed. There occur flows around them creating an impression of sunken craters.

Fatigue wear includes cases when a tribosystem works, there are no abnormal damages (seizure, scuffing, microcutting, burning surfaces, etc.), friction runs in normal conditions, with lubricant, but owing to friction, the surface material "fatigues" and begins to separate in the form of wear particles. Here it is possible to draw an analogy to the concept "fatigue strength".

There are fatigue wear of two modes: polycyclic and monocyclic. Polycyclic wear arises at elastic contact. Repeated influence on the microasperity leads to gradual accumulation of microdefects, microcracks formation. When merging, they form superficial macrocracks which cause material destruction and wear particles separation. At monocyclic wear a common action of normal and tangent loadings during friction leads to the fact that the maximum tangent tension arises not on the surface, but under the contact spot at a small depth where damages are collected and cracks are formed. A crack often arises on the surface of fragile material. Monocyclic wear is observed at plastic surface deformation (without cutting) of the softer material by asperities of the firmer one. In places of such deformation fill slopes are often formed which can separate as wear products at the subsequent passes.

Fretting wear is mechanical wear of contacting bodies during small vibrational relative movements.

Adhesive wear is the phenomenon of formation of solid compounds in areas of actual contact of rubbing bodies, deep tearing of material of one body and transferring it to the friction surface of another one which is followed by change of their linear sizes. Adhesive wear is observed in gears and screw gears, heavily loaded sliding bearings, antifriction bearings, friction pairs of a hydraulic piston – the plug, the cylinder – a piston ring, guides of metal-cutting machines – carriage, in tribosystems which are operated in vacuum or inert environment; in combinations which are operated at high temperature (rollers of pusher furnace, rolling machines, brake parts).

Mechanochemical wear is the result of mechanical friction action, accompanied by chemical and (or) electrochemical material interaction with the environment.

Oxidative or oxidation wear is a special case of mechanochemical wear. It proceeds in conditions when the metal enters into the chemical reaction with environment oxidizers or lubricants. Air oxygen, interacting with metal, forms an oxide film on it which considerably influences the process of friction. In case of friction in the conditions of lubrication metal is oxidized by oxygen dissolved in oil. Oxidized films in the places of surface contacts protect metals from direct approach to the distance when gripping is possible. Inability of oxidizing films to gripping is caused by their nonmetallic nature.

Oxidized films are gradually erased during friction or, coming off, they are removed by the lubricant. Then oxidized films are formed again. Thus, oxidizing wear represents wear of continuously renewable oxidizing films.

Oxidative wear takes place when the speed of oxides film formation is higher or is equal to the speed of their destruction. Otherwise, the course of other wear modes, for example, adhesive is possible.

Oxidative wear is experienced by antifriction bearings, hinge-bolt connection, metal wheels of friction gears, wrist-pins of engines, parts of hydraulic pumps and internal-combustion engines.

Fretting corrosion wear is a destruction process of friction surfaces during small cyclic movements of coupled bodies which are followed by the change of the linear sizes of these bodies. This process is shown as a strongly expressed process of oxidation and gripping materials of rubbing bodies, localized on small sites of the contact and is followed by fatigue and abrasive wear. This wear mode is observed in rivet, pegging and key-and-slot joints, on pairs shaft-bush, on landing surfaces, in hinge pivots, carriage springs, regulators of electric contacts, cam boxes, steel ropes.

The requisite of fretting corrosion emergence is slipping of contacting surfaces of bodies beginning from values which considerably exceed the interatomic distance. The maximum shift of rubbing bodies that fluctuates shouldn't exceed the contact spot size. Thanks to it wear particles can't go beyond the contact platform, but provide emergence of high pressures on local sites.

Wear kinetics at fretting corrosion happens in the following case. At first there occurs dynamic loading of the material of the contacting roughnesses and removing adsorptive and oxide films on contact spots. During repeated loading the top material of some contacting roughnesses is plastically deformed. It leads to increasing to concentration of defects and physical and chemical activity of the material on contact spots.

Further loading is followed, on the one hand, by growth of material's local oxidation intensity, and on the other hand, – formation of junctions of small sizes. The shift of the rubbing bodies causes destruction of these junctions and separation of microscopic metal particles from the surface of one of rubbing bodies.

The friction surface of parts subjected to fretting-corrosion wear is covered by dents and resembles by the nature of destruction a surface after corrosion wear. Damages concentrate on the separate sites corresponding to the waves' tops.

Electrosparking wear results from the impact on the friction surface of the electrical discharges when the current flow is passing.

In actual practice of work of mating components these or those wear modes are often combined. In some friction conditions the combination of two different wear modes can lead to new phenomena. An example of this is wear at fretting corrosion – a combination of abrasive wear with oxidative surfaces under certain contact conditions.

An approximate conception of the speed of wear can be gained from such data as following: micron/h: oxidizing wear – 0,1-0,5, abrasive wear – 0,5-5,0, adhesive wear – 10-15.

The wear speed significantly decreases in conditions of friction when lubrication is present. According to the division type of friction surfaces with a lubricating layer, lubrication is divided into three main types: hydrodynamic (full division of friction surfaces is carried out as a result of the pressure arising in the liquid layer during relative movement of surfaces), boundary (wear and friction between the surfaces moving from each other are defined by the properties of surfaces and lubricant different from volume viscosity) and mixed (it is carried out partially by hydrodynamic lubrication, and partially by boundary lubrication). For example, lubrication of main bearings of the crankshaft.

Impact of macro- and microstructure of parts' material on their operational properties

Depending on the type and quality of the part processing, formation of properties, various macrostructural changes appear on the friction surface. They slow down or accelerate metal wear process. Intensive destruction of the part working layer and wear are influenced by tension concentrators. They can be connected with deep scratches or metal structure (large nonmetallic inclusions, pores, sinks, cracks, etc.).

A great influence on wear resistance has the microstructure of parts' material, a phase structure and a physical state of the surface layer. Materials with mainly ferritic or ferrite-pearlite matrix have minimum resistance against wear, and materials with bainite and martensite basis with inclusions of cementite and special carbides have maximum one.

High-strength and special cast iron (alloyed by nickel, chromium, molybdenum) has high wear resistance. They have up to 20% of the carbide phase, bainite matrix and graphite inclusions. The last are characterized by the lubricating effect. Such materials differ in the low friction coefficient.

During operation, depending on the extent of operating loadings, the speed of sliding and temperature friction conditions, special structures are formed on the surface. In the initial stage of operation structural changes occur at the electronic level: density of dislocations increases, and then sorting take place. Occurrence of such structures leads to changing the microstructure. Excess phases are allocated on the congestion sites of dislocations. They are, first of all, carbon (carbides, nitrides), oxides which cause discontinuity of the surface layer and chipping individual sections.

In the process of friction, the thin surface layer is subjected to shock peening the value of which is estimated by the change of microhardness of the phase. The softer is a structural component, the greater is its hardening degree. The depth of the cold-worked layer depends on the size of the specific pressure and, as a rule, doesn't exceed 0,5-0,8 mm. In solid phases (carbides, cement carbide) facing is insignificant, and the effect of big specific pressures is revealed in formation of dislocation grids and subboundaries.

In addition, it is possible "white" layers to appear on the friction surface. They cannot be etched, but may have a dual nature: Created under the influence of high specific pressures and high temperatures, they represent ultradisperse (very small) conglomerate of phases, including carbides, carbonitrides, created as a result of the chemical interaction of metal with oxygen and by forming highly solid oxides.

Such structural changes on the friction surface lead to gradual destruction. That is why before repair and restoration of the surface layer of parts it is necessary to eliminate the damaged zones which can become a cause of destruction during further operation or even repair (surfacing, spraying, etc.).

The level of stretching tensions has also a significant effect on the operational indicators of parts. The higher it is, the greater is the tendency of the part working layer to damages. The level of stretching tensions is especially high during worn-part reclamation by surfacing, spraying, superficial temper. Relaxation annealing is carried out to reduce such tensions. After restoration the part is subjected to superficial temper and the macrostructure improves (spongy defect decreases).

General regularities of wear process

Wear process is the irreversible monotonous process with gradual accumulation of wear, which is possible to present in the form of integrated function:

$$U(t) = \int_{\upsilon}^{t} \upsilon(t)dt, \qquad (1)$$

where *U(t)* – accumulated wear during time t;

υ(t) – a wear process speed which generally can depend on the wear time.

The timing change of the wear speed can be affected by the shape of conjugate surfaces, their roughness, and a permanent or discrete contact of surfaces during mechanism operation etc.

Wear dynamics. Fig. 3 shows curves variants of wear dynamics of friction pair surface.

Let’s consider the most common variant Fig. 3, *a* – a typical curve, which consists of three specific areas:

I – characterizes initial work of the coupling when the process of geometry change (roughness) of friction surfaces and physical and mechanical properties of material's surface layers distinctly takes place. They become apparent under constant external conditions when friction work, temperature and wear intensity are decreasing. This initial period defines the bedding process of the friction pair;

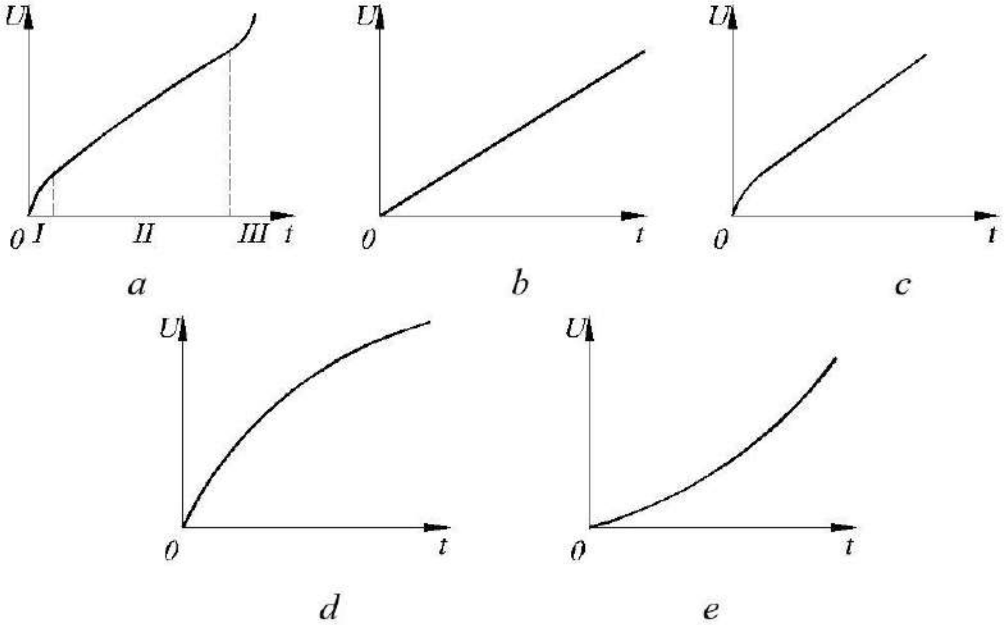


Fig. 3 – Curves of wear dynamics.

II – characterizes normal work of the coupling. During this period gradual accumulation of wear takes place; in some cases, it has a steady linear character (on average the wear speed is constant);

III – describes intense, forced accumulation of wear. During this period the work of the coupling can be followed by occurrence of various noises and knocks and even lead to part destruction i.e. having achieved the third period, the further work of the coupling is inadmissible.

The most typical graphics of wear dynamics are shown in Fig. 3, *b, c, d, e*.

b – the line that is typical for abrasive wear of parts of farm vehicles (ploughshare, hinges of conveyor chains, etc.);

c – the curve that is typical for wear of shaft neck conjugated with the seal and for moving couplings under work circumstances when the gap is always chosen in one direction (for example, the roller of the fuel pump pusher jointed with an axis);

d – the curve that is typical for couplings working at big specific loadings which increase simultaneously with increase of the gap (for example, crankshaft – bearing);

e – the curve that is typical for wear of parts as a result of fatigue destruction of metal surface layers (treadmills of racers of bearings, gear teeth, etc.). During the initial period there is almost no wear because fatigue defects of the metal structure are accumulated, and then lead to forcing the separation of particles, i.e. wear.

It is known, the process of wear is categorized as a random processes, which leads to dissipation of the operation time of the same parts to their limit condition, i.e. to scattering of the resource of parts.

The assessment of the real resource of parts (knots, units of machines) and its probable characteristics (the average resource, the gamma percent resource, etc.) have a great importance as the information obtained during such research is initial to identify the reserves of product resource increase.

The assessment of durability parts and couplings is to search a function of resource distribution, which is defined according to the data conducted on purpose of operational or accelerated tests.

Methods of wear determination

Micrometrized measurement of parts is the most common method applied to identify parts wear dynamics of parts, research of the wear nature of working surfaces (wear topography).

For micrometrized measurement of parts universal and special measuring micrometric means are used. The size of wear is defined as a difference of sizes of component surfaces before and after wear. The method has its disadvantages: it is necessary to disassemble the unit, it is difficult to repeat measurements in the same points, and it is impossible to separate that part of wear which has occurred owing to plastic deformation from the whole magnitude. Reduction and even elimination of the specified disadvantages in some cases can be reached by carrying out some special statistical tests without intermediate disassembling, using special devices to ensure repeatability of measurements in the same places.

Strip chart recording of surfaces is carried out by special devices – profilographs which give a chance to write down graphically the actual relief of the worn-out surface.

The method of artificial bases is applied in two variants: by means of prints and cutting holes. In the first case it is applied by pressing a dent of a certain form (a cone, a pyramid) on the friction surface. Descending deepening, which is individually measured on a print in the plan before and after wear, the magnitude of wear is determined. In the second case on a friction surface holes are cut with a trihedral diamond rotating cutter. In this case, unlike the previous way, there are no bulges from pressing.

Determining wear by weight loss is an integrated method as the general wear of the part surface is established. The measurement is taken by weighing parts before and after wear. The method is applied to the parts of small sizes with the use of analytical scales with the division value 10^{-4}g.

Determining wear by the content of wear products in oil is carried out on the selected oil test (for example, from the engine case). The content of metal is determined by the chemical or spectral analysis of the burned oil ashes. The advantage of the method is that it does not require disassembly of the unit or assembly, the disadvantage is that it is impossible to determine the quantitative wear of certain parts.

Determining wear by means of radioactive isotopes is carried out according to the following scheme: a radioactive isotope is introduced into a sample (part). Wear products are taken out by oil together with the radioactive isotope which passes through the counter of impulses measuring radioactivity of lubrication increasing when a part is being worn. It is possible to determine by this way the wear dynamics without disassembly, but without the data on distribution of wear on the surface. The way demands special equipment.

When repair is carried out, not only the working capacity (or serviceability) of the machine but also its overhaul life must be restored. Therefore, only parts and couplings with residual life equal or exceeding the overhaul life resource of the unit or the machine are left for further operation in the machine. In this regard the limit condition of parts and couplings gets a bit different sense in repair and is defined as admissible in repair (or just admissible) value of the state parameters.

Thus, the allowable value of the state parameter is its value when the residual life of parts or couplings is equal to overhaul life of a separate element (a knot, a unit) or the machine in whole.

Parameters of the limit (allowable) state of parts and couplings include the limiting values of the coupling gap, the size or wear of part items, shape errors (ovality, conicity) and mutual location of axes and surfaces (misalignment, radial beating, etc.), and also parameters of elasticity of springs, piston rings etc.

Limiting and admissible values of geometrical and other parameters can be established by the following ways: theoretical calculations; micrometrized measurement of parts to be repaired and the corresponding statistical analysis of data; special tests (accelerated or operational); comparison with the previous design (at the first production phase of a new machine). Capacities are set by technical, technological and economic criteria.

Before considering the problems of repair production let's recall some terms and concepts of the reliability theory.

Reliability – an object's ability to store in time in set limits the values of all parameters that characterize the ability to follow the necessary functions in specified modes and application conditions, maintenance works, repairs, storage and transportation. The object in use in some timepoint can be serviceable or faulty, functional or unable to work.

State of operability is a condition of an object when it meets all requirements of the normative and technical and (or) design documentation.

Workable condition (functionality) – a state of the object characterized by its ability to perform all required functions, meet the requirements of the normative and technical and (or) design documentation. The efficient object can be considered as faulty. For example, the tractor keeps working capacity when there are dents on facing, a faulty counter of engine hours etc.

When an object changes one state to another, it is determined by the following events.

Damage – an event which is violation of the object operative condition, when it keeps working.

Failure – an effect of loss of the object's ability to perform a required function, i.e. object functional state violation.

It should be noted that such properties of reliability as durability and non-failure operation have the greatest influence on the operational qualities of agricultural machinery.

Failure-free performance – an object property to carry out the demanded functions in certain conditions for a set period of time or operating time.

Durability – a property of the object to perform desired functions before moving into marginal status in the installed maintenance system and repair.

Limit condition – a state of the object when its further operation is unacceptable and inappropriate or restoration of its operable condition is impossible or impractical.

Durability is quantitatively estimated by two indicators: resource and service life.

Resource – total object operating time from the beginning of its operation or renewal after repair before transition to the limit state. (duration or volume of the object operation.).

Service life is calendar duration of the object operation from its beginning or restoration after repair to the limit state.

Lecture № 2
General technological process of machinery and equipment repair. Basic concepts and definitions

Structure of machinery repair technological process

Relying on the concepts and terminology of reliability defined in the science, it is easy to identify relevant terms used in technical equipment maintenance.

Repair is a complex of operations designed to restore proper operation or efficiency of products and resource restoration of products or their component parts. There are two types of agricultural machinery repair: overhaul and maintenance.

Overhaul is a kind of repair performed to restore proper operation and full (or nearly full) recovery of product resource with replacement or restoration of any component parts, including the basic ones. Relatively we distinguish the overhaul of machines and component parts (assemblies).

Maintenance is a kind of repair performed to provide or restore machines' working capacity with replacement or restoration of certain component parts. The component parts under repair reached the limit condition are subjected to overhaul, and those which have not reached the limit condition are subjected to maintenance (if necessary).

Maintenance can be carried out both on the site of using a machine, and in the appropriate workshops or maintenance stations. Planned current maintenance of the tractors is carried out according to the results of resource diagnostics in a certain period of operating time, provided by the normative documents and maintenance of the combines and agricultural machinery – after harvest seasons and field works, respectively.

The most common methods of machinery repair are the following:

repair with responsibility and repair without responsibility, which differ in the following: during the first one the renewable component parts belonging to certain machines (equipment) are retained, and during the second one are not;

unit replacement is a kind of repair without responsibility when defective assemblies and units are replaced by new or previously repaired ones. The unit replacement method is used to repair machines, design features that allow dividing them into component parts (assemblies and uits). Thus, each component part must be autonomous, constructively completed, easily separate (without complex disassembly and assembly and adjustment works) from other parts of the machine. Due to autonomy machine component parts can be repaired at overhaul plants on one's own.

The terms "restoration" and "repair" of parts are considered as technological processes, implementation of which is aimed at restoring original properties of parts, but they differ in terms of achieving these properties.

A remanufactured part must have complete interchangeability due to dimensional accuracy parameters, and physical and mechanical and other properties of the surface layers and in the amount of the material provide the resource to the limit condition not less than the new one (unless the other is determined by the current normative and technical documentation).

A repaired part should change its inoperable into operable condition and keep a complete and partial interchangeability; the corresponding technological operations should ensure its resource at least to the next regular repair.

Manufacturing process of repair – a complex of interconnected human actions, production tools and separate process required at the given enterprise to repair machines, equipment, machinery and other mechanisms (repair objects).

The manufacturing process includes basic (technological), secondary processes (production of appliances and tools, the repair of one's own equipment) and service processes (intraproductive material and parts transportation, storage operation etc), which ensure accomplishment of the basic (technological) process.

The technological process of repair is a basic part in the manufacturing process and includes actions on a consequent change of the state of repair objects or their component parts (machine, assembly, unit, part) when their proper operation or efficiency is restored.

The technological process of machinery repair, in general, includes a set of component parts, closely related in their technological sequence. The structure of the technological process also characterizes the extent of operation dismemberment. The need to develop the variants of the structural construction of the technological processes is determined by a number of types and brands of repair objects, types of overhaul plants according to their assignment, specialization and program.

Fig. 1 shows the schematic diagram of the overhaul technological process of machines. It illustrates the enlarged dismemberment of the process into component parts and their technological links from the beginning of repair to the output of the sound machine.

Technological process schemes must be informative (within their assignment). In the schematic diagram, for example, in addition to the composition and assignment of the certain parts of the technological process, one can find a multistage of clearing work, the need and nature of repair stock parts sorting etc., provided by the process.

The structure of the technological process can vary, for example, by branching on the main direction of the process because of the need to make (based on the results of the diagnostic control) technological solutions on the alternative features (Fig. 2).

If an overhaul plant has a large program, there is a possibility to divide the technological repair process into a large number of individual technological processes and create some conditions to fit out work places with highly productive technological equipment and tooling.

Technological equipment – the production means where repair objects or materials, means of the action on them, and if necessary – a source of energy are placed to perform certain parts of the technological process. Repair and technological equipment includes metal-working machinery, welding plants and deposition devices, heating furnaces, stands etc.

Production accessories – means of technological equipment which complement the equipment to perform a certain part of the process. Cartridges, lunettes, tool-based devices, parts and other belong to production accessories.

Diagnosis of repair objects

Diagnosis – the process of determining the technical state of the repair object (machine, assembly, unit, mechanism, part) at the appropriate operation stages and repair of agricultural machinery.

Diagnosis of machines on-stream is performed in accordance with the maintenance and repair plan. In case of sudden failures and machinery malfunctions, there is a diagnosis by order; its purpose is to identify and eliminate their causes.

Prerepair diagnosis of machines determines the capability of their further operation or need to repair, its type and content.

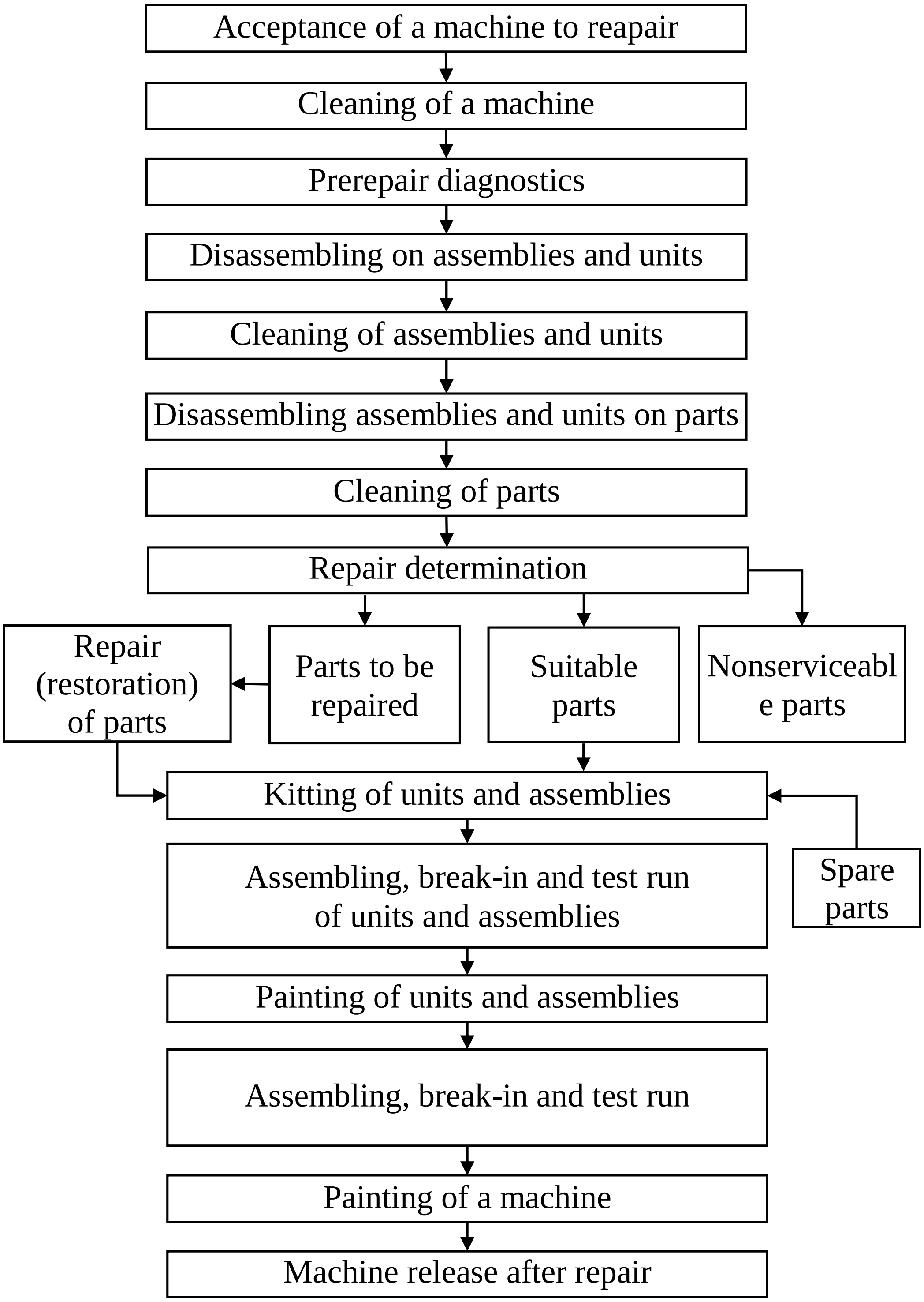


Fig. 1 – Schematic diagram of the overhaul technological process

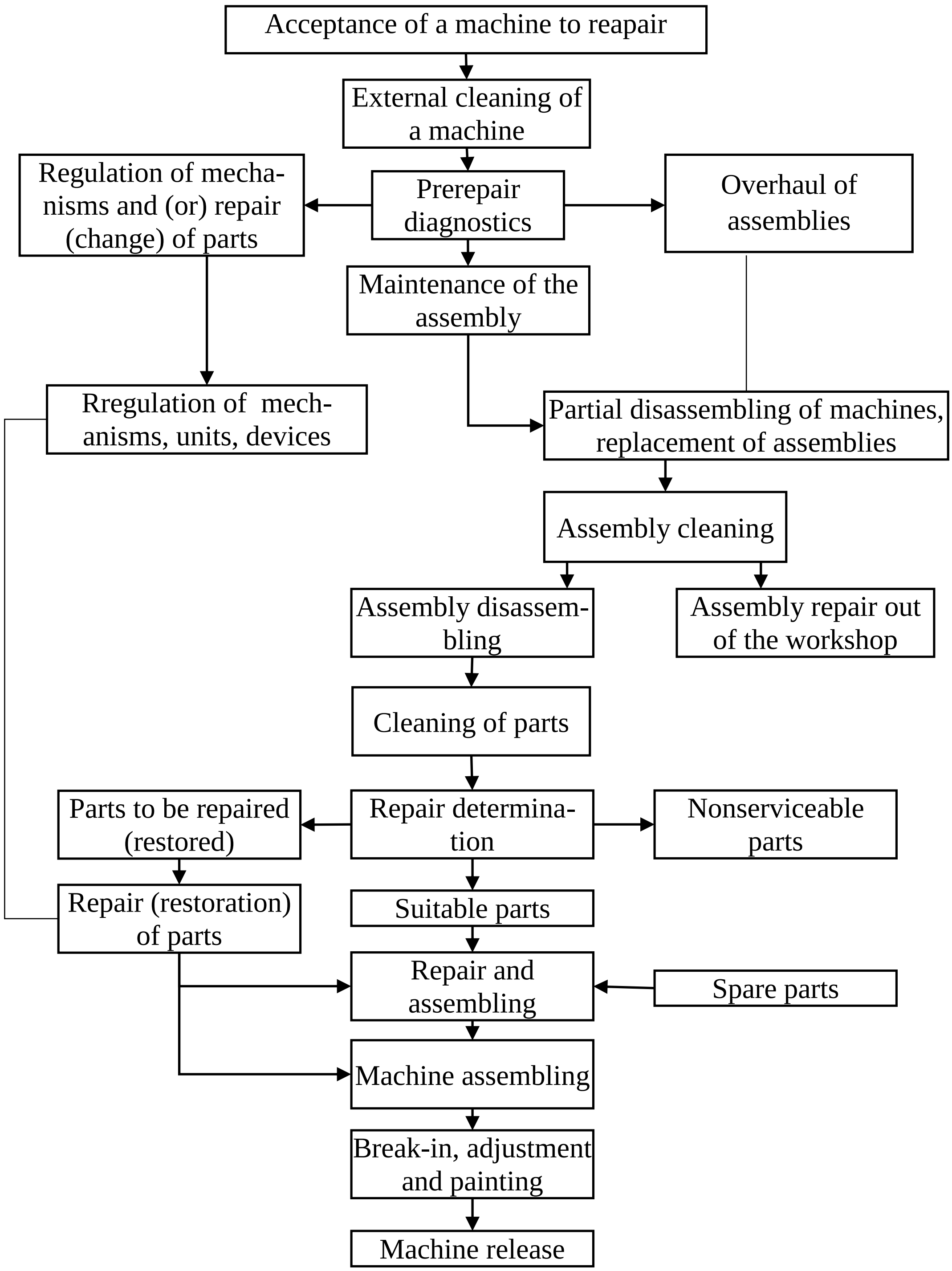


Fig. 2 – Schematic diagram of the machine maintenance technological process

Diagnostic operations are also performed while machines are repaired; it is fulfilled the following operation: precheck of assembly conjugations, bench running of assemblies and units before disassembly, repair determination of parts after cleaning works. All these operations are designed for the objective estimation of the technical state of assembling parts and making grounded decisions related to the repair technological process.

Post-maintenance diagnosis involves testing of units, assemblies and machines after repair, when it is determined the correspondence of their technical state with the requirements of the current normative and technical documentation for the given repair type and a brand of the

Methods and means of diagnosis. To determine the technical condition of machines two inspection methods are used: organoleptic, i.e with the help of the sense organs (examination, listening, touch test, etc.) and instrumental. The first method is subjective, with the limited reliability of estimates. At the same time it is simple and is used quite frequently for the preliminary estimate of the technical state of assemblies, mechanisms and systems. The second method provides the use of special devices, stands and other equipment that provide an objectivity of information by determining a change in the state parameters with the help of corresponding measuring means.

Acceptance of machines to repair

Tractors, cars, harvester combines and their assemblies must meet certain technical requirements, which are in effect in a particular period. They include requirements about the list and registration of technical documentation (technical passport, etc.) on the repair object, its completeness and the level of external cleaning, approved limitation on the missing structural elements (glass, handles of the cabins etc.), fasteners etc.

While leaving a machine or an assembly to be repaired, an acceptance report is registered, in accordance with the current international standards (GOST 24408 and GOST 18524, etc.) as well as the corporate standards of Ukraine (SOU 74.3-37-121: 2004 et al.), which are signed by the customer and the receiver of the overhaul plant. The act indicates the data about the prerepair operating time of the object, the type and a summary of necessary repair works and other contractual terms between the customer and the contractor. A separate document (act, warranty card) specifies a warranty policy regarding postoverhaul resource of the machine (or its parts), which the performer (an overhaul plant) guarantees when the fulfillment of the technical requirements on the repair object maintenance procedures in operation is provided.

Disassembling of machines, assemblies and units

In the total labor intensiveness of the machinery repair disassembly and assembly works comprise: 52-56% for tractors and 33-41% for cars.

A disassembling process is a complex of different operations of disconnection of all repair objects on parts in a certain sequence. It consists of operations, transitions and acceptances.

Disassembling operation is a part of the disassembling technological process which is performed on one unit or product at one workplace.

Transition – a part of disassembling operations characterized by the immutability of the mating surfaces and the equipment in use.

Acceptance – a self-contained complex of the specific movements while disassembling or prepairing for disassembling.

The technological process of machine disassembling depends on the peculiarities of its design, dimensions and mass, as well as on labor intensiveness of operations.

Disassembling a machine into assemblies, units and parts is carried out in a strict sequence, which is provided by the technological process using the necessary equipment, devices and tools (Fig. 3). The set of the technological documents for disassembling usually includes the following documents: a title page, a technological document sheet, an equipment sheet, a tooling sheet, a sketch-map and a route sheet.

Disassembling machines and their assemblies is carried out according to the following main rules:

- at first, the protective parts are removed, and then those ones which are easily damaged (electrical equipment, fuel and oil lines, hoses, fenders etc.) and then self-assembly units (radiators, cabins, engines, reducing gears) which are cleaned and disassembled into parts;
- after removal from the tractor assemblies (hydraulic systems, electrical equipment, fuel equipment, pneumatic systems, etc.) are sent to the specialized areas or workplaces to determine the technical condition and to repair if necessary;

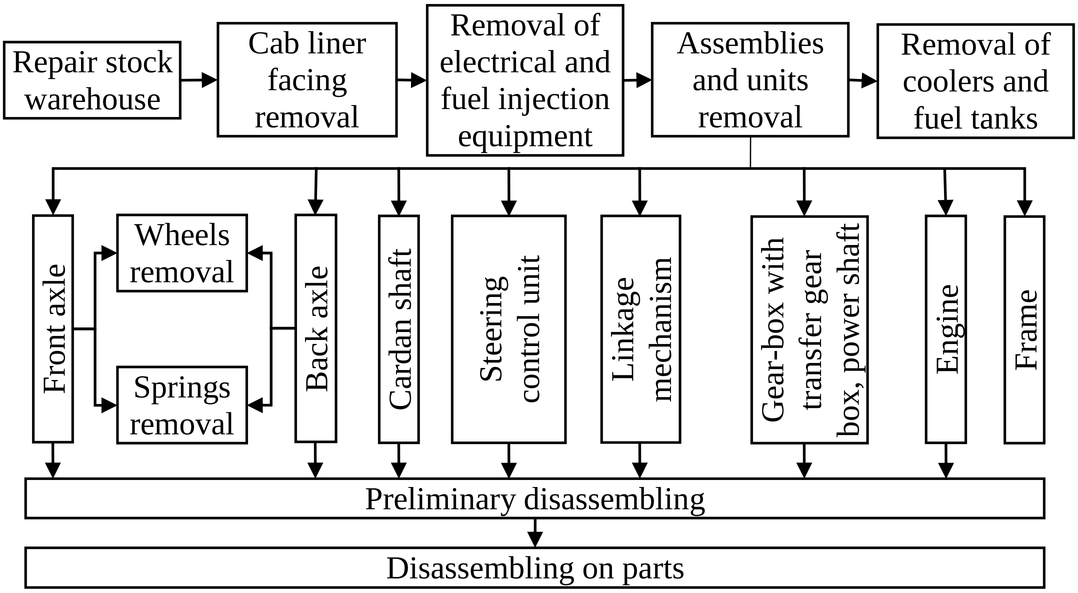


Fig. 3 – Disassembling scheme of the wheeled tractor of type T-150K

- while disassembling, it is not recommended to disasseble interconnected pairs which are processed at the manufacturing plant as an assembly or balanced (main bearing caps with cylinder blocks, big end caps with piston rods, clutch housing with the cylinder block, crankshaft with the engine flywheel) and also bevel gears of the final drive, timing gears, gears of oil pumps etc. Then the parts which are not subjected to featurelessness, are labeled, bounded, again connected with bolts, placed in separate baskets or their completeness is retained in other ways;
- while disassembling, it is necessary to use stands, pullers, equipment and tools which allow to center parts, which are removed, and to distribute evenly the force on the perimeter. When bearings are pressed out, oil seals, sleeves adjutages with soft points (copper, aluminum alloy) are used. If the bearing is pressed out of the hub or piston, the force is applied to the outer ring, and during removal from the shaft – to the internal one. At the same time it is forbidden to use percussive tools;
- while disassembling a machine, the fasteners (nuts, bolts, studs) are placed in the net package for better cleaning in washing facilities or installed in their places. It is forbidden to disassemble parts with cuts of the extended precision (bolts and nuts of big end caps fastening, the flywheel to the crankshaft). While disassembling, especially for cast-iron parts (to prevent cracks because of the skewness), at first all bolts

and nuts are released on a half-turn and then they are disconnected completely;

- open cavities and holes for oil and fuel and fuel in hydraulic units and fuel injection equipment are closed with the lids or stoppers after removal from the tractor;
- if marks before disassembling are poorly visible, they must be renewed;
- performing disassembling works it is necessary to know the ways and peculiarities of their performance;
- to lift and transport parts and assemblies weighing over 20 kg lift-and-carry, vehicles and gripping devices are used.

The most common operations while disassembling are as follows: unscrewing screws, studs, bolts and looseining nuts, removing broken bolts or studs, removal of rolling-contact bearings, sleeves, pulleys, fingers and pins.

According to the principles of organization, disassembling may be stationary and changeable (flow production).

The stationary form of disassembling is used in the single-part production, usually in small workshops. In this case, disassembling machines and assemblies on units and parts is made at one working post, taken from the machine assemblies and units are dismantled on stationary stands.

During the flow production method equipment and working posts are placed consecutively one by one in the order of performing the technological process operations, carried out at several posts. Moreover, the consistency and a number of the operations, as well as a number of workers on the posts are those, that for a certain period of time equal to the stroke of the belt line, one product is disassembled.

The flow production method of disassembling machines on assemblies is carried out using load-carrying and chain conveyors (Fig. 4). Dismantling assemblies into units and parts is carried out on stands, platforms or conveyors (Fig. 5).

As for a number of the installed assembly stands, used to dismantle machines and assemblies, stands can be distinguished into single-object and multi-object stands; as for the purpose – universal and specialized (Fig. 6) stands. Universal stands are designed for installation of one-type assemblies of various models of repaired machines or different assemblies of the same machine model. Multiple stands by the nature of performing works are divided into two types: one worker serviced and more-than-one-worker serviced.

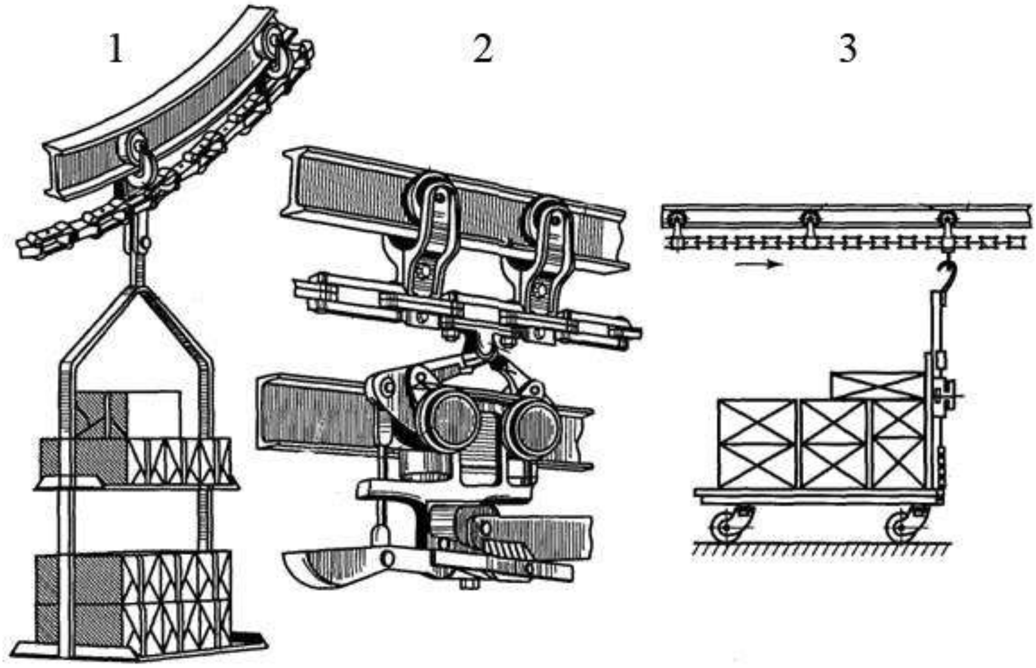


Fig. 4 – Overhead conveyors: 1 – load-carrying conveyor; 2 – pushing conveyor; 3 – pulling conveyor

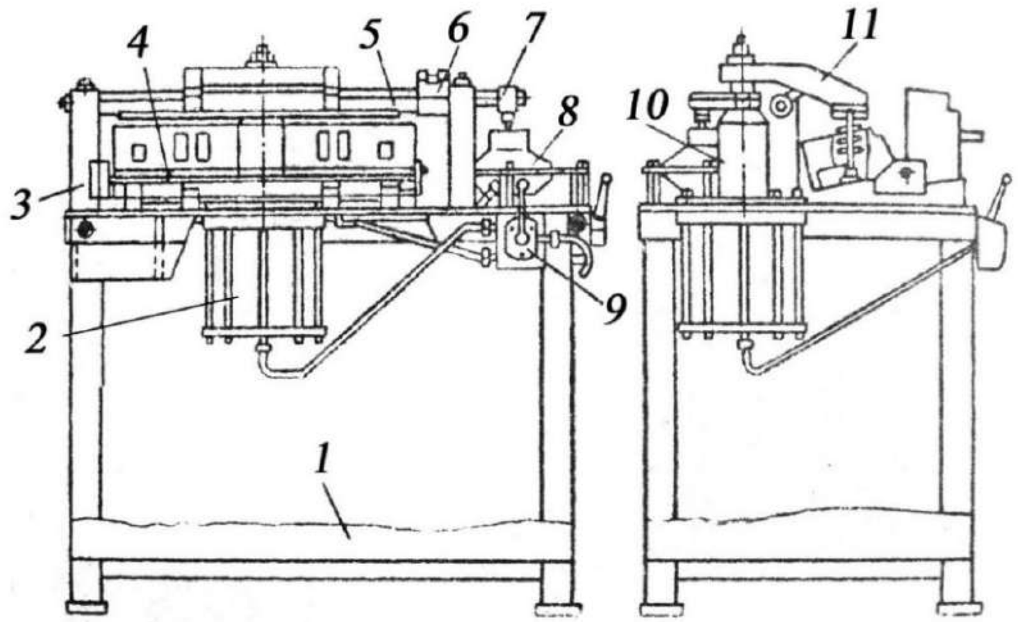


Fig. 5 – Stand for disassembling and assembling cylinder heads: 1 – table; 2 – pneumatic cylinder; 3 – riser; 4 – stand; 5 – axis; 6 – small lever; 7 – lever; 8 – pneumonic cell; 9 – drive valve; 10 – sleeve; 11 – lever with cleat

Combined stands are the most rational ones, because their integral parts are nutrunners, electromechanical heads, pullers, presses etc.

While disassembling (assembling), we use lifting and handling machinery.

Lifting equipment includes hand hoists with carrying capacity of 0,2-2,0 tons and lifting height up to 3 m; electric hoists (0,25-5,0 tons) with lifting height up to 18 m; winches (1-10 tons); mechanical and hydraulic lifts; hoisting devices (strap stiffeners, chains, cables).

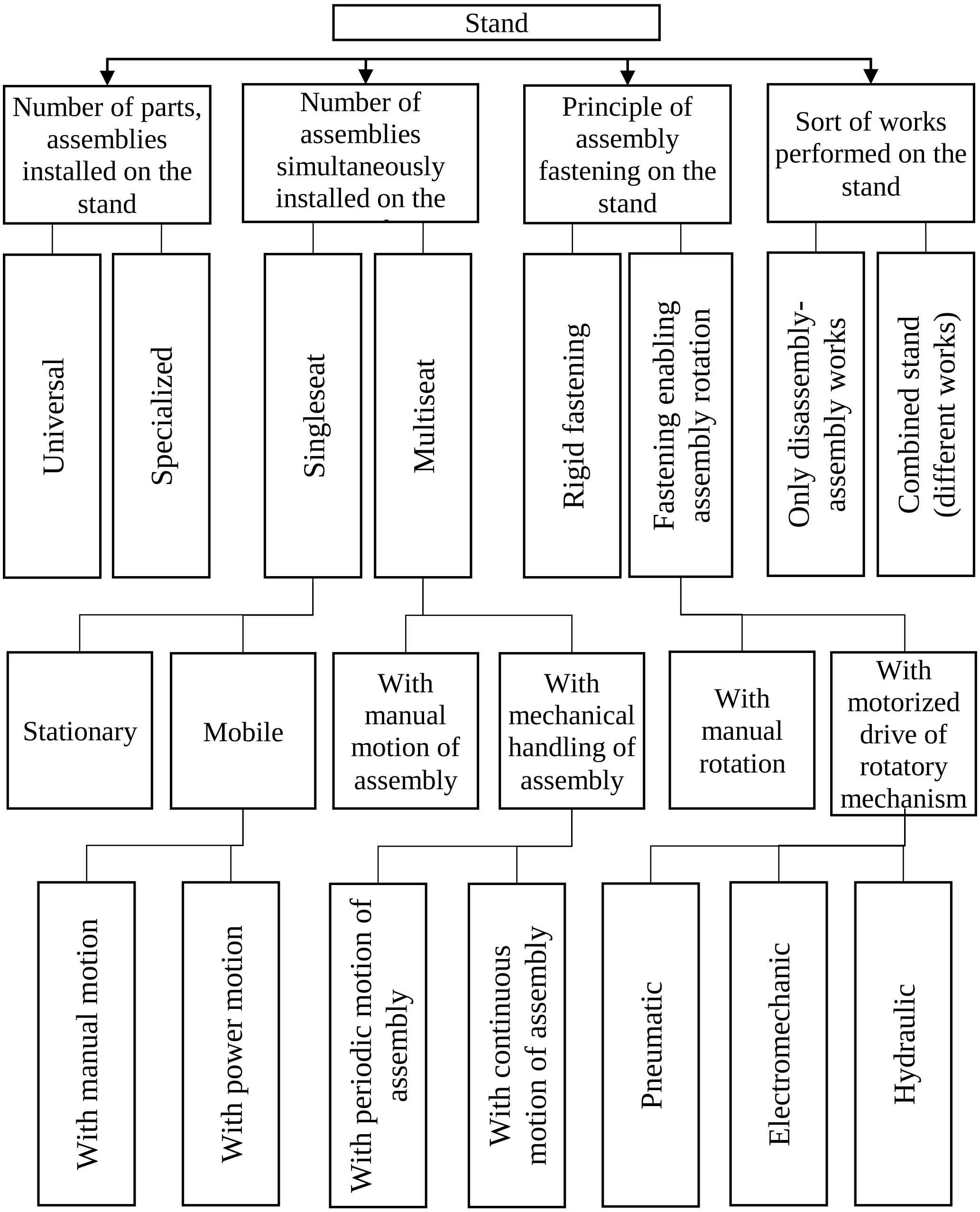


Fig. 6 – Classification of stands

Handling equipment – monorails to move parts attached to the elements of building constructions (columns, beams, trusses); walking cranes; overhead traveling cranes with carrying capacity of 1-5 tons;

Means of transport include: hand barrows and towed trolleys, electric cars (to 2 tons), mobile stands, conveyors (plate, roller, overhead).

Disassembling operations of machines being repaired are quite branched and multistation on their structure. Their performance is greatly simplified when there are technological schemes, which specify the procedure of disassembling parts, units and assemblies of a machine.

Dismantling of an assembly unit should be carried out in a certain sequence, depending on its design. To this end, at the beginning it is rational to design a disassembling scheme (Fig. 7).

This disassembling scheme of an assembly unit is output information to describe the disassembling technological process, and also can be used as a self-standing technical document in a workplace at the overhaul plant. The disassembling process is shown in the scheme Fig. 7 like a straight (vertical or horizontal) line, to which at the appropriate places rectangles adjoin which indicate component parts of the product (assembly units and parts). For better visualization, the rectangle which schematically depicts an assembly unit is performed in two parallel lines.

The beginning for the disassembling scheme is a product (an assembly unit) and the end is a basic part. The beginning of the assembly scheme is a basic part and the end is a product (an assembly unit).

Each rectangle in the scheme is divided into four fields, which indicate the name of the part or assembly unit, their designations, number and position number according to the specification on the main design drawings of the product.

The disassembling scheme is followed by the sketch of an assembly unit (Fig. 8) and its specification. All component parts of the assembly unit are numbered on the sketch according to the position numbers stated in the specification. Position numbers are put down in the scheme in the left upper squares of rectangles.

While machines are repaired, the main part of labour intensity of disassembly works takes dismantling assembly units, parts of which are connected with negative allowance corresponding to shrink and force fits. The actual force taking place while such connections are pressed out often considerably exceed the theoretical ones, especially if these connections are in corrosion conditions.

In the disassembling scheme rectangles which represent assembly units removed, are placed left along the disassembly line, and separate parts – at the right side.

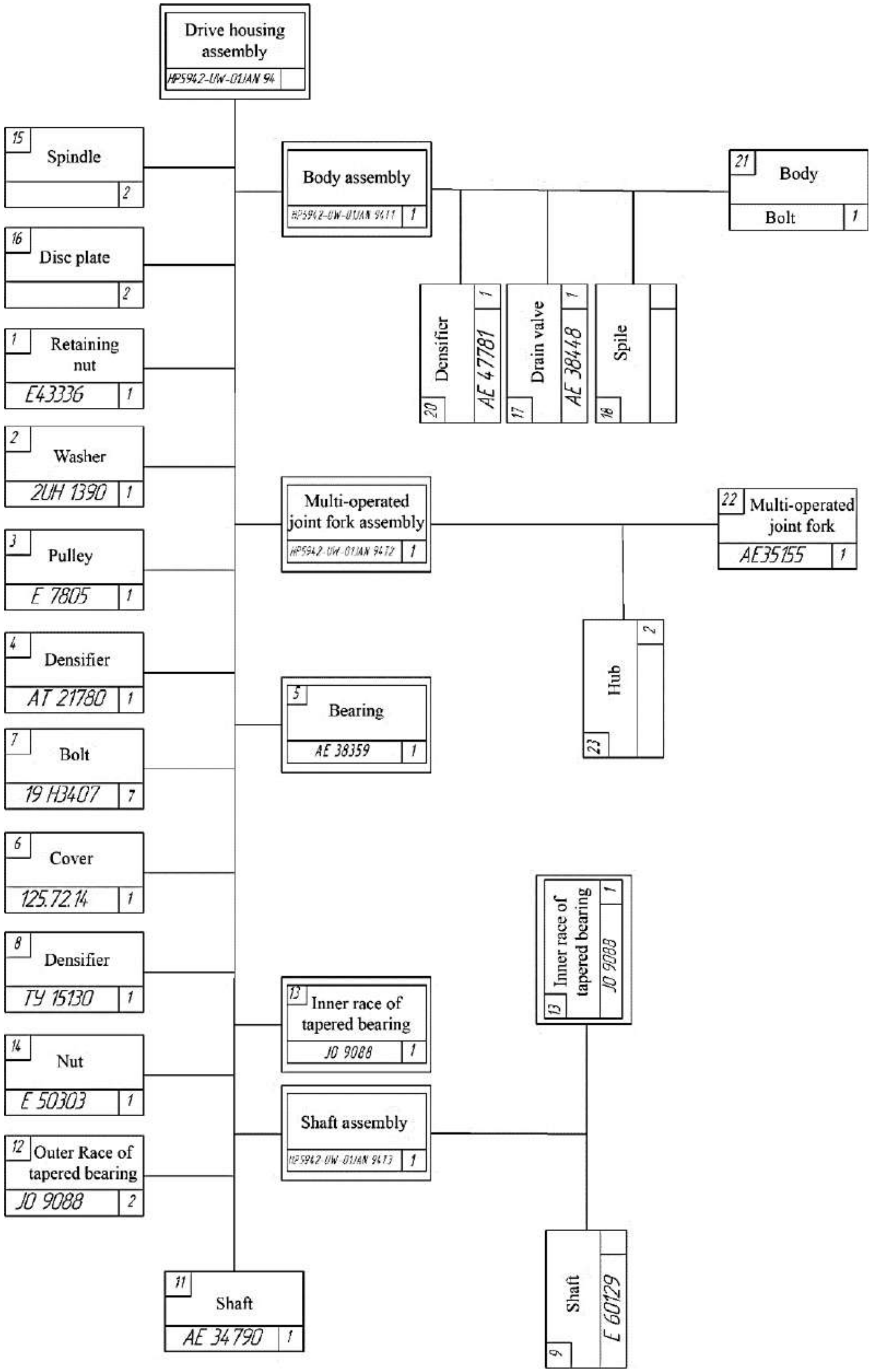
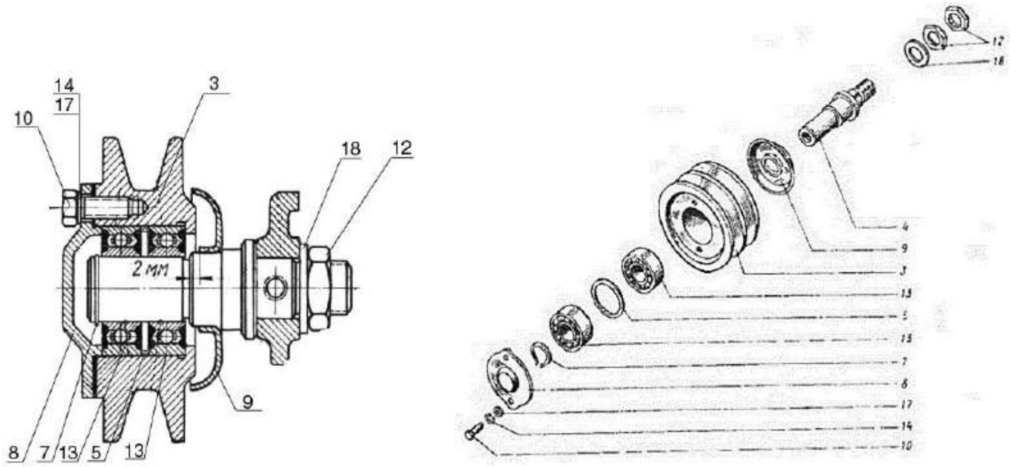


Fig. 7 – Disassembling scheme



a b

Fig. 8 – Sketch of assembly unit; a – a sketch as an assembly drawing; b – a sketch as a three-dimensional image of component parts of an assembly unit

An assembly unit, parts of which are connected with negative allowance, can be dismantled in various ways. They can be divided into mechanical, hydraulic, thermal and combined as for the principle of influence on mounting surfaces of related parts.

When mechanically dismantling assemblies, the coated part under the influence of overflow forces applied to it is pressed out from the coating one, i.e. there is the inverse operation of press fitting – pressing-out. The overflow force is 10-25% larger then the press fitting force. The main equipment for disassembling connections with negative allowance are pullers, presses, stands and tools. Depending on the method of dismantling assemblies with negative allowance, the applied technological equipment has different major parameters which are a function of negative allowance.

When using the mechanical method of dismantling assemblies with negative allowance, the main parameter is the force which is developing by the press or puller – the pressing-out effort determined from the formula:

$$P_{вип} = \frac{\pi \cdot l \cdot \delta \cdot f_{вип}}{\left(\frac{C_1}{E_1} + \frac{C_2}{E_2} \right)}, \quad (1)$$

where $f_{вип}$ – a friction coefficient together with negative allowance when pressing-out is carried out;

δ – a rated negative allowance.

The magnitude of negative allowance is determined while designing a machine on the basis of the given external loads, accepted sizes and the selected material.

The estimated negative allowance is determined according to the formula:

$$\delta = p \cdot d\left(\frac{C_1}{E_1} + \frac{C_2}{E_2}\right), \tag{2}$$

where p – contact pressure;

d – a diameter of the mounting surface;

C_1 and C_2 – Lame coefficients;

E_1 and E_2 – modulus of material parts elasticity, respectively internal and external.

The contact pressure is determined by external loads:

$$p = \frac{K}{\pi \cdot d \cdot l \cdot f}\sqrt{P_{oc}^2 + \left(\frac{2M\kappa p}{d}\right)^2}, \tag{3}$$

where K – a safety factor (K = 1,5-2,5);

f – a friction coefficient between connected parts;

P_{oc} – the largest axial force which a unit has to withstand;

$M\kappa p$ – a maximum torque;

l – a connection length.

To determine the force of pressing-out of bearing rings the following formula is used:

$$P_{\textit{вип}} = \frac{d}{d+30} \cdot \frac{fE\pi BN_p}{2K_n}, \tag{4}$$

where $P_{\textit{вип}}$ – the pressing-out force of bearing rings, H;

d – a nominal diameter of the bearing bore, mm;

f – a friction coefficient in the coupling (0,10-0,25);

E – a modulus of elasticity for the bearing material ($2{,}2 \cdot 10^5$ МПа);

B – a width of the support ring of a bearing, mm;

Np – a rated negative allowance, mm;

K_n – a coefficient characterizing bearing production run (2,78 – for th bearings of light series, 2,27 – for the medium one, 1,96 – for heavy series).

To determine the pressing-out force of pulleys, gears and sleeves one can use approximate relations to calculate the press fitting force with the following additional adjustments:

– for a steel hub and shaft

$$P_3 = 20N_б l\,; \tag{5}$$

– for a cast iron hub and steel shaft

$$P_З = 20N_б l\ , \qquad (6)$$

where $P_З$ – the press fitting force, Н;

$N_б$ – the biggest negative allowance, мкм;

l – the length of the hub, mm.

Press fitting force take 1,20-1,30 $P_З$.

Disassembling assemblies hydraulically (using hydraulic thrust device) with negative allowance is made by oil injection under high pressure in the area of connection. Oil pressure has to exceed a value of the average contact pressure on the connected surfaces. Oil supply into connections is made on a prearranged-during-part-production system of holes and recesses or from the free end wall. For this one use special settings that provide automatic differentiated oil supply under high pressure (Fig. 9).

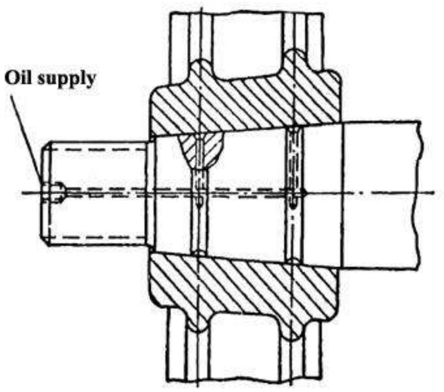


Fig. 9 – End diagram of oil layer creation

Recesses are located at the distance of 0,3-0,5 of the connection length from the end, for the units with hubs of constant stiffness.

At the same time the pressure in the contact area of the surfaces varies within 90-125 MPa.

The thermal method of dismantling assemblies with negative allowance is carried out if there is a thermal gap Δ_T formed by heating or cooling the connected parts. Connections collected in this way are often called cross-moulding.

The thermal method can be performed by several methods: torch heating, inductive thermal heating; use of the thermoplastic deformation, deep cooling.

Torch heating is used in dismantling assemblies with thin-walled external parts.

The inductive thermal method is the most universal and effective. Inductive heating of parts made of ferromagnetic material is carried out by inducing eddy currents in them.

The thermoplastic deformation method is used when dismantling assemlies with negative allowance which have external thin-walled parts with close values of the linear expansion coefficient of parts materials. Its essence is that an assembly (assembly unit) is heated with a torch or in the furnaces to a certain temperature and then quickly cooled. As an external part cools down quicker than an internal one, an additional temperature negative allowance is formed in the connection and plastic deformation of connection surfaces takes place. As a result, an assembly unit loses its strength and after the temperature equalization there is its involuntary dissolution. This method is the most effective in individual and small-scale production at thin-walled external parts $d/d_2 < 0{,}5$ (*d* – a diameter of the mounting surface; d_2 – an outer diameter of an external part).

When dismantling assemblies with negative allowance by deep cooling an inner cavity of the internal part is filled with liquid nitrogen. It allows creating a mounting thermal gap between external and internal parts.

When using thermal methods of dismantling assemblies with negative allowance the main parameter of the technological equipment is the heating temperature or cooling connected parts.

The thermal gap Δ_T and the rated negative allowance δ influence on the desired temperature of the $T_Д$ part which responds to the thermal influence.

$$T_Д = \frac{\delta + \Delta_T}{\alpha \cdot d} \pm T_0, \tag{7}$$

where α – a coefficient of linear expansion or contraction of the part material;

T_0 – a temperature of the environment.

The sign (+) is used while heating, the sign (–) is used while cooling.

The maximum heating of the connected parts is 200-400ºC.

The lowest temperature, that provides dismantling assemblies with negative allowance by the thermoplastic deformation method, for parts from the same material is determined by the following formula:

$$T_H = T_X + 1{,}16 \frac{\sigma_П}{\alpha \cdot E \cdot q}, \tag{8}$$

where T_X – a temperature of the coolant;

$\sigma_П$ and α – respectively a yield strength and a coefficient of linear expansion of the part material;

E – Young's modulus.

Disassembling thread connections of modern machines consumes a large amount of manual labor, and thread connections are the most common connections in machine design and constitute 15-20 % of a total number of connections.

It is known from the repair experience that when unscrewing thread connections which were in use, it is necessary to apply a stronger torque. So the main initial parameter while developing mechanized tools is a torque value required for unscrewing a thread connection during the whole process.

To demonstrate the unscrewing process with the dependence of the torque on the angle of nut rotation and the analysis of the process diagram (Fig.10), three phases have been selected. They are characterized by their completeness and definiteness: shift (I phase), weakening (II phase) and free unscrewing (III phase).

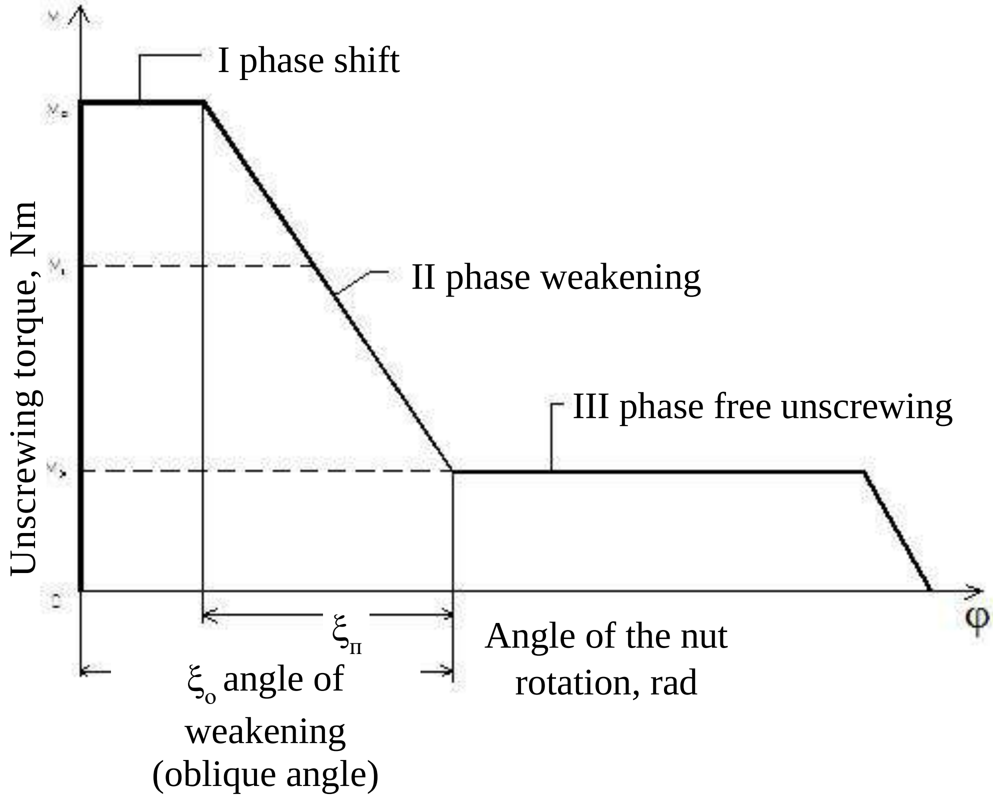


Fig. 10 – Diagram of thread connection nut unscrewing

It should be noted that the shift time is influenced by: the preliminary tightening torque (taking into account weakening during the process), the area of contacting surfaces, operating conditions, specific pressure on the contacting surfaces and adhesive force of the connecting material formed on-stream (corrosion, seizure, diffusion, non-metallic inclusions).

Research established that while a thread connection is used, the force interaction is growng. Meanwhile, protective coatings of the thread connection parts such as cadmium coating 2 times slow down the growth rate of the force interaction.

The study of microsections of thread connections at different stages during operation stated that under the impact of the force in the tightening end there is crumpling and shifting of the boundary metal layers of parts' contacting surfaces in the thread and at the end of the nut, and under the influence of the environment between contacting surfaces is gradually formed a layer of material which consists of wear products, contamination and corrosion filling gaps of the thread connection (Fig. 11).

While shifting, the torque can be represented by the following formula:

$$M_{ЗР} = M_{з}K_1 + M_{\partial р} + M_{\partial т}, \qquad (9)$$

where $M_{з}$ – a tightening torque;

K_1 – a coefficient taking into account weakening of preliminary tightening;

$M_{\partial н}$ and $M_{\partial т}$ – an additional torque spent on destruction of the material layer, which fastens the parts of the thread connection, in the thread and at the end of the nut.

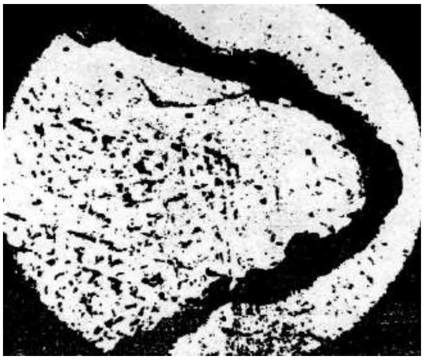


Fig. 11 – Fastening material formed in turns of thread on-stream (spring center clamp, × 70)

Considering unscrewing as destruction of fastening material layer between the contacting surfaces of the thread connection parts and parts that are connected, one can determine the force required for its destruction on the unit area, as a product of its area for the shifting force and torque – as a product of the force at a distance from the platform to the axis of the thread connection. Integrating these moments on the contacting surfaces of the thread connection we have obtained an equation that defines the torque of shift. Taking into account the specific thread connections, the torque of shift can be defined as follows:

$$M_{3P} = \frac{\tau_3}{16}\left[\pi\left(D_0^2 - d_0^2\right)\cdot\left(D_0 + d_0\right) + 5Hd_{cp}\sqrt{p^2 + \left(\pi \cdot d_{cp}\right)^2}\right], \tag{10}$$

where τ_3 – a coefficient of the force interaction of the shift when unscrewing the thread connection parts;

D_0 – an outer diameter of the nut end, mm;

d_0 – a diameter of the screw hole in connected parts, mm;

H – a height of the nut, mm;

d_{cp} – an effective thread diameter, mm;

p – a pitch of thread, mm.

Torques of unscrewing nuts of the corresponding thread connections of machines to be repaired, ranging from M8 to M16, have 1,5-2,5 times, and at free unscrewing – 5-20 times bigger tightening torques and free torsion than while assembling new thread connections.

Lecture № 3
Cleaning of repair objects

Classification of contamination types

Carrying out of washer-cleaning operations is connected with certain difficulties caused, firstly, by a variety of contamination types (Fig. 1), which require using different methods of cleaning, detergents, equipment and secondly, by cleaning objects (machine, assembly, unit, part) of different weight, material, structure, shape, etc.

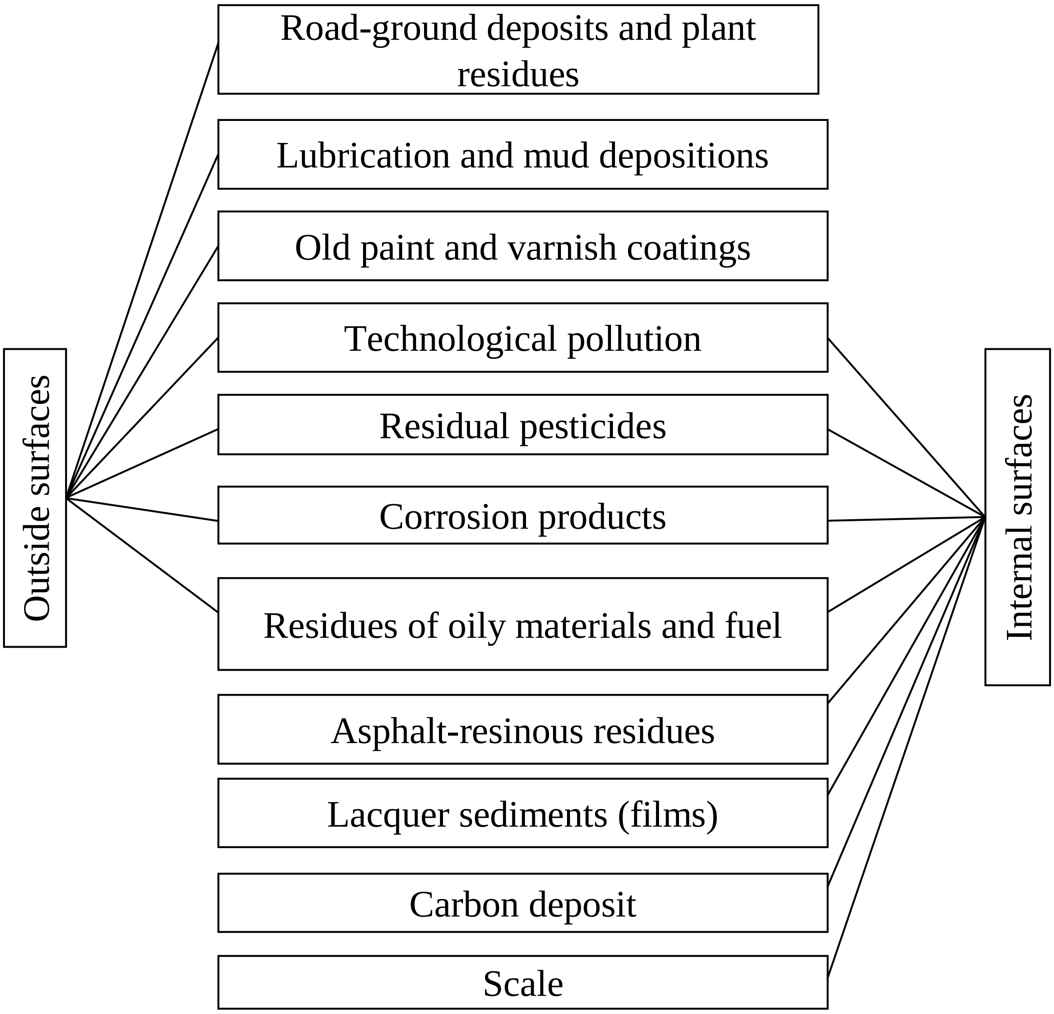


Fig. 1 – Classification of contamination types

Road-ground deposits and plant residues mainly accumulate in the running gear. The extent of pollution depends on operating conditions of machines (work season, road conditions, etc). The strength of particles retention on the surface (adhesion) depends on the surface roughness, particle sizes, air humidity and other factors. Adhesion of small flour particles to the surface is considerable. Thus, after dryout of the machine surface, being washed with the high pressure water jet, deposition from small flour particles remains on the surface. We can remove them only by means of mechanical wiping of the surface with brush or cleaning cloth.

Lubrication and mud depositions. It is caused by road mud and dust appearing on the surfaces of parts, polluted by lubricants. It is possible a reverse phenomenon – appearance of lubricants on the surfaces, polluted by road mud. In addition, mud penetrates due to lubricants.

Old paint and varnish coatings. We have to remove old paint and varnish coatings whilst a machine is repaired. For this purpose, we use concentrated alkaline solutions and special paint-removers.

Technological pollution. Parts, entered to be assembled, may be polluted with residues of foundry soil, calces, grinding compounds, dust from the air, chips and solid particles in oily channels, abrasive grains, overacted on the surface, etc. In case of poor cleaning of parts from these contaminants during running-in of the friction surface, we observe intense wear.

Residual pesticides. It is a mineral-organic complex consisting of various contaminants (lubricants, road grime, rust, old paint, etc.) mixed with pesticides. A number of pesticides during normal operation of machines is up to 26 mh/cm^2 of the surface.

Corrosion products. They are formed by chemical or electrochemical destruction of metals and alloys. A foxiness film – hydrated iron oxide (rust) appears on the surface of steel and cast iron parts. Hydrated iron oxide is dissolved in acids and just slightly in alkalis and water. Aluminum parts are also corroded, and products of corrosion have off-white scurf; they are oxides or aluminum oxide hydrates.

Lubricants – the most common type of part pollution. Lubricants considerably change their condition during operation, caused by "ageing processes", oxidation and polymerization. The extent of changes depends on thermal factors and other work factors of assemblies and units.

Neutral resins – substances that are a part of tarry oil and oil decomposition products. Neutral resins are compounds that have liquid or semi-liquid consistency, completely soluble in petroleum ether and petroleum fractions.

Oxyacids – organic acids containing hydroxyl and carboxyl groups. Oxyacids are able to dissociate, salify (reactions of saponification), acidify.

Asphaltenes – compression products of neutral resins, they are dark brown or black substances; they are solid, crumbly, nonfusible and they decompose at the temperature above 300^0C forming coke and gas. Asphaltenes are insoluble in petroleum ether, but are easily dissolved in petrol, chloroform and carbon disulfide. They are not exposed to saponification, are not emulsifiers.

Carbenes and carboides are insoluble products of compression and polymerization of hydrocarbons in benzol, arising under thermal decomposition of oils and fuels. Carbenes are soluble in carbon disulfide, and stagnant carboides are insoluble in any solvents.

The process of carbon deposit formation is basically as follows. In the area of high-temperature, fuel and oil are burned forming solid, not sticky carbonaceous particles. In the area of lower temperatures, oil is exposed to less profound changes – oxidation and compaction forming sticky macromolecular compounds.

Asphaltic-resinous residues are composed of combustion products and the results of physical and chemical changes of fuels and lubricants, mechanical impurities, absorbed together with air, wear products of parts and water. Those substances, which are not dissolved in lubricants and have high density in comparison with them, are moved to sedimentation. Precipitations are 40-80% composed of lubricants and resins; there are 10-30 % of carbenes, carboides and ashes.

Depositions occur in two areas: at the high temperature – on parts of cylinder-piston group and at the low temperature – in the crankcase.

Lacquer sediments – films, produced in the area of piston rings, as well as on the inner walls and skirts of pistons.

Carbon deposits – solid carbonaceous substances that deposit on engine parts (combustion chamber walls, valves, spark plugs, piston crowns, and collector).

Scale. Scale occurs in water cooling system engines during operation. Scale complicates heat exchange processes and violates normal operation of the engine due to sedimentation on the walls of the engine water jacket and radiator. Scale is caused by calcium and magnesium salts in the dissolved state, i.e. water hardness. It is known that corrosion processes take place in cooling systems along with scale. It is necessary to use special additives to prevent scale and reduce corrosion in engine cooling systems in case of pouring unprepared water in them.

Characteristic of detergents
Physical and mechanical bases of detergents

Theory of detergent action. The detergent action consists in removing liquid and solid contaminations from the surface and their moving to the detergent solution in the form of solutions or dispersions. The detergent action appears in complex interaction processes of pollution, detergents and surfaces. The main elements of detergent action are wetting, emulsification, dispersion, foam formation and stabilization; they are closely associated with surface tension and surface activity of detergents.

It is known, that tension forces act along the liquid surface, and they seek to reduce this surface. They are called surface tension forces. Surface tension is measured by the work that must be expended to increase the liquid surface at 1sm^2, this work is expressed in erg/cm^2.

The product of the surface tension force on the size of the surface is called thefree surface energy. The ability of substances to reduce free surface energy (surface tension) describes the surface activity of these substances. The substances reducing the surface tension of the solution are called surfactants (SAS).

Surfactants are polar organic compounds. High surface activity and ability to micelle formation provides colloidal surfactants with a set of properties that determine their detergent action: wetting, emulsifying, dispersing and stabilizing abilities.

Wetting consists in spreading of a drop of liquid, placed on the surface of the solid body. The surfaces, wetted with water, are called hydrophilic surfaces and the surfaces, wetted not with water, are called hydrophobic surfaces.

Wetting of a solid body with liquid depends on the surface tension of liquid, as well as the nature and composition of the liquid and solid body.

In most cases, contaminations consist of two phases – liquid (oils, resins) and solid (asphaltenes, carbenes, carboides). Removing such contaminations from the surface occurs in two ways – by emulsification of the liquid phase (emulsion formation) and by dispersion of the solid phase (formation of dispersions).

Emulsion is a system of liquids, which are not mixed, one of which is divided into the form of small drops in the other. Emulsification of the liquid phase of pollution is possible in aqueous solutions of surfactants.

Molecules of surfactants create durable adsorption layer on the surface of oil drops. The hydrophobic part of the molecule is bound with oil, and the hydrophilic part is oriented toward the aqueous solution (Fig. 2). Dispersion of the solid phase of pollution occurs due to adsorption of surfactants on the particles of contaminations.

The small surface tension of the solution allows it to penetrate into small cracks of pollution particles and adsorb the surfactants on the surface of these particles. Adsorbed molecules of the surfactants create disjoining pressure on the particles, destroying and crushing them. In the process of emulsification and dispersion, the mechanical impact of the solution has a great importance, and it contributes to destruction of contaminations.

An important stage in washing process is stabilization in solutions of washed contaminations and preventing their redeposition on the cleaned surface. Stabilization of pollution mainly depends on the composition of detergent and technological conditions of its usage (concentration, temperature, pollution).

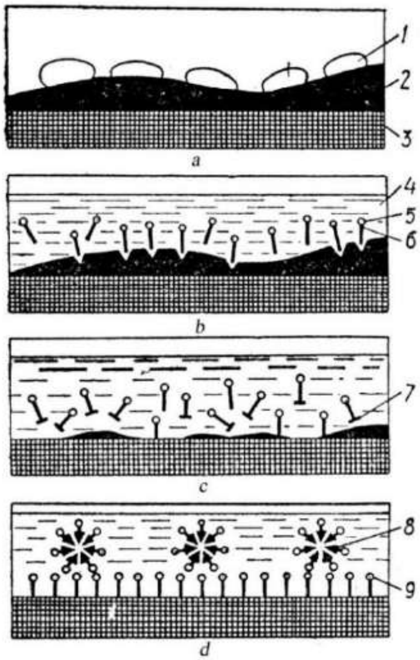


Fig. 2 – Scheme of washing process:

1. – drops of water;
2. – contamination;
3. – surface being cleaned;
4. – detergent composition;
5. – hydrophilic part of surfactant molecule;
6. – hydrophobic part of surfactant molecule (radical);
7. – transition of pollution particles in solution;
8. – pollution particles, stabilized in solution;
9. – adsorption of surfactant molecule on the cleaned surface.

Finally, the washing process can be represented by a number of consecutive stages. Since almost all contaminations are hydrophobic, water having greater surface tension, does not wet polluted surfaces, but converges in the separate drops (Fig. 2a). During dissolution of detergents in water, the surface tension of the solution decreases sharply and the solution wets contaminations and penetrates into its pores and cracks

(Fig. 2b). Under these circumstances, a combination of pollution particles between themselves and with the surface decreases. Due to mechanical impact, mud particles-captured by the molecules of the detergent, pass into the solution (Fig. 2c). Detergent molecules envelop contaminations and the cleaned surface, preventing consolidation of particles and their sedimentation on the surface (Fig. 2d). As a result, pollution particles in a suspension state are stabilized in the solution and removed together with it.

Alkalinity of detergents is an important factor defining effectiveness of cleaning. The detergent action of solutions depends only on the level of active alkalinity.

The pH index is a characteristic of alkalinity, as well as of acidity. To avoid corrosion it is necessary to keep a certain level of pH solution when various metal surfaces are cleaned. For zinc and aluminum, pH solution must be 9-10, stannum – no more than 11, brass – no more than 12,0-12,5, steel – to 14. The practical processing of light and nonferrous metals are made at considerably higher pH values, for example – 11,5-12,8.

The fouling factor of the surface also influences a sort of pH solution. Cleaning parts with strong contaminations, for example – asphaltic and resinous sediments, is necessary to conduct at pH 11,8-13,6, and for not strong contaminations e.g. oily ones, cleaning can be conducted at pH 10-11,5.

<u>Corrosion inhibitors</u>. Machine parts in service, repair and storage, are subjected to corrosion due to chemical and electrochemical environment influence.

Detergent solutions containing alkalis, acids or their salts can also have a corrosive action on metals. Special additives called corrosion inhibitors are introduced into the detergent composition to prevent part corrosion. The protective action of many corrosion inhibitors is associated with making a protective film on the metal surface as a product reaction between the metal, inhibitor and corrosive-active environment.

<u>Synthetic detergents</u>. The surfactants, which activity is increased by introduction of alkaline electrolytes, are the base of synthetic detergents. The main national synthetic detergents for jet and submersible purification methods are presented in Table 1.

Also, synthetic detergents include sodium hydrate, soda ash, sodium silicate, trisodium phosphate, bichromate etc.

Table 1 – Technical synthetic detergents

Name and assignment	Purification method	Solution temperature	Processing time, min	Packing, concentration
1	2	3	4	5
"AM-15" is used for cleaning engine parts from asphalt-resinous residues, and also for recovering throughput capability of the coarse mesh filter.	immersion	20-40, and then it is washed with aqueous solutions "Labomid 203	Individual for each processing	Polyethylene barrels with capacity no less than 50 kg, 100% concentrate
"THERMOS-concentrate" is used for cleaning parts, machines and assemblies with regeneration of spent aqueous cleaning solutions.	jet method	50-60	Individual for each processing	Polyethylene barrels with capacity no less than 50 kg, 100% concentrate
"Karbozol" is used for cleaning engines and their parts from carbon deposits and oily contaminations.	immersion	40-50	Individual for each processing	Polyethylene barrels with capacity no less than 50 kg, 100% concentrate
"KM-1" – for cleaning metal surfaces, cleaning the chassis of automobile and tractor engineering.	spraying	40-60	1-3	Paper or polyethylene bags with weight to 40 kg, 2-10 g/l
"Labomed 101" – for cleaning the engineering filtering elements from operational contaminations, separate parts of ferrous and nonferrous alloys from oily and asphalt and resinous sediments.	jet method	70-85	2-5	Paper or polyethylene bags with weight to 40 kg, 20-30 g/l
"Labomid 203" – for cleaning the engineering filtering elements from operational contaminations, separate parts of ferrous and nonferrous alloys from oily and asphalt and resinous residues.	immersion	80-90	2-5	Paper or polyethylene bags with weight to 40 kg, 25-30 g/l
"ML-51" – for cleaning machines, parts of industrial equipment from combustive and lubricating materials, and oily sediments of protective coatings.	jet method	75-85	5-15	Paper or polyethylene bags in weight to 25 kg, 20-30 g/l

Table 1 (continued)

1	2	3	4	5
"ML-52" is used for cleaning machinery, assemblies, parts, industrial equipment from residuals of combustive and lubricating materials, oily and mud sediments, protective coatings.	immersion	80-100	Individual for each processing	Paper or polyethylene bags with weight to 40 kg, 25-25 g/l
"MS-6", is used for cleaning chassis of tractors, cars, harvesters, their assemblies, parts and units.	Jet method	70-80	Individual for each processing	Paper or polyethylene bags with weight to 40 kg, 10-20 g/l
"MS-8" – for cleaning detachable parts and units of the airframe of flying vehicles, engines, their assembly units and parts of oily and resinous contaminations.	immersion and spraying	75-85	5-15	Paper or polyethylene bags with weight to 40 kg, 10-20 g/l
"MS-15" is used for cleaning machines, assemblies and parts from resinous sediments when agricultural machinery is repaired.	immersion and spraying	75-85	2-5	Paper or polyethylene bags with weight to 40 kg, 20-30 g/l
"Rhyth" is used to remove carbon sediments, residues of separate paint and varnish coatings.	immersion	20-40	Individual for each processing	Polyethylene barrels with capacity no less than 50 kg, 100% concentrate
"Temp-100" is used for cleaning metal parts.	jet method	70-80	Individual for each processing	Paper or polyethylene bags with weight to 40 kg, 20 g/l
"Emulsyn" is used for cleaning parts of chassis and engines.	immersion, and afterward it is rinsed with solutions of technical detergents of type of ML and MS	40-60	Individual for each processing	Polyethylene barrels with capacity no less than 50 kg, 100% concentrate
"Karbozol" is used for cleaning engines and their parts from carbon deposits and oily contaminations.	immersion	40-50	Individual for each processing	Polyethylene barrels with capacity no less than 50 kg, 100% concentrate

Solvents and soluble emulsifying agents (SEA). The ways to remove contaminations from the part surface with solvents are widely used. Molecules distribute in the solvent during collision of the solvent with contaminations. Contaminations are accumulated in the solvent during purification. If you do not take precautions and perform special operations (rinsing with a pure solvent, degreasing in solvent vapor), then some contaminations remain on the part surface in solvents after purification.

The most widely-used solvents during purification are as follows: acetone, technical benzine, benzol, butyl acetate, butyl alcohol, kerosene, xylene, toluene, white spirit, ethyl acetate, technical ethyl alcohol, organochlorine solvents, trichlorethylene, tetrachloride carbon etc.

Soluble emulsifying agents (SEA) are now widespread during purification.

Purification occurs due to dissolution, during immersion of a part in soluble emulsifying agents that used in the pure form or in the mixture with other solvents. Then the part is immersed in water or aqueous solution of alkaline synthetic detergents, and emulsification of the solvent and residual contaminations takes place, and then their transition into solution that provides the necessary quality of purification. Soluble emulsifying agents are commonly used in purification of parts from strong, for example – asphaltic resinous sediments, and also in cases where purification occurs under moderate temperatures (from +20 to + 50^0C).

Soluble emulsifying agents consist of the base solvent, additional solvents, surfactants and a small amount of water. Water is essential for dissolution of surfactants. Additional solvents provide uniformity and stability of the solution, formed by components, soluble in water and solvents.

Soluble emulsifying agents are prepared in the form of concentrate to dilute in the cheap solvent (kerosene, diesel fuel), and its ratio is from 1 to 5 parts.

Washer-cleaning technological equipment

Abstergent-cleaning technological equipment is classified by the following features:

- Performed functions in the technological process (external washing, purification of assemblies, etc.);
- A type of cleaning machines (monitor, jet, with immersion, combined, special);

- The intended purpose, depending on the type of repair enterprises and repair objects.

Purification of metal surfaces by removing pollutions with manual and mechanized tools. Mechanical methods of removing contaminations are based on adding to tangential and normal forces of the mechanical impact.

The methods mentioned above include: 1) Removing contaminations with manual and mechanized tools; 2) removing contaminations under the influence of fluid jets.

The first method includes removing contaminations by scrapers, and also purification in barreling machines. The second method, along with waterjet purification, includes hydroabrasive and purification by drupaceous crumb.

A manual or mechanized tool is used at mechanical purification of surfaces: metal brushes, scrapers, chisels, abrasive or carborundum stones, as well as abrasive skins. Mechanical purification is used mainly to remove accumulations of mud, corrosion products, scum, and carbon deposits from the external part surfaces and for additional purification of surfaces after washing.

Surface purification of machine parts by using brushes is called scratch brushing.

Purification of machine parts in barrels (barrel finishing). During barrel finishing, machine parts are placed in rotating barrels where they are subjected to abrasive action of abrasive particles, loaded into the same barrels (porcelain crumbs, scraps of abrasive wheels, etc.). Parts are cleaned from contaminations due to mutual friction between themselves and the abrasive filler (Fig.3).

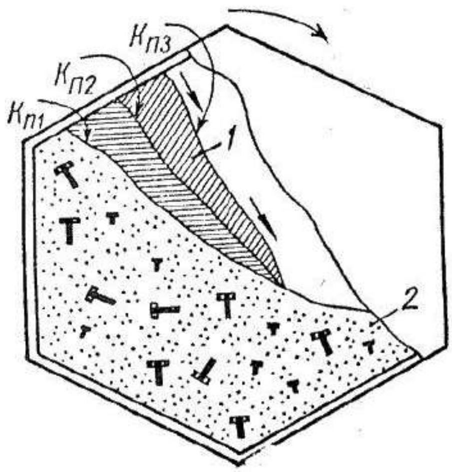


Fig. 3 – Scheme of process of barrel finishing in hexagonal barrel:

1. – active zone;
2. – «dead» zone; $K_{n1} - K_{n3}$ separation place of parts and filler from the wall of the barrel.

Organic solvents or aqueous solutions of alkalis are added in barrels in case of wet barrel finishing along with abrasive particles. Most often barrels are immersed in baths with appropriate cleaning reagents which penetrate into the cavity of the barrel through its perforated surface (Fig. 4). Hexagonal barrel 4 with holes in the side walls is immersed in the bath 3, filled with a detergent solution; the detergent solution is heated with vapor, applied to the coil pipe 6.

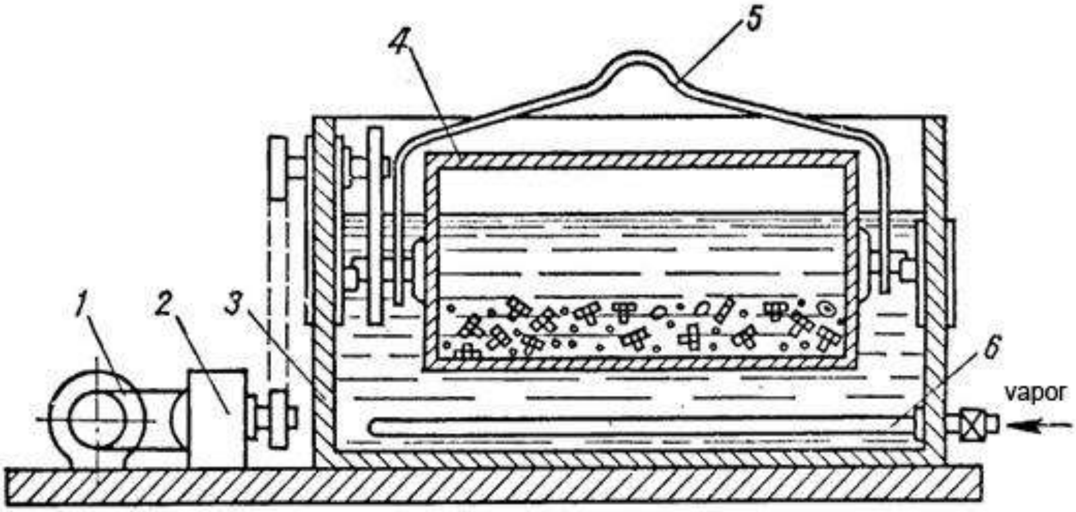


Fig. 4 – Scheme of the plant to purify parts in the barrel:
1. – electric motor; 2. – reducer; 3. – bath; 4. – holed barrel; 5. – brace; 6. – coil pipe.

The barrel is rotated by electric motor 1 through reducer 2. During rotation of the barrel, parts that moved are bumped one against another and against the abrasive particles of the filler. As a result of mutual friction, contaminations are gradually removed from the surface parts.

The solution that comes from the bath into the barrel through its perforated walls softens a cutting action of the abrasive and removes contaminations.

Hydroblasting. It is used to remove dust, mud and oily-mud sediments from the external machine surfaces if the content of oil in the latter does not exceed 35%.

Hydroblasting plants consist of a plunger or a vortex pump, an electric motor, a hose and a gun (hydraulic monitor). Stationary plants are mounted on the frame, and portable installations are additionally equipped with a special trolley. Water supply and change of the jet shapefrom fan-shaped to dagger-shaped is regulated with a spray gun (Fig. 5).

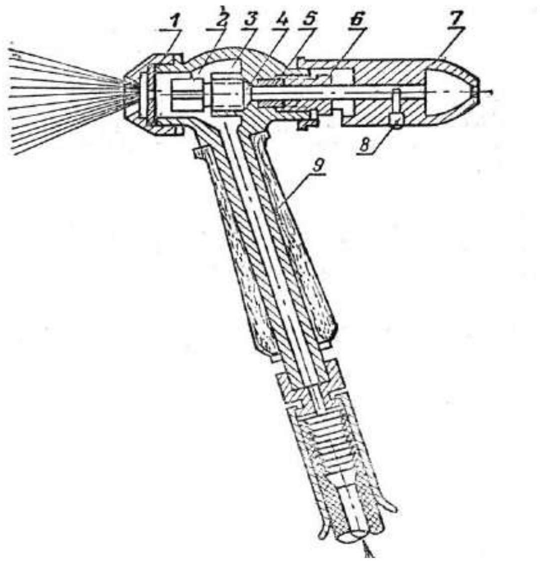


Fig.5 – Detergent gun of model 134-1:

1 – plate;
2 – cork;
3 – chamber;
4 – core of cork;
5 – oil seal;
6 – oil seal nut;
7 – adjusting handle;
8 – screw;
9 – pistol handle.

A layer of mud is eroded with the dagger-shaped jet during hydroblasting of metal surfaces, and mud is washed off with a fan-shaped jet. It is not recommended to wash a car body and the plumage of machines with a dagger-shaped water jet, because solid particles of dust and mud can scratch an enamel film.

External purification of machines is performed before their installing to the repair fund area and before repair diagnostics, and also in cases provided by the technological process of machinery repair. For this purpose, portable and stationary washing plants and machines are used.

The simplest one is a hydroblasting plant for hose washing with a jet with working pressure of 2 MPa. The most effective plants are portable monitor washing machines with high pressure (10 MPa) with the adjustable section shape of the jet. These machines are produced of three modifications: for purification with cold water, for purification with cold water and abrasive aqueous-sandy mixture, and for purification in several modes – the vapour aqueous jet mixture, with hot and cold water (80°C) and with and without synthetic detergents.

Stationary chamber-deadlock and passable washing machines can also be used. They can be distinguished by the construction of shower devices and the character of relative motion of shower devices and objects of cleaning. At repair enterprises, machines for purification of units and assemblies of tractors and cars are used by immersion that allows cleaning both external surfaces and internal cavities of crankcase. To increase effectiveness of purification by immersion, an oscillating platform is used, on which a machine, submerged jets, etc (a jet of liquid in liquid) are installed.

Cleaning assemblies, units and parts is performed in jet washing machines of the submersible and combined types, where submersible and jet methods are used in one assembly.

At repair enterprises three types of jet washing machines are used: chamber-deadlock, passable chamber and sectional jet washing machines. The parts of these machines are cleaned with jets of detergent solution, given from adjutages under pressure of 0,4-1,4 MPa.

Chamber-deadlock washing machine MPP-250 (Fig. 6) has a rectangular chamber with folding doors and a roll-out platform that allows product loading from outside. Automated Control System of machine allows changing of processing parameters as for the type of products. The machine can be equipped with a required number of tanks to fulfill relevant technological operations. The working fluid influences the surfaces straightway in three directions.

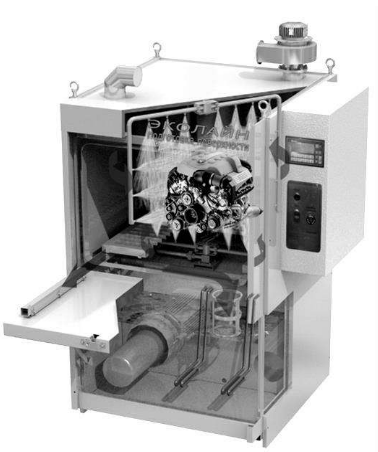


Fig. 6 – Chamber-deadlock jet washing machine MPP-250

The passable two-sectional washing machine refers to the conveyor, and it is equipped with an outboard conveyor for moving parts in containers or large parts directly on pendants. The washing chamber of the machine has a rectangular shape and is designed with the rinsing section. The construction of the washing chamber allows you to perform jet purification with solutions of synthetic detergents and jet rinsing with water.

Spray washing machines for purification of assemblies, units and parts have the following drawbacks. Firstly, their operation is connected with large energy consumption and, secondly, they do not provide complete removal of contaminations in different cavities: holes, pockets, shielded from the direct action of detergents. These drawbacks led to designing and distributing submersible machines of a submersible type (Fig. 7), where containers with parts are submersed into baths with detergent.

During purification by submersion, submerged jets (jet of liquid in liquid), i.e. a combination of submersible and jet purifications, are used to identify process.

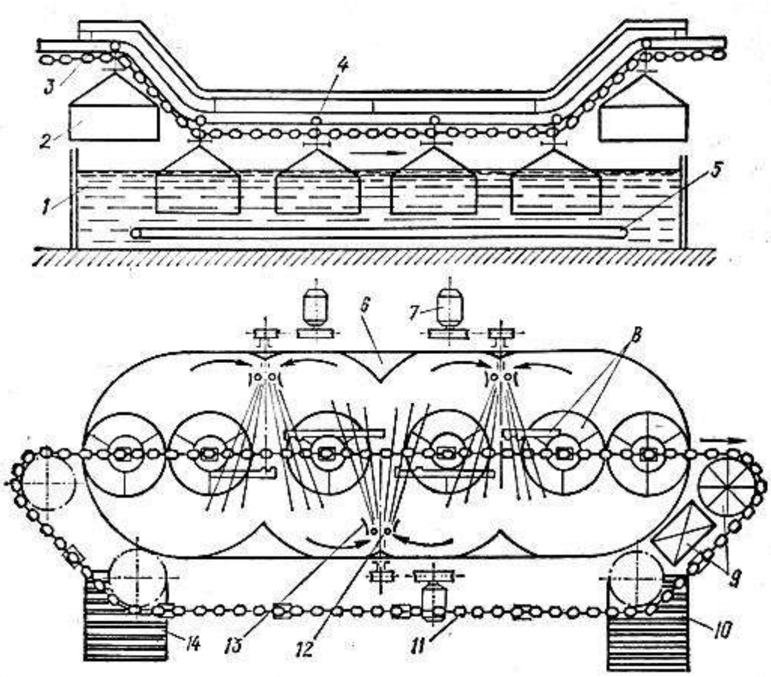


Fig. 7 – Scheme of conveyor washing machine 1 – bath; 2 – container; 3 – beam, 4 – carriage; 5 – tube; 6 – divider; 7 – electric motor; 8 – gear with rack; 9 – drive device; 10 and 14 – live rolls; 11 – container; 12 – vane pump; 13 – diffuser.

Steam-and-water cleaning. The method of steam cleaning consists in supplying a steam jet with the temperature of 90-100°C under the pressure of 5-20 kg/cm^2 on the cleaning surface. High temperatures, a large volume of washing fluid and flow turbulence, occurring due to the impact of the jet on the surface, provide cleaning efficiency.

Steam-and-water cleaning efficiency is determined by energy of the jet, depending on the pressure and volume of the fluid ejected on the surface, on the temperature of the jet, as well as the activity of chemical additives added to the mixture.

The output parameters of purification mainly depend on the type of water pump. Some plants are equipped with diaphragm pumps, others with syringe pumps or plunger pumps.

It is necessary to use detergents from oil, lubricating grease, carbon deposits and conservation coatings while cleaning. Short duration of the cleaning process and low concentration of detergents in the solution, and also the design of steam-and-water cleaning machine represent a certain requirements for detergents.

Firstly, detergents should not form scum, passing through the coil-pipe of the heat exchanger; it can only form loose sludge, which is easily removed. The carrying capacity and efficiency of the heat exchanger are reduced during scum sedimentation on the walls of the coil-pipe, causing reduction of capacities and temperature of the jet. It is necessary to avoid using detergents with a significant content of silicates (sodium metasilicate, liquid glass) to prevent scum.

Secondly, detergents must have an ability to moisten and emulsify pollution quickly, and also to produce abundant foam. Abundant foam formation increases an emulsifying action of the solution during steam-and-water cleaning and reduces its spattering while interacting with the surface cleaned.

Using detergents reduces the cleaning time of purification on the steam-and-water mode twice and 1,5-2 times reduces the cost of purification on the mode of hot water.

The hydroabrasive cleaning method is different from the water jet way, because the water jet is introduced by special abrasives; meanwhile, the main energy source is compressed air that captures abrasive fluid and throws it on the cleaning surface with a high speed.

The fluid consists of abrasive material located in this fluid in a suspension state.

To prepare a water-sandy suspension, we use quartz sand, aluminum oxide, boron carbide and silicon carbide with a particle size of 0,8-1,0 mm as abrasive.

Plants for hydroabrasive purification of metal surfaces can be divided by the method of supplying the abrasive fluid into the following types:

1) plants, operating on the principle of ejection of the abrasive mixture (plants of a pneumo ejection type) (Fig. 8);

2) plants, operating on the principle of extrusion of the abrasive mixture by the compressed air;

3) plants, operating on the principle of supplying the abrasive mixture by a centrifugal-type pump or syringe pump;

4) plants, operating on the principle of separate supplying the mixture of air with sand and water to the nozzle.

Purification of parts in molten salts and alkalis. Cleaning parts in molten salts and alkalis are widely used in mechanic engineering and repair production, especially to remove carbon deposits and scum (Fig.9).

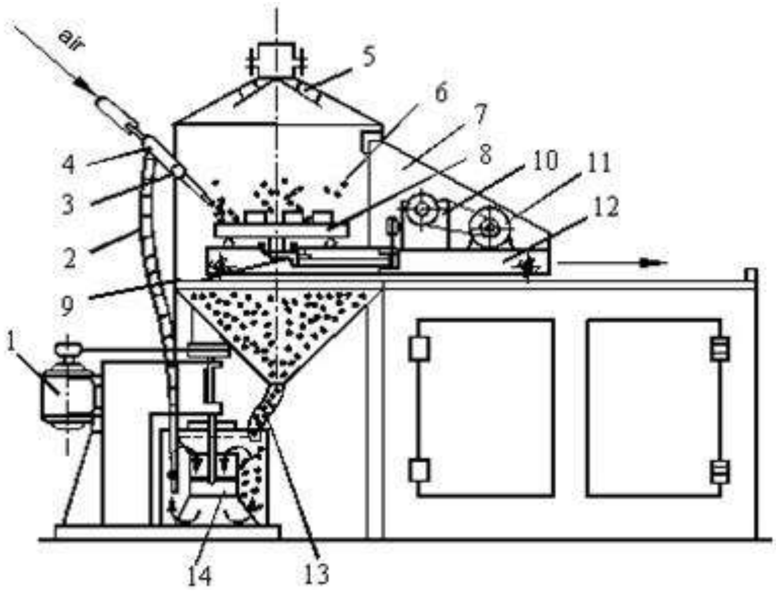


Fig. 8 – Plant, operating on ejection principle of abrasive mixture: 1 and 11 – electric motors; 2 and 13 – hoses; 3 – ball bearing; 4 – jet apparatus; 5 – reflector; 6 – chamber; 7 – casing; 8 – rotary table; 9 – bevel gear; 10 – reducer; 12 – trolley; 14 – agitator

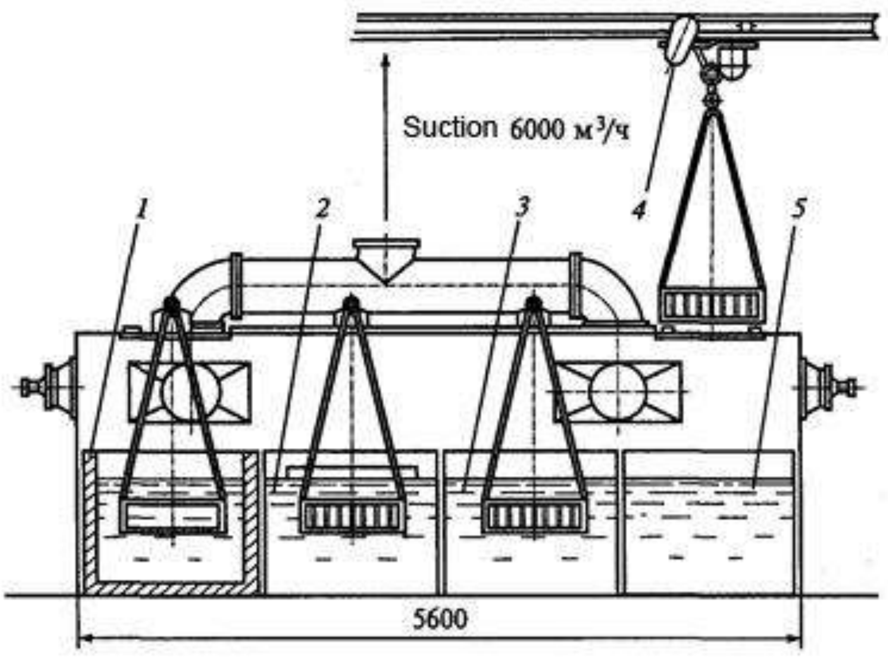


Fig. 9 – Scheme of plant for purification from carbon deposits and scum in molten salts and alkalis: 1 – bath with melt; 2 – first washing bath; 3 – bath with acid solution; 4 – monorail motor hoist for loading and unloading of parts; 5 – second washing bath.

For chemical and thermal purification of parts, the following melt composition can be recommended: NaOH – 60-70% $NaNO_3$ – 35-25% and NaC1 – 5%.

The operating temperature range of the melt is approximately 400 ± 10 °C. Thus, we need 5-15 minutes to clean parts of motor and tractor engines. If the parts with scum sediments are predominated in the processed consignment, it is necessary to reduce the temperature of the melt up to 340-350°C. While cleaning, the temperature of the melt can be increased up to 420°C mainly with carbon deposits, and for parts of gray cast iron – up to 450°C. The temperature of over 450°C is impractical, because it leads to changes in physical and mechanical properties of some parts.

Contamination removal by means of ultrasound. Good results to clean parts of fuel equipment, hydraulic systems, carburetors, rolling bearings and other parts are achieved by the ultrasonic treatment in special baths with detergent solution. Complex nature of powerful ultrasonic fields creating a wide amplitude-frequency spectrum of mechanical vibrations in the fluid causes a number of hydrodynamic phenomena which determine the mechanism of pollution removal.

Schemes of baths for ultrasonic washing are shown in Fig. 10.

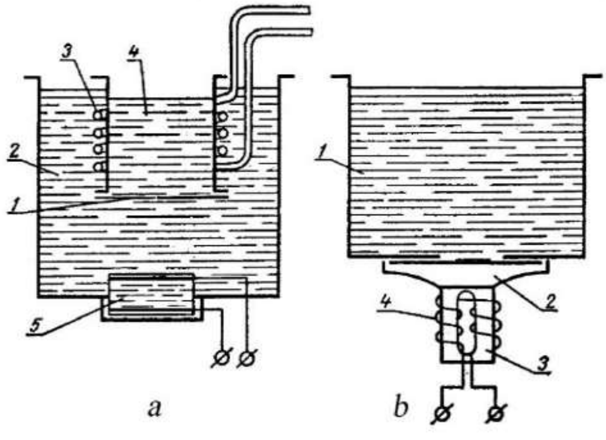


Fig. 10 – Schemes of baths for ultrasonic washing: a) – with piezoquartz emitter; 1 – diaphragm; 2 – intermediate medium (transformer oil); 3 – heater coil-pipe; 4 – bath with detergent solution; 5 – piezoquartz emitter; b) – with magnetostriction emitter; 1 – detergent solution; 2 – transformer of ultrasonic vibrations; 3 – converter; 4 – winding.

In the practice of ultrasonic purification, high power ultrasonic vibrations with frequency of 35 kHz are used, it creates an irregular field with discontinuities of continuous medium. Vibrations are created by the quartz or magnetostriction converter. The principle of the first one is in using piezoeffect of quartz and some ceramics, and the principle of the latter is in changes of the length of the converter plates under the influence of the magnetic field.

Quality control of cleaning

There are several methods of purification control depending on the pollution level of parts after purification and the height of microroughness of their surfaces. During macropurification (removing contaminations impeding disassembling, defecation and mechanical processing), all kinds of contaminations are removed to the levels, caused by the surface roughness, ignoring contaminations in cavities of microroughnesses. During micropurification traces of contaminations from cavities of rough surface remained after macropurification are removed as well as light technological contaminations. The build quality, reliability and resource of repair object depend on micropurification, and during painting – adhesion of paint and varnish coating. This distribution of cleaning operations on macro- and micropurification is economically viable.

The gravimetric method of control is used after macropurification. Pollution of the surface is calculated by weighing parts on the analytical balance before and after contamination removal.

The permissible residual impurity of the surface after macropurification: for surface roughness Rz 40 is 1,25 mg/cm^2, for Rz 40-Ra 2,5 – to 0.70 mg/cm^2 and for Ra 1,25-Ra 0,32 – 0,25 mg/cm^2. Contaminations must not occupy more than 0,10-0,15 mg/cm^2 during assembly, and before painting – more than 0,005 mg/cm^2.

The surface of parts with roughness of Ra 1,25 and higher is controlled by the luminescent method based on the property of oil to glow under the influence of ultraviolet rays. The extent of surface pollution is determined by the size of glowing spots. There are special devices for this purpose.

The method when a part is immersed in cold distilled water, is used for parts with roughness of Ra 0,63 and higher. In case of contaminations on the part surface more than 0,01 g/cm^2, the water film after surfacing immediately tears, and at 0,005 g/cm^2 the film tear comes in 4-7 sec.

Lecture № 4
Repair determination

Limiting state criteria of parts and couplings

The aim of repair determination is to define parts' operating conditions while machines and assemblies are repaired.

To make objective decisions regarding further use of parts, it is used the normative and technical documentation for the type and repair object. Comparison of actual (measured or determined by other methods) and standard values of state parameters allows defining part defects (hence, there is a term "repair determination").

In the normative documents (technical requirements for repair determination) it is defined two types of estimated parameters, i.e the criteria of part operating condition: the admissibility criterion of further use of a part; it provides resources to the next repair, and the limiting state criterion when the part cannot be installed on a machine.

While repair works are carried out, not only machine working ability should be restored (or operability), but also its interrepair life. Therefore, in machines we leave for further operation only those parts and couplings, the remaining resource of which is equal to or exceeds the overhaul period of an assembly or machine. In this regard, the limiting state of parts and couplings being repaired becomes slightly different and is defined as the admissible (or acceptable) variable of the state parameter in repair.

Thus, the admissible value of the state parameter is a variable when remaining life of parts or couplings is equal to overhaul periods of individual elements (unit, assembly) or machines in general.

The parameters of the limit (admissible) state of parts and couplings include limit clearance values in couplings, sizes or wear of part elements, defects of forms (ovality, cone shape etc.) and positional relationship of axes and surfaces (disalignment, radial runout, etc.) and characteristics of spring resistance and piston rings etc.

Quantity values of the limit (admissible) state of parts and couplings are stipulated in the technical documentation. For machinery repair such documentation is considered the technical requirements for repair determination for a specific machine brand.

Limit and admissible values of geometrics and other characteristics can be set by the following: theoretical calculations; mass micrometerage measurement of parts received to be repaired, and corresponding statistical analysis of data; special tests (accelerated or operational); comparison with the previous design (at first production stage of a new machine).

The capacity of parts and couplings cannot be assigned randomly.

The capacity are set by the technical, technological and economic criteria.

Criteria application depends on the assignment of a machine and its unit or mechanism. So, one of the criteria will be of primary importance, the others may be auxiliary or subsidiary.

Technical criterion. By this criterion the capacity of parts and couplings are set taking into consideration the strength, the character of acting load changes, friction conditions, the heat tension, the properties of friction surfaces etc. The capacity of parts is defined by the moment of the sharp instance wear increase or termination of mechanism operation.

The technological criterion (quality criterion). By this criterion the capacity of parts and couplings are set due to the standards of changes of operation quality indexes of machines or its assemblies and units. This criterion may be basic for working bodies of agricultural machines and mechanisms controlling them, because the main assignment of their parts and couplings is to ensure certain operation quality (admissible fluctuations in depth of plowing, seeding irregularity, etc.).

The economic criterion is basic for mechanisms controlling the processes of engine fuel supply, its combustion, removal of combustion products etc.

In most cases, basic parts reach their limit state not because wear causes their failure, but because operating characteristics of the engine worsen (the power decreases, the specific fuel consumption increases, etc.) when increasing clearances in couplings and, thus, the machine productivity decreases and operating material costs that affect economy increase.

Optimal durability is one of widespread characteristics of the economic criterion of the capacity of a unit, assembly or machine, i.e. a resource or service life, when minimum costs for its purchase, operation and repair per product unit or operating time unit (Fig. 1) are achieved.

Machine operating after an optimal time t_{opt}, and according to its wear, causes cost increase that may be taken as limit.

So, during the repair determination process parts are sorted into groups which define the process flows of parts: the parts suitable for further use in machinery repair; the parts are sent to be repaired; the nonrepairable parts which are utilized. In some cases, the first group is divided into two subgroups in the technological normative documentation: the parts suitable for coupling only with a new (or renewed) part, and the parts suitable for coupling with a partially worn part. This approach involves the use of the parts which are not suitable for coupling with worn parts due to their wear value, but in couplings with new parts which provide the admissible clearance value in a joint. Availability of such an additional part group to some extent increases a number of parts which do not require repair costs, but organization of process flows and parts kitting get complicated.

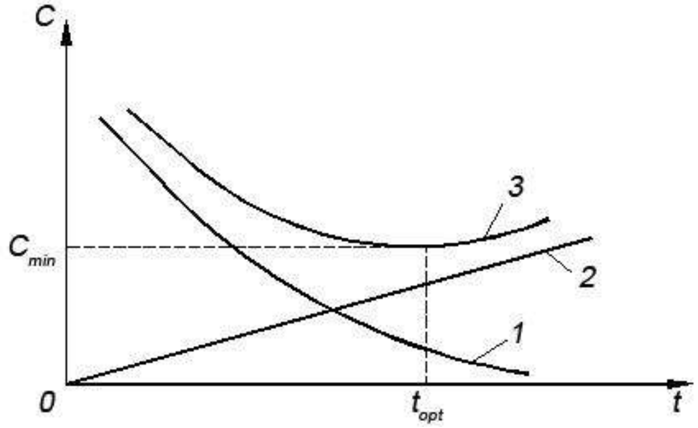


Fig. 1 – Scheme to identify machine optimal resource: specific consumption:
1 – amortization;
2 – operational;
3 – total

In terms of repair production, the maintainable parts can also be divided into two groups: being repaired at the enterprise, and sent to a trade shop.

After repair determination the parts are marked with paint: maintainable – with green, suitable in a coupling with new or renewed parts – with yellow, parts to be repaired at the enterprise – with white, at repair trade shops – with blue, nonrepairable – with red.

An important task, especially for large overhaul plants is accumulating information about repair determination results and part sorting to improve repair organization.

For all groups of the sorted parts for cars of the brand we determine the coefficients of availability ($K_П$), restitution ($K_В$) and variation ($K_З$) according to the accumulated information.

They characterize a number of maintainable parts, and nonrepairable parts regarding all similar parts which have gone through repair determination:

$$K_П = \frac{n_П}{N};\ K_В = \frac{n_В}{N};\ K_З = \frac{n_З}{N};\ N = n_П + n_В + n_З, \qquad (1)$$

where *n* with indexes «*П*», «*В*» and «*З*» – respectively, a number of maintainable, requiring restoration and nonrepairable (replaceable) parts. The defect repeatability factor $K_{ПДi}$ is important for overhaul plants; it determines a number of parts of one type of the defect to the total number of maintainable parts:

$$K_{ПДi} = \frac{n_{Дi}}{n_{Bi}} \qquad (2)$$

Having data about the repeatability factors of part defects, it is possible to assess much more accurately the need of labor and material costs for worn-part reclamation during designing as well as during operation of an overhaul plant, and thus to influence the reduction of production costs.

Repair determination methods

To implement repair determination tasks the following methods are used: organoleptic, toolmaking by geometric parameters and detection of hidden defects.

The organoleptic repair detection methods are based on the evaluation of part operating condition through sense organs and they are performed:

- by external examination, when visual damages and changes of the original part form (cracks, holes, chips, crumbs, abscesses, scorings, flutes, thread damages) are defined;
- by knocking – subtle cracks, weakening of frame rivets, clearances in immovable joints of parts are defined by listening (either chattering or dull sound);
- manual testing – for example, serviceability of thread by screwing a bolt or a nut up and down, scoring in rolling bearings by turning their inner or outer rings, freedom of part movement in movable joints are defined in this way.

In many cases all these methods of repair determination make it impossible finally to conclude about the operating conditions of repair determination objects as they are subjective.

Instrumental methods of repair determination by geometrical characteristics anticipate determining actual sizes of worn parts, errors of their form and mutual placement of axes and surfaces, as well as clearances in couplings. Universal and special measuring instruments are used for this purpose. Besides that, calibers and pattern which relate to monitoring, rather than to measuring instruments are used, as they identify only geometric parameters correspondence to the technical requirements, instead of their real values.

Repair determination measurements are performed in the areas of the maximum wear at the lowest value of the shaft size and the largest value of the hole.

Universal measuring instruments include: calipers, micrometric, indicator, lever-mechanical, optical-and-mechanical and optical instruments.

Special means of repair determination include various indicator devices to check shaft bends, bends and twists of rods, socket misalignment of main bearings, radial clearances in rolling bearings, piston-ring tension and spring resistance, etc.

Measuring instruments have certain metrological characteristics. Measurement limits, division value and measurement margin of error belong to the basic of the measuring instrument for a particular measurement object. The choice of measuring instruments depends on the ratio between the allowance for the permissible wear $\delta_з$ (but not the allowance for the size) and the tool margin of error Δlim (according to the reference data). The following ratio has to be kept, in order to have small rejection probability of maintainable parts or to pass nonrepairable parts:

$$\Delta lim \leq K \cdot \delta_з, \quad (3)$$

where K – a precision factor of a measurement method is equal 0,25-0,30.

Tolerance $\delta_з$ is defined as the difference between the average size according to the draft and the admissible size in repair.

Calibers for repair determination are used without two limits as when parts are manufactored or restored, but with one limit: derivative and established only for the admissible size. Application of calibers with two limits is also possible, for example, if one side is adjusted to the admissible size in the joint with a new part, and the other – to the size admissible with the part, which was in operation, so parts are sorted into two groups.

Complete plugs are used to control holes while manufacturing (restoration), and incomplete plugs or in the form of unregulated calipers – during repair determination. Such caliber designs allow to avoid errors related to nonuniformity wear of the inner surface (complete plug can miss nonrepairable part because it will not enter into the hole on the smaller size of the unevenly worn surface, although its larger size has gone beyond admissible).

<u>Methods to detect hidden defects</u>. Physical methods of flaw detection (magnetic, capillary, ultrasonic, hydraulic and pneumatic) are used to determine fatigue cracks, power and heat load cracks and weld defects.

The following methods of nondestructive check are currently widely-used in operation and machinery repair: optical and visual; capillary; magneto-powder; hypersonic.

<u>The optical and visual method</u> in comparison to the other methods has low sensitivity and accuracy in repair determination. It can detect opened cracks (with the width 0,1...0,01 mm), wear, corrosion, erosion damages, holes, breakages, permanent deformation, carbon deposit, leakage in systems.

Magnifiers and microscopes are used when controlling closely placed objects. The magnifier is placed near the part surface 1 (Fig. 2) to magnify an image so that the distance between them was slightly smaller than the magnifier's focal length.

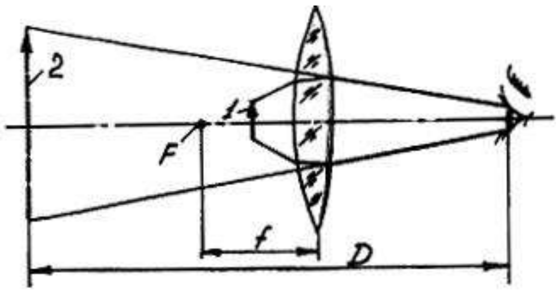


Fig. 2 – Scheme of view using magnifier:

1 – control object;
2 – virtual image;
F – magnifier focus;
f – magnifier focal length;

Parts and structural elements, which are inaccessible to direct observation, are examined with the use of rigid or flexible instruments such as endoscopes. Flexible endoscopes contain bundles of optical fibers usually with the diameter less than 0,3 mm which have a light thread of transparent material and a coating of lower refractive index material. Lens and eyepiece are set at the ends of the endoscope bundles (Fig. 3).

High light of examined parts is provided in all cases of control; it is approximately to 4,000...5000 lx. Such lighting of parts is an indispensable condition for effective optical and visual control.

Advantages and disadvantages of the optical and visual control; its sphere of use:

A d v a n t a g e s :

- the method can be applied to any materials and structures without any limitations;
- it is a direct control method, a defect can be photographed and documented;
- an easy method in use.

D i s a d v a n t a g e s :

- it allows detecting only superficial defects;
- it has low sensitivity (resolution).

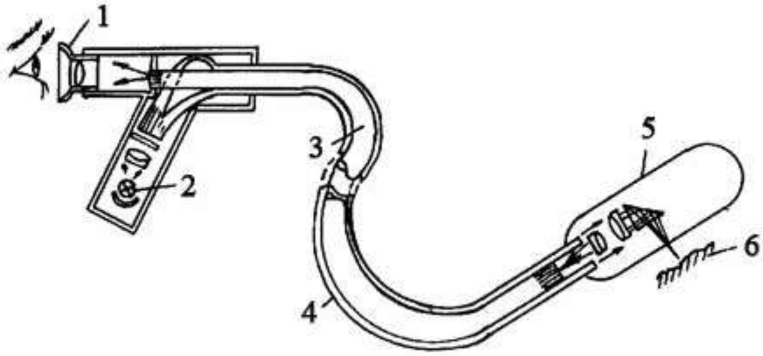


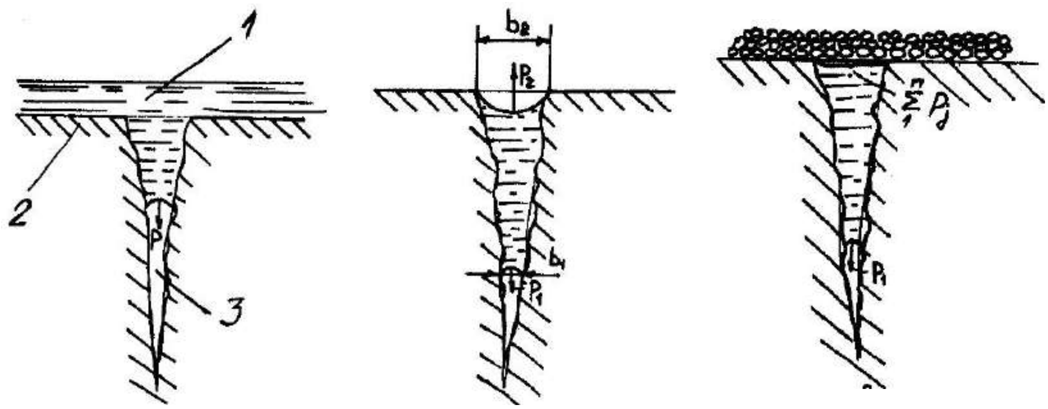
Fig. 3 – Scheme of flexible endoscope: 1 – eyepiece; 2 – light source; 3, 4 – bundles of fibers; 5 – lens head; 6 – control object

The capillary methods are used for any materials except of porous ones. They allow controlling parts of a complex shape across the whole surface at once; they are characterized by high sensitivity and resolution, clarity of results according to which it is possible to set the defect location and its length.

Repair determination of parts is carried by the color method using three basic flaw detection materials (Fig. 4): red penetrant; cleansing liquid; developing white paint.

The technology of the color control method consists of the following operations: preparation of the part surface for control; application of the red penetrant to the part; removal of the penetrant from the part surface; application of the developing white liquid; conditioning of a part to develop defects; part examination and removal of the developing paint.

Luminescent repair determination (control) peculiarities. The physical phenomena of wettability and capillary effect discussed above underlie the luminescent control.



a b c

Fig. 4 – Filling with the liquid 1 the crack cavity 3 on the part surface 2: a – application of red penetrant; b – removal of red penetrant; c – application of white penetrant.

The technology of this method consists of the following steps: 1. Surface preparation for control; 2 Application of the penetrant. Penetrant is the fluid consisting of gas and luminescent powder dissolved in it; 3. Removal of the penetrant. 4. Part examination and defect detection. Examination is held under an ultraviolet lamp in the dark room (Fig. 5). The penetrant in defects starts glowing with bright green or bright blue light, indicating the defect location.

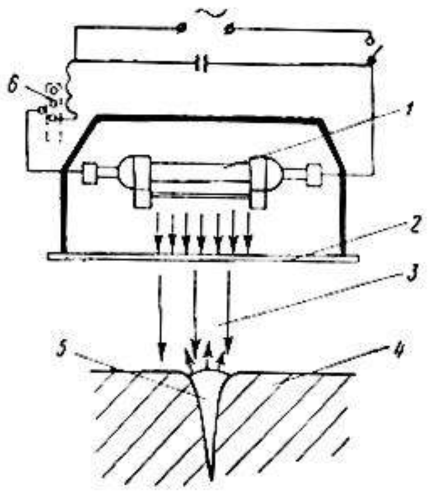


Fig. 5 – Scheme of luminescent repair determination:

1 – mercury-quartz lamp;
2 – light filter;
3 – beam of ultraviolet rays;
4 – part;
5 – defect filled with phosphor;
6 – restrictor.

This method of control is half shorter in time than the color method, and therefore, more productive.

Advantages and disadvantages of the capillary methods, their spheres of use:

Advantages:

- it can be used on any materials and constructions except of porous materials and prone to dissolution in organic solvents;

- it has high sensitivity;
- easy to use;
- it is a direct control method, defects can be photographed and documented;

Disadvantages:

- it requires careful surface preparation;
- it has a great control time;
- it has complicated control at low temperatures;
- it allows to detect only superficial defects;

The magneto-powder method is basic to control magnetic steel parts. It allows detecting surface and subsurface defects (Fig. 6). It has great sensitivity and reliability, simplicity and versatility of control methods (it is possible to determine precise location and the length of defect according to control results.)

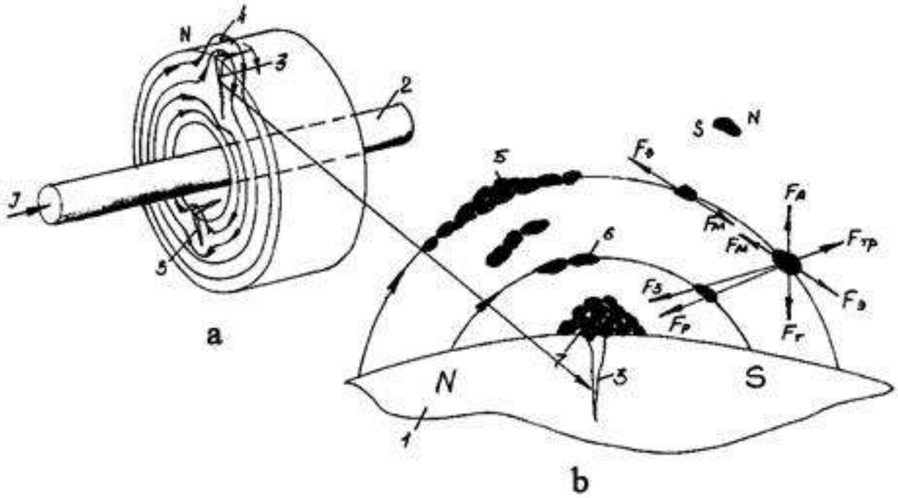


Fig. 6 – Scheme of formation of magnetic stray fields above the crack (a) and the forces acting on the particle in the stray field (b): 1 – part 2 – cable, 3 – cracks, 4 – stray field, 5, 6 – chains of powder 7 – powder above the crack

The magneto-powder method is based on detection of magnetic stray fields of defects using ferromagnetic particles. If the electric current passes through the cable 2, (Fig. 6 a) flowing through the hollow part 1, the occurring magnetic flow will close up in the part. In the places of cracks it flows beyond the part, creating a nonhomogeneus magnetic stray field 4 and local magnetic poles N and S. The highest density of magnetic field lines is observed directly above the crack (or another absence of integrity) and it decreases moving away from it.

The defect size, which can be detected, depends on the strength of stray field caused by the defect. The stray field strength drops rapidly with the increase of defect depth below the surface.

Oxide powder – ferrous oxide Fe_3O_4 of black or brown color is used in repair determination of parts with the light surface. The volume of the powder particles does not exceed 30 μm.

The powder mixture of gas and mineral oil, as well as possible replacement of gas with gasoline or diesel fuel is used during control of parts with the dark surface.

The location of magnetic stray fields relatively to the defect is a necessary condition for defect detection.

For qualitative control it is necessary for magnetic field lines to be placed perpendicularly in relation to the defect or at the angle no less than 30º. In case of parallel orientation of field lines to the defect, formation of stray fields is minimal at the surface, and therefore, defect detection is impossible. That is why, the pole (longitudinal), circulation and combined magnetization is used during the magneto-powder control.

The sequence of technological operations when controlling the friction surface by magnetization is shown in Fig. 7.

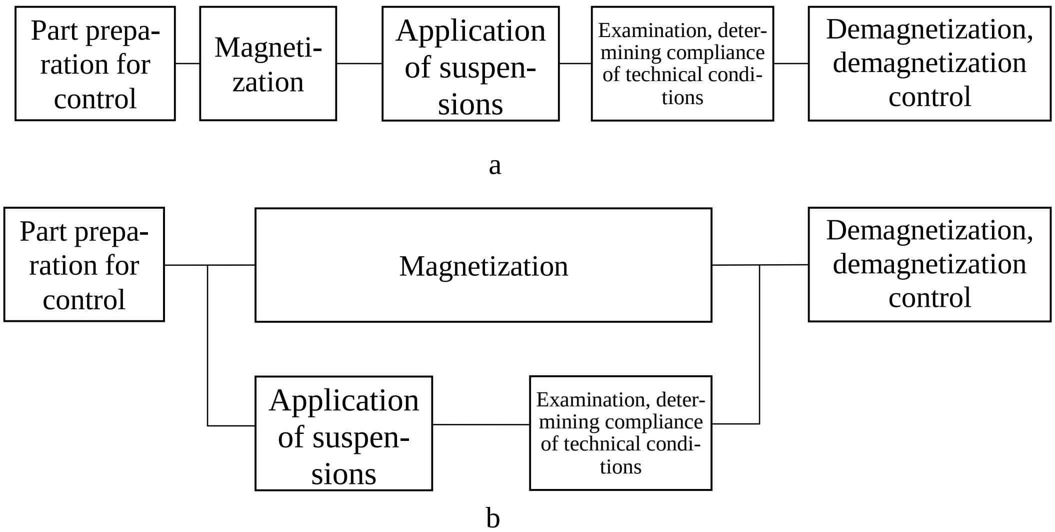


Fig. 7 – Sequence of performing operations while controlling: a – during residual magnetization (pole or circular magnetization); b – in the applied magnetic field (combined magnetization)

The magnetized parts have to be demagnetized after being controlled and before being installed in the construction.

Domain disorientation is necessary for demagnetization. Two conditions have to be fulfilled for this:

1. To switch the part cyclically.
2. To decrease the strength of the magnetic field to zero along with switching.

Advantages:

- it allows to detect surface and subsurface defects;
- it has considerable sensitivity;
- it is a direct control method; it does not require a standard sample, defects can be photographed and documented;
- it does not require careful surface preparation;

Disadvantages:

- it is applied only to ferromagnetic materials;
- a part has to be demagnetized after being controlled.

The ultrasonic method has become more widely used and serves as the main method of control. Any part made of any material (except of rubbers and composites) is checked by this method. Having high productivity, the method allows detecting superficial, subsurface and deep surface defects with high sensitivity.

Electroacoustic converters are used to excite hypersonic waves: magnetostrictive and piezoelectric. Piezoelectric converters of piezoceramic – zirconate lead, titanate lead and barium titanate are used in hypersonic flaw detectors.

The action of such elements is based on the piezoelectric effect, which consists in occurring electric charges on converter surfaces while compressing and stretching (Fig. 8).

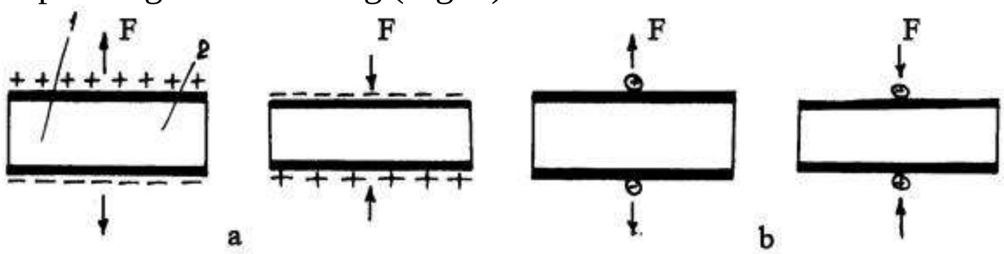


Fig. 8 – Direct (a) and reverse (b) piezoelectric effects: 1 – piezoplate; 2 – silver layer; F – force of compression or tension

The sign of charges is detected by the type of deformation (compression or tension) and value – by the applied force.

The properties of reflection, refraction and transformation of hypersonic vibrations on the boundary between two mediums are used to excite waves of different types in parts. If a longitudinal wave falls on the part on the normal to its surface, then some energy of hypersonic vibrations gets into the metal and spreads there also in the direction of the normal, and a part of it reflects. So, the waves which go through and which are reflected have the same type as the initial, i.e. are longitudinal.

Thin layer of mineral lubricant (couplant), which fills hollows of rough surfaces, thereby eliminating air clearances is applied to improve the acoustic contact on the part surface in the place of the locator installation. So that around 10-20% of the initial energy of hypersonic vibrations can be entered into the metal.

Defect sizes in the surface perpendicular to the direction of the spreading wave have to be more than 1/3 λ (λ – a wave length) to get intensive reflection of the ultrasonic vibration energy from the defect.

The pulse-echo technique of the hypersonic control is based on the detection of the material discontinuity flaw (cracks, abscesses, corrosion, etc.) from the reflected surface or other reflectors of hypersonic waves. The essence of the pulse-echo technique is clear from the analysis of Fig. 9.

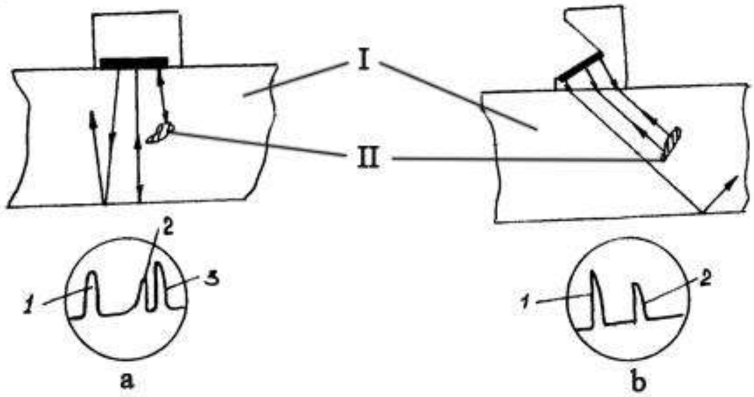
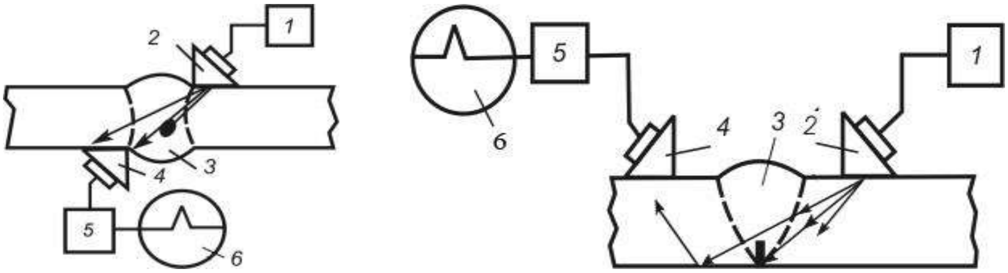


Fig. 9 – Scheme of sonic test carried by pulse-echo technique using straight (a) and inclined (b) locator; I – part II – defect: 1 – initial signal; 2 – echo signal from the defect; 3 – bottom signal

According to this method, a projector which carries out the functions of radiation and reception is used for radiation and hypersonic wave's reception. The cathode-ray tube of the flaw detector in this case serves as an echo signal indicator.

The pulse-echo technique sensitivity (the minimum area of defects which are reliably detected) depends on the wave length and the difference of acoustic supports of the material and the defect. In turn, the wave length depends on the spread rate of fluctuations in the material and the working frequency, i.e, the higher working frequency is and the less spread rate of fluctuation distribution is in the controlled material ($C_{\text{поп}} < C_{\text{под}}$), the higher sensitivity becomes.

The shadow method is used to control parts of a simple shape and small thickness (flats, pipes, cross-sections etc.). The method is clear from Fig. 10. While controlling by this method, a continuous or pulsed wave is sent into the part material on the one side of the part and on the opposite side it is registered.



a b

Fig. 10 – Scheme of sonic test carried by shadow (a) and reflector-shadow (b) methods: 1 – generator; 2 – projector; 3 – weld; 4 – receiver; 5 – amplifier; 6 – indicator

If the moving locator comes across a defect on the wave path, then depending on its size, waves will be completely or partially reflected from it or fade away. A complete signal disappearance or a significant decrease of its amplitude indicates a defect.

A d v a n t a g e s :

- it allows to control parts of any material (except of porous, rubbers and composite materials with filling compounds);
- it allows to detect surface, subsurface and deep defects;
- the minimum time of controlling a part (without taking into consideration setting).

D i s a d v a n t a g e s :

- the indirect method of control, control samples are necessary to set a flaw detector;
- it requires careful surface preparation in the installation site of the locator;
- it is difficult to set a flaw detector and decode the indicated values;

- it requires high qualification of working staff;
- it has relatively low sensitivity of the method.

General methods to eliminate worn part and coupling defects

Surface wear of coupled parts leads to violations of dimensional connections between coupling, mechanism or unit parts. These connections are expressed by the basic equation of the dimension chain:

$$A\Delta = \sum_{i=1}^{p} A_{iзб} - \sum_{i=1}^{q} A_{iзм} \quad , \tag{4}$$

where $A\Delta$ – a master link;

$A_{iзб}$ and $A_{iзм}$ – components which respectively increase and decrease links of the dimension chain;

p and q – a quantity of magnifying and diminishing links.

The value of the master link changes in the operation process of the interconnected parts. At the same time its size is one of parameters; its limiting value defines the loss of coupling's (mechanism's, unit's) working capacity. The restorative function due to restoration of the initial value of the master link can be achieved by the influence on the changes of sizes of chain links.

At the same time, restoration of a mechanism (unit) is initially possible with adjusting operations on multilink dimensional chains. For example, adjusting the clearance between the valve and the valve lever of the gas-distributing mechanism of the engine, between the teeth of the bevel pinions of the main gear of the rear axle, etc.

However, restoration of the master link by adjusting is limited by an error of part shapes as not only sizes but also shapes of the rubbing surfaces change as a result of the wear process. In this case, other methods of restoration of dimensional chains are needed.

Let's consider these questions for three-link dimensional chains, which are included into dimensional chains of mechanisms and units. The equation of such chains is given as the following:

$$S = A - B, \tag{5}$$

where S – a clearance (in some cases – tension);

A – a hole size (of an envelopment surface, including, for example, a key groove, etc.);

B – a shaft size (of an envelopment surface, including, for example, groove, etc.);

Changes of A and B through wear leads to changes of S, i.e to changes of the fit nature. A fit can be restored due to changes of sizes of worn parts A_p B_p to the values of $A_н$ $B_н$ by some methods of repair influences if the equality is kept:

$$S = A_н - B_н = A_p - B_p, \tag{6}$$

where a subscript «*н*» refers to new parts of a normal size, i.e. the size according to the working (basic) draft.

The common methods of fit restoration of mating parts can be determined from the analysis of the given below equity (Fig. 11, where the surface wear is attributed to one side). There is a diagram of the initial state of the coupling in Fig. 11, and in Fig. 11 b – 11 d – after repair actions. The worn surfaces are marked with the dotted line.

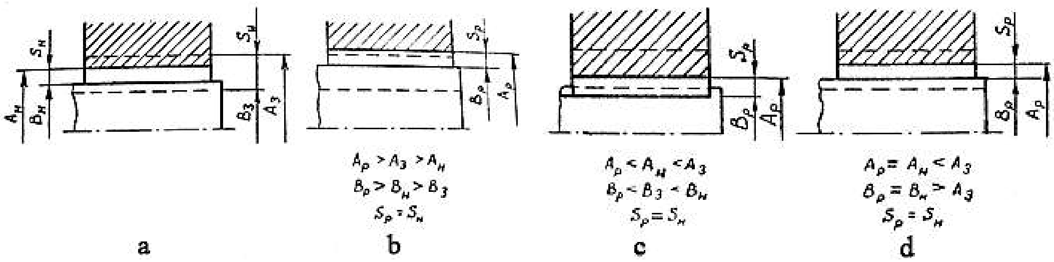


Fig. 11 – Schemes of common restoration methods

Fit restoration by simultaneous extension (Fig. 11 b) or narrowing (Fig. 11 c) of the hole and shaft sizes. These variants allow restoring the fit, but sizes of the hole and shaft will differ from the sizes provided for manufacturing these parts. Dimensions, set for repair or production of a new part which differ from analogous part sizes by the (basic) working draft are called repair sizes. They are divided into categorical and fitting. Categorial repair sizes are final repair sizes of parts set for special repair categories, fitting repair sizes are repair sizes of parts set taking into consideration fitting allowance of parts at the place of destination.

Parts of repair sizes are used when couplings are repaired with fit restoration only. During its application one of them is subjected to the mechanical processing while being repaired, and the second one (of a larger size for the shaft and of a reduced size for the hole) is produced in the form of spare parts. The mechanically processed part costs more. For example, restoration of the coupling cylinder–piston is performed by the mechanical processing of the cylinder to its repair size corresponding to the piston of the repair (increased) size produced by industry; the worn main journal parts and crank bearings of the crankshaft are polished and assembled with bushes of the repair (reduced) size of industrial production.

Repair sizes are set depending on the extent and nature of the surface wear. There may be several sizes for this part.

Fig. 12 shows the diagram of repair size formation for the hole and the shaft.

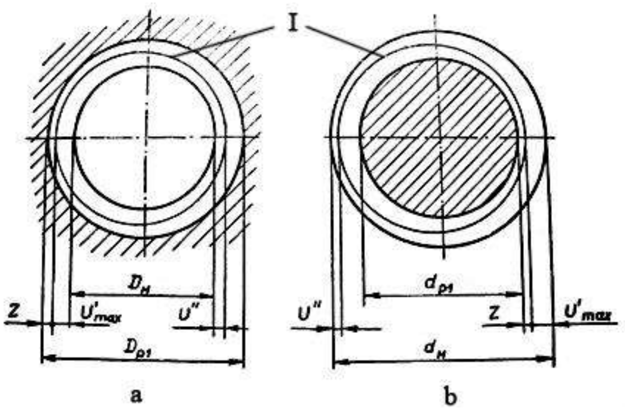


Fig. 12 – Scheme of making repair sizes of:
a – hole;
b – shaft;
I – worn surface

From the scheme we can see that, taking into consideration wear irregularity, the first repair size can be calculated from the following dependencies:

for a hole $D_{p1} = D_H + 2(U'_{\max} + Z)$, (7)

for a shaft $d_{p1} = d_H - 2(U'_{\max} + Z)$, (8)

where D_H, and d_H – normal sizes of a hole and a shaft;

$U'_{\max}$ – a maximum one-side wear;

Z – an allowance for the mechanical processing on the side.

The irregularity coefficient of wear is used for calculation instead of the maximum one-sided wear. It is defined as:

$$K_{нз} = \frac{U'_{\max}}{U'_{\max} + U''}, \quad (9)$$

where U'' – a diametrically opposed wear relatively to $U'_{\max}$;

U – a total value of wear by a diameter;

Hence $U'_{\max} = K_{нз} U$, dependence to calculate the repair size will be as follows:

$$D_{p1} = D_H + 2(K_{нз} U + Z) \text{ i } d_{p1} = d_H - (K_{нз} U + Z) \quad (10)$$

In case of symmetric wear relatively to the part axis $K_{нз} = 0{,}5$, in case of one-sided wear– $K_{нз} = 1$, i.e 0,5< $K_{нз}$ <1. $K_{нз}$ for special parts is set experimentally. For example, for shaft necks $K_{нз} = 0{,}7...0{,}8$, for cylinders of an engine $K_{нз} = 0{,}6...0{,}7$.

If the expression $2(K_{нз}U + Z)$, that defines the repair interval is marked as Δ, then the formulas for repair sizes will be as follows:

$$D_{pl} = D_H + i\Delta \text{ i } d_{pl} = i\Delta, \tag{11}$$

where i – a number of the repair size (1, 2, 3, ...).

Limit, maximum for a hole ($D_{p\max}$) and minimum for a shaft ($d_{p\min}$) repair sizes are set taking into consideration the possible impact of changes of part sizes to reduce stiffness and mechanical strength, to increase specific pressure and to reduce surface hardness of repaired parts, in other words, to reduce resource (service life).

There is a number of repair sizes defined by repair interval values and limit repair sizes of a hole or a shaft:

for a hole $$n_A = \frac{D_{p\max} - D_H}{\Delta}, \tag{12}$$

for a shaft $$n_B = \frac{d_H - d_{p\min}}{\Delta}. \tag{13}$$

However, repair sizes application has a significant imperfection – interchangeability of parts is violated (it is stored only within one repair size). In addition, the list of spare parts increases and the organization of completing processes and unit assembly, part storage in warehouses becomes more complicated. Despite these imperfections, the application of standard repair sizes is proved by certain economic profitability.

Fit restoration is performed by changing sizes to initial ones and keeping interchangeability of recovered parts with new ones, first of all, by the same principle as in case of parts of repair sizes. The only difference is that in one case the coupling scheme looks like: processed part – clearance – new part of repair size, and in the second: built up part – clearance – new part of standard size. For example, the worn matching site for a rolling bearing in the transmission case can be restored by local dry topping with setting a new standard rolling bearing.

There are a lot of ways to compensate the worn surface layer and they are used depending on the factors affecting the wear rate of a specific coupling and economic profitability of the method. Various types of surfacing and spraying, electrolytic, electrophysical and other coatings, installation of additional parts (for example, entire and complex hubs, metal strip welding) belong to the latter. Compensation of the worn surface layer by the methods mentioned above is a part of the technological process, followed by the compulsory usually dimensionally precise and often strengthening processing.

Coupling restoration to its initial sizes is possible by the ways of compensation of the worn surface layer not only to one, but two parts of a coupling at the same time.

The precision of the master link has to match the initial one for all methods of fit coupling restoration. Since the tolerance of the master link is equal to the amount of tolerances of chain links, then the tolerance to process a shaft and a hole has to be the same as while producing a new part.

Lecture № 5

Parts kitting. Setting-up, running-in and testing of units, assemblies and machines. Painting, drying and quality control of paint-and-lacquer coatings

Parts kitting

Parts kitting – a prior operation to assemble units, assemblies and machines.

During basic working conditions parts are made-up according to assortment of its assembly part taken into consideration uniformity of groups in case of selective assembly as well as selection of parts by mass.

Selection of parts by mass belongs to parts of the control and piston group of engines and is significant because the mass difference of moving parts of various cylinders can cause engine vibration and increase of part wear intensity. The number of selective group and the part mass are marked on a part.

Parts kitting during repair working conditions has its peculiarities: assembly parts are made-up not only with parts of normal precise dimensional parameters set by the basic working draft taking place while parts are manufactured, but also with parts of repair sizes as well as with partly worn parts with characteristics allowable while being repaired.

Individual part selection which allows the normative value of joint clearance, for example plunger – cylinder, is also applied in small repair workshops.

Fitting operations are performed during kitting-up, for example processing of inner hub surfaces of the upper head of connecting rods (after pressing in a hub) under the size of a piston pin.

Therefore, full interchangeability is kept only while assembling parts with normal conditions (new or remanufactured) in repair production. Some couplings in such parts are made up by the selective method, i.e. the method of partial interchangeability (piston – sleeve, piston – piston pin etc.) Interchangeability is retained only within the repair (categorial) size for parts of repair sizes (new or repaired). Worn parts loose their interchangeability in the majority of couplings even if they have parameters admissible during the repair process. That is why the process of machine assembling can be performed by the methods of full and partial interchangeability, especially – methods of selective assembly, as well as with the use of control instruments – compensators (valve regulation, tapered bearings (bearing by SSTU 3321-2003 (State standards of Ukraine)), rolling bearings, bevel pinions etc.) and adjustable operations (unscrewing of hubs of the upper head of connecting rods etc.). Fitting operations are labor-consuming and have to be minimized especially in trade shops.

Parts of some couplings which have admissible sizes during the repair process loose their interchangeability and have to arrive for assembly in the separated state.

The specific weight of any method of assembly depends on the type and brand of machines in for repair, programs and overhault plant availability of equipment.

The considered peculiarities of assembly during machinery repair require organization of kitting-up of part and units not only according to their assortment (specification or part lists), as it takes place in producing new machines, but also taking into consideration partial interchangeability and even its absence.

Completing charts or specifications given in process charts for assembly are used during kitting-up of assembly parts.

Parts are put into a container (for this assembly part), which is delivered to proper assembly points during parts kitting. A container can be moved on special mobile carts or in packages hung up to the overhead conveyor.

Setting-up of units, assemblies and machines

Assembly of units, assemblies and machines is a set of consecutive operations on assembly of separate joints, quality of which is defined by such basic factors as:

- accuracy of purification, washing, blowing of parts delivered to be assembled by compressed air;
- correspondence of geometrics and mass, surface roughness, imbalance of parts and units according to characteristics set in the normative and technical documentation;
- absence of disassembling of mating parts listed in the documentation (corresponding selection and fitting of parts takes place when replacing a part);
- quality of parts kitting, using corresponding equipment, devices and tools which ensure the specified quality of assembling junctions;
- adherence of regulated process conditions, instructions and requirements of assembling junctions;

➢ using recommended materials, sealing elements and lock members etc. during assembling.

All assembling stages are performed in correspondence to the technological assembling processes. Tools and equipment are analogous to those which are used during disassembling.

Assembling threaded connections (stud pins, screw nuts, studs, and screws) makes up 25-34% of the total labor-consumption of assembly works.

While assembling threaded connections, it is required the following:

➢ concentricity of stud axes, stud pins, screws and threaded openings as well as required tightness in the thread;

➢ absence of drunkenness of nut ends or screw heads relative to the surface of the mating part because drunkenness is the main reason of breakaway of screw and stud pins;

➢ adherence of consequence and stability of tightening efforts of the group of screw nuts (cylinder head etc.)

Assembling of fixed couplings. The quality of assembling press-fit couplings is formed under the influence of the following factors: the material of mating parts, geometrical sizes, forms and surface roughness, concentricity of parts and applied force of pressing-in, availability of lubricant etc.

The roughness of the surfaces in fixed couplings should not exceed Ra = 2,5-1,25 microns, because there will be mashing of irregularities and it can reduce tension.

The external member is heated and the internal one is cooled down during assembly of junctions with big tensions. Temperatures of heating and cooling are defined by the formula:

$$T = (1{,}2 - 1{,}3) \cdot 10^{-3} \frac{N}{\alpha d}, \quad (1)$$

where α – a coefficient of linear extension of the part material;

N – a tension in a coupling, μm;

d – a nominal diameter of mating parts, mm

To avoid losses of the part initial strength, the heating temperature should not exceed 500°C. Before pressing-in part is heated in oil, molten lead or by the open way and cooled down by condensed gases, air, nitrogen or dry ice.

During pressing-in of rolling bearings with bearing drivers, efforts of pressing-in should be transmitted directly to the butt end of the correspondent race: inner race – during press fit on a shaft, external race – on a frame and on both butt ends of races if bearings are press-fitted on a shaft and put into a frame. Bearings are heated in oil at up to 80-100°C to make the press fit process easy.

Assembly of gear drives. The working capacity of gear drives is defined by the geometrical accuracy of gear wheels and interlocks (side clearance, form, square and location of tooth contact pattern). These factors depend on frame part conditions, accuracy of fitment bores, axle base, inclination error etc.

Accuracy of assembly of the majority of gear drives is ensured by the method of full interchangeability i.e. geometrics accuracy of mating gear wheels and the frame part.

Therefore, gear wheels and frame parts have to correspond to the set technical documentation.

Side clearances between teeth are measured with an indicator or feeler and for toothed gearings with a big module – with a lead plate, after having pricked it between its teeth and after having measured its thickness. The side clearance in the gearing is measured with an indicator in case of an unchangeable central distance (Fig. 1) is defined by the following formula:

$$\Delta = \frac{D}{2L} h, \tag{2}$$

where D – a diameter of the initial circle of the gear wheel, mm;

L – a reach, mm;

h – indicator reading, mm.

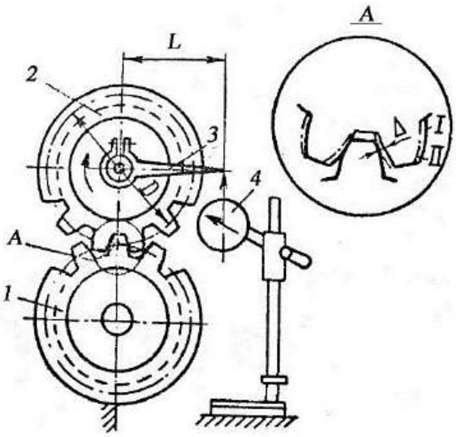


Fig. l – Control of side clearance in interlock of cylinder gear wheels:

1 – lower pinion;
2 – gear wheel;
3 – loop;
4 – indicator;
I-II – location of gear wheel.

Abutment (surface contact) of working surfaces of gear wheels is checked «on paint». For this the working surfaces of pinion gears are coated with paint and the gear wheels are rotated in different sides several times. Form and location of a print gives information about the quality of working surfaces (Fig. 2) Accuracy of cone and hypoid gear drives is performed by regulation with the help of compensators – a set of adjusting washers, rings, fillings or screw nuts.

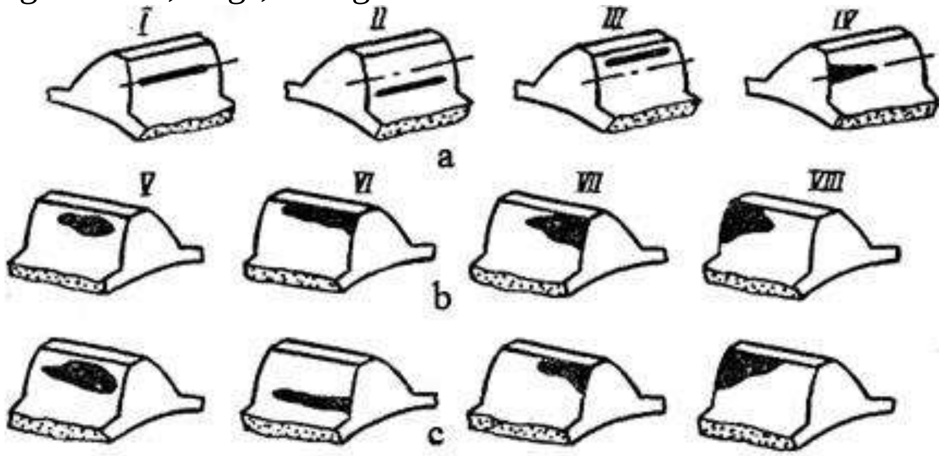


Fig. 2 – Check-out of contact accuracy «on paint» of gear wheels: a – cylinder; b – conic teeth of drive pinion; c – conic teeth of follower gear; I – ordinary center-to-center distance; II – declined; III – increased; IV – misalignment of axes; V – normal gearing; VI, VII, VIII – abnormal gearing

Assembly of key and spline joints. Three basic types of key joints are used; they are prismatic (ordinary), semicircular and wedge keys. Special attention is paid to fitting of key to butt ends and the clearance to its outer sides while key joints of the first two types are being assembled. Butt ends of keys have to be accurately fit to the key slot of mating parts because torques are transmitted through butt ends of keys. Wedge keys have to enter the slots of mating parts in heights, clearance has to exist between side edges.

An external member, a pinion gear are heated to 90-120°C, and then press-fitted on a shaft against stop while stationary spline joints (tension 0,03-0,04 mm) are being assembled. In case of movable fit of pinion gears on a spline shaft it has to move freely on a shaft without any sticking.

Special attention is paid to abutment of cone-shaped surfaces while taper joints are being assembled. The process begins with fitting an external member to the shaft cone, checking some couplings «on paint», or rolling and on depth fit on a shaft. Taper joints are placed in a way to leave a clearance between butt ends of external and internal members to tight a joint and its next tightening.

Balancing of parts and machine units

Products with large rotating masses and high angular velocities (crankshafts with flywheels, cardan shafts, thrashing drums, etc.) are subjected to this operation.

Additional dynamic forces which influence bearings and other bearing components appear due to mechanic imbalance of parts. All of these lead to vibrations and as the result of rapid wear and parts destruction. To balance rotational body two conditions are to be fulfilled: the center of mass has to be located on the geometrical axis of rotation; the axis of rotation has to be the main axis of inertia.

These conditions are kept in the process of designing and manufacturing machines, but during operation, due to wear and part deformation as well as repair impacts, the terms of balancing are violated. Thus, rotational elements of repaired objects have to be obligatory balanced.

There are static and dynamic imbalances (balancing). Static imbalance of parts – mismatching of its gravity center with the axis of rotation. For example, if we attach a plummet with mass mH to the ideally (theoretically) balanced body (Fig. 3 a) at a distance R_H from the center of rotation O, then the gravity center will shift toward the cargo. Static imbalance appears under the influence of centrifugal force: during rotation of the body:

$$P_H = m_H R_H \omega^2, \quad (3)$$

where ω – a body's circular velocity.

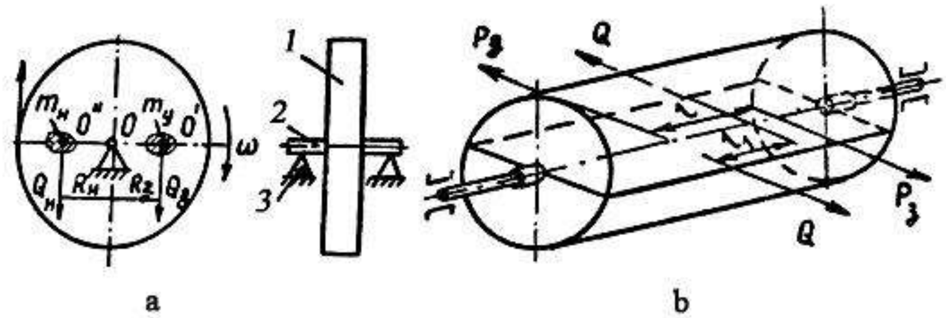


Fig. 3 – Scheme of part balancing:
a – static; b – dynamic; 1– part; 2 – bearing driver; 3 – seating

Static balancing of parts and units is used to eliminate this kind of imbalance. The part 1 is placed on the smooth, precisely machined and balanced bearing driver 2, which is set on parallel, precisely horizontal seatings with low friction (of prisms or bearings). Under the influence of the imbalanced mass part freely rotates and settles in a way that the mass is located in lowermost position. Having found out the concentration place of the imbalanced mass (O '), the plummet with the mass of $m_з$ should be attached in the diametrically opposite point (O') at a distance $R_з$. In this case a part is balanced:

$$\Sigma M_o = Q_H R_H - Q_з R_з = 0 \quad (4)$$

Hence the mass of the balanced plummet:

$$Q_з = Q_H \frac{R_H}{R_з}, \quad (5)$$

From the set dependence we see that static imbalance does not depend on the length but on a diameter of parts. Therefore, static balancing is carried out for parts (units) with the relatively large diameter and the small length (flywheels, pulleys, wheels etc.) by removing metal, screwing pins, installing additional washers, moving special plummets.

Dynamic imbalance appears when the axis of rotation (node) does not coincide with the main axis of inertia. When the shaft is rotated (Figure 3, b), imbalanced (by length) masses cause an effect of a pair of forces Ql_1, which tries to turn the axis of the shaft at an angle, that means that the main axis of inertia is shifted according to the axis of inertia. The torque of this pair is balanced by another pair of forces applied in the same plane:

$$Ql_1 = P_з l, \quad (6)$$

where $P_з$ – an outer balancing force;

l – a distance (arm) of a pair of balancing forces.

Parts with the large length and small diameter (crankshafts and cardan shafts, etc.). are subjected to dynamic balancing. Dynamic balancing is performed on special balancing machines.

Running-in and testing of units, assemblies and machines

Running and testing of repair objects after assembly – final and particularly responsible repair operations. Mutual running-in of rubbing surfaces in order to prepare them to work with normal workload is reached through running.

Running-in of mating parts is characterized by the change of geometry of the friction surfaces and physical and mechanical properties of the material layers in the initial period.

Basic running-in of coupling surfaces appears during first 2-3 hours and ends for engines in 50-60 hours and for assemblies of transmission in 100-120 hours. It is performed in two stages: first – while running at an overhaul plant and second – while running in operating conditions during part-load operation.

Running-in of units, assemblies and machines (oil and fuel pumps, hydraulic pumps, transmissions, driving axles, etc.) is performed on special stands, where operating regimes are set in advance at the overhaul plant. Durability and operating regimes are set by the normative-technical documentation. Running in operating conditions is performed according to the service instructions of car operation of this brand.

Testing – an inspection job which estimates the repair quality. Basic operation figures of repair objects are defined when testing is carried out. Tests are carried out after sufficient running-in of surfaces on the modes which do not cause surface fractures due to overload. The defects of assemblying as well as some mechanisms (a gap between a valve and a pusher, the moment of injection in the fuel pump, etc.) are also checked and adjusted during test run.

Painting of machines

Car painting and its parts – application of paint-and-lacquer coatings (PLC) on metal and wood surfaces to protect them from environmental influences, corrosion and wood rotting, and also to decorate items and to meet requirements of technical aesthetics.

One of relatively simple and cheap ways against corrosion is application of paint-and-lacquer coatings on the surface.

Service life period of machine and its marketable state depend on the quality of painting. Surface painting can be reliable only if there is a solid, durable coating layer which does not have any damages.

Resistance of paint-and-lacquer coatings, i.e. reliability of painting depends on external factors which cause destruction of the paint layer, as well as on the level of the painting process.

Painting is recommended to be carried out indoors or in special chambers or on exhaust grills protected from dust, dirt and moisture. The indoor temperature has to be no less than 15ºC; the relative humidity must not exceed 70%. Peculiarities of renewing paint-and-lacquer coatings should be considered before application of paint-and-lacquer materials. Preparing to paint consists in removing scale, rust, old paint from the part (product) surface, and then stripping, degreasing and drying. Defects of surfaces (dents, scratches, etc.) are removed due to manual cleaning, electric- and pneumatic grinding machines.

Facing surfaces with dents and other defects should be flattened and corrected, if necessary – puttied.

Internal surfaces of covering parts and assembly units which are not subjected to the direct action of rainfalls, sunlight and wind, should be painted with enamel in a single layer on the priming or with two layers of enamel. External surfaces of assembly units exposed to the direct action of rainfalls, sunlight and wind, should be painted with enamel in two layers on the priming.

Part surfaces which are not subjected to painting should be isolated by caps, plastic coatings, removing polymer inhibited coatings or waxed paper. Rubbing surfaces which are not subjected to painting have to be lubricated with solid oil.

The painting process has to be carried out according to the following scheme: applying a layer of the priming with corresponding viscosity of 15 mkm thickness (for surfaces not treated with priming-modifier), drying, puttying (if necessary), drying, sandpaper grinding by hand or using a special grinding machine (if necessary), applying the first layer of paint, drying, applying the second layer of paint (if necessary), drying.

The total thickness of the paint-and-lacquer coating has to be at an average of 100 mm. Destruction of the coating accelerates due to vibrations of painted surfaces and sharp temperature fluctuations when the layer thickness increases. The layer with the less thickness wears faster and does not protect the painted surface against corrosion.

The basis of the painting technology of machines, units and parts is formed by preparation of surfaces for painting and conduction of consecutive operations to create paint-and-lacquer layers. Assemblies and some other components of machines (engine, axles, frame, etc) are painted before their installation on a car. Cabs, bonnets and other external parts of vehicles are flattened in advance, and then they are subjected to two-layer painting and finishing works – writing signs, applying decalcomania labels etc.

Choosing a particular method of surface preparation for painting, the size and weight of the product, its shape and nature of contamination, operating conditions, type of production and technical and economic profitability should be considered.

The minimum thickness of paint-and-lacquer coating has to be 20% higher than the maximum height of microcracks. The surface roughness admissible for painting can not exceed 40 mkm. The rougher surface leads to increase in consumption of paint-and-lacquer materials, meanwhile, durability of coating does not increase.

Choosing a method of surface preparation for painting we should keep in mind the following factors:

- the most common and frequently used methods are mechanical and chemical (physical and chemical) methods of surface preparation. Thermal and electrical methods are used less often because of their significant energy capacity;
- the bead blasting and wheel blasting processing methods may be applied to the surfaces with the wall thickness of at least 3mm and the gas-flame method – with the wall thickness of at least 6 mm;
- selecting chemical methods of surface preparation, we should consider a possibility of the neutralization process of waste etching solutions and drains;
- it is necessary to wash carefully remains of salts and acids out of the product surface after etching;
- it is allowed to use solutions of phosphoric acid for etching of rolled iron with weld joinings;
- it is not allowed to use highly alkaline (pH = 12-14) solutions for aluminum degreasing;
- welds should be additionally cleaned and protected by phosphate and other prime coatings in all processing methods;
- it is necessary to control strength characteristics of welds during product phosphatization with welded joinings.

Several paint-and-lacquer materials are usually used to form protective, decorative and electro insulating coatings on products. This combination of consequently applied paint-and-lacquer materials of different purposes is called a coating system.

Basic layers of paint-and-lacquer coatings are as follows: a priming coating is applied directly on the prepared surface; a spackling coating is applied on the priming layer for surface leveling and pore filling; a covering layer is formed after applying covering materials (enamels, paints, varnishes).

In the paint-and-lacquer production initial components are as follows: film-forming substances (natural and synthetic resins, vegetable oils); organic volatile liquids, dissolvent fats and resins (solvents); mineral pigments and organic stains (pigments); plasticizers; fillers (chalk, kaolin, talc, barite). In addition, paint-and-lacquer materials may contain hardeners, catalysts, siccatives, initiators and polymerization accelerators as well as emulsifiers.

All paint-and-lacquer materials are classified according to three criterions:

- by a type: varnishes, paints, powder paints, enamels, primers, putties;
- by the chemical composition of resins, oils, cellulose ethers, included in film-forming substances: glyptal (GP), pentaphtol (PP), melamine (ML), urea (UR), phenolic (PL), epoxide (EP) and alkyd- and oleaginousi (OG), polyurethane (PR), nitrocellulose (NC), perchlorovinyl (CV), organosilicone (OS), bituminous (BT) etc;
- by the primary purpose, i.e according to operation conditions of paint-and-lacquer coatings: weatherproof (symbol – 1), limited weatherproof (2), waterproof (4) special (5), oil-resistant (6), chemical-resistant (7), thermo (8), electric insulating (9), primers (0), fillers (00).

Choosing a paint-and-lacquer material for a particular coating you should follow not only protective, but also technological properties of the material, i.e an ability to put it on the surface of the product in this or another way with the help of drying modes etc.

A coating material is selected depending on operation conditions and required product appearance. A prime coating is selected taking into consideration peculiarities of metal needed to be painted, a coating material and operating conditions of the product; fillers are chosen depending on the type of priming and coating material; a number of coating layers is selected depending on the coating system purpose and operating conditions of the product.

Selection of a coating (coating system) for product surfaces and the painting process largely depends on the properties of paint-and-lacquer materials and a method of coating application.

There are some methods of applying paint-and-lacquer materials on the product surface: with a pneumatic spray (the most common), electroplating, and spraying in the electrical field, current flow coating, immersion, roller, brush, spatula and other methods.

Pneumatic spray painting. The essence of this method is that the paint-and-lacquer material is sprayed by compressed air on tiny particles and evenly applied to the product surface.

The method of applying paint-and-lacquer coatings with a pneumatic spray allows to paint products of complex configuration of any dimensions with high process productivity. There are some disadvantages of the method such as: fogging losses wary from 20 to 25% and as a result, there is significant specific consumption of painting materials; a need to apply special paint cameras with devices for air drawing and cleaning emitted into the atmosphere, contaminated by paint fog; a danger of fires.

Pneumatic spraying is used with and without heating.

The spraying method without heating allows applying paint-and-lacquer materials on the basis of almost all types of film-forming materials and is applied during painting of products of various configuration (except products with internal cavities).

A plant for pneumatic spraying consists of a compressor (if there is no supply line with centralized compressed air), an oil-and-moisture separator, a tank with a reduction gear and an agitator, hoses to supply compressed air and paint, a paint sprayer.

Paint sprayers of medium pressure (0,25-0,55MPa) and low pressure (to 0,15MPa) are used for pneumatic spraying of paint-and-lacquer materials and applying it to the surface. Paint sprayers of low pressure are not almost used in production conditions.

The main part of paint sprayers is a spray head, equipped with two tubes with a common axis (Fig. 4).

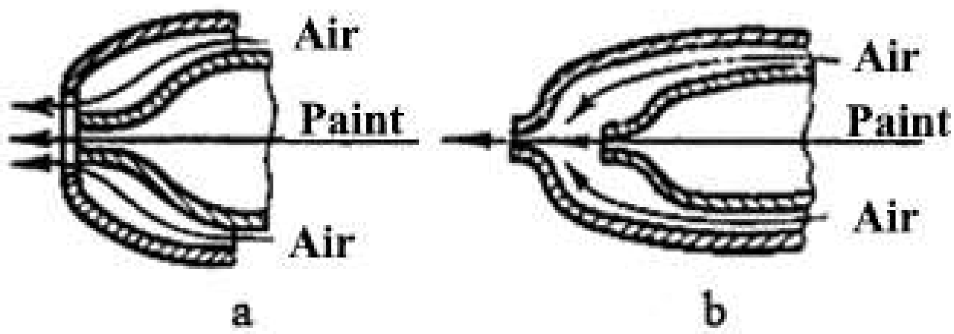


Fig. 4 – Schemes of spray heads:
a – external mixing; b – internal mixing

There are different in design spray heads which form a jet of a painting plume of different configurations (Fig. 5). A plume jet with a round print is created by a spray head that has a nozzle with a round hole coaxial with a material nozzle projecting out of it. Heads of this type are used for painting complex salient surfaces and small products.

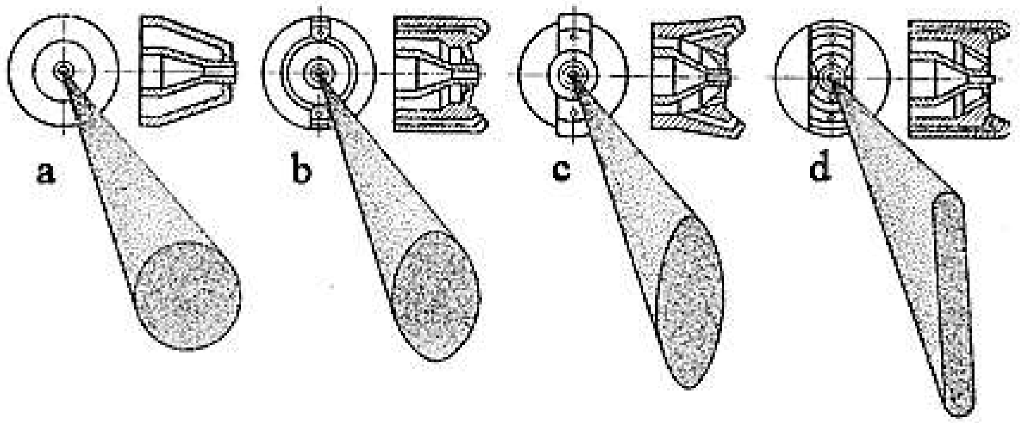


Fig. 5 – Spray heads of pneumopainting sprayers, shape of jet and prints of plumes: a – head without additional holes; b – head with two additional holes; c – head with four additional holes; d – head with eight additional holes

Fig. 6 shows a pneumatic sprayer of external spraying of average pressure. Compressed air is supplied to the handle channel through materials come from the reservoir 3, and when painting large surfaces – from the paint delivery tank through the sleeve 7. If we press the hook 5 weakly, the needle 6 goes back and thus opens an air valve at the top of the paint sprayer handle. Compressed air enters the system of distribution and circuit cameras as well as air vents through a channel and a valve of the air supply control. While further pressing on the managing hook, the needle end 6 opens a hole of the material nozzle 1 with the nut 2 to supply and spray paint-and-lacquer materials.

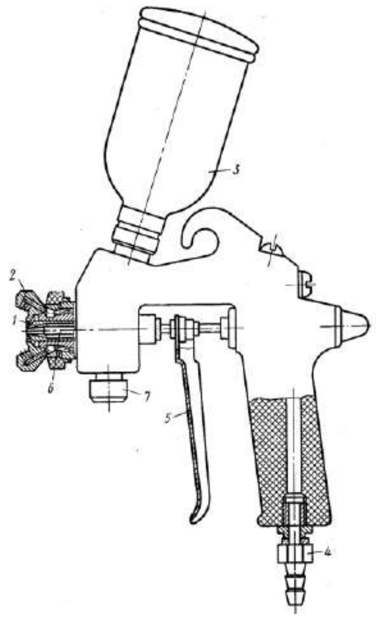


Fig. 6 – Paint sprayer (Universal paint sprayer UPS -1)

Using paint sprayers, a part of paint-and-lacquer materials does not reach the surface of the painted product or is reflected from it, forming mist of paint particles. The more air consumption spent on spraying, the higher its pressure, the greater the loss of paint-and-lacquer materials.

Pneumatic spraying painting with heating paint-and-lacquer materials. Heating paint-and-lacquer materials is used to reduce their viscosity. As a result of heating, paint-and-lacquer materials become more liquid and it eliminates the need of their dilution in expensive solvents or the need in them decreases. The layer of paint-and-lacquer material applied in the heated condition is thicker than the layer applied without heating, thus a number of coating layers is reduced and efficiency of painting process increases.

The level of viscosity drop as a result of heating depends on the film-forming component included into the composition of paint-and-lacquer material. Therefore, a different optimal initial viscosity is recommended for certain groups of paint-and-lacquer materials. Fig. 7 sets the temperature of paint-and-lacquer material when it is sprayed at different distances from a paint sprayer.

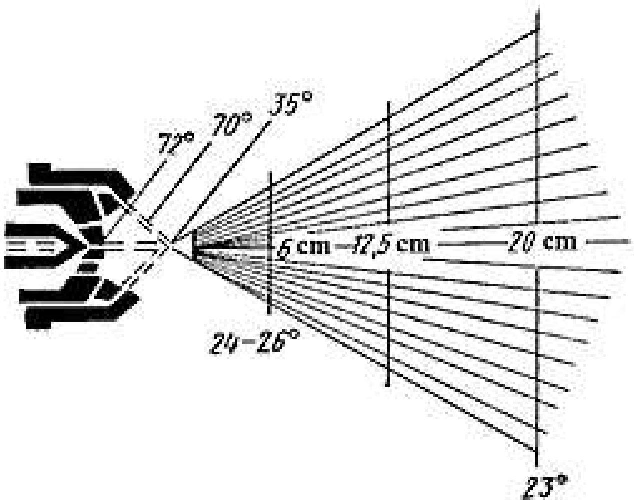


Fig. 7 – Scheme of temperature change of paint-and-lacquer material when it is sprayed at different distances from a paint sprayer.

The temperature of the paint-and-lacquer material does not drop below the temperature in a workroom during spraying with heating that is opposed to spraying without heating when the temperature of the plume near the painting surface is 10-15ºC lower than the initial temperature of the spraying material.

According to the corrosion resistance and its physical and mechanical properties, the coatings received by material heating, with the same film thickness, do not yield to the coatings of the same materials applied without heating and diluted by the solvent to the working viscosity.

The heated paint-and-lacquer coatings applied to the painting surface with a thick layer have better fluidity, the coating gloss increases and a possibility of moisture condensation vanishes.

We use hot painting plants for application of heated paint-and-lacquer materials.

Airless spray painting with and without heating of paint-and-lacquer material. Paint-and-lacquer materials are heated to 50-100ºC and are sent to the spraying device with a special pump under the pressure of 6-8 MPa for airless spray painting with heating. Heating a paint-and-lacquer material reduces its surface tension and viscosity, and the combination with high pressure provides an ability to spray materials of high viscosity. A spraying plume is formed due to the pressure drop of the paint-and-lacquer material in the output of the spray nozzle and subsequent instant evaporation of particles of the heated solvent, accompanied by its significant expansion. In the output of the nozzle a paint-and-lacquer material is split into the smallest particles (aerosol formation) which, loose their speed overcoming air resistance and deposit on the painting surface.

A paint sprayer for coatings by airless spraying using heating a paint-and-lacquer material is presented in Fig. 8. The main parts of the paint sprayer are the frame 3, the spray head 1, the regulating bush 2, the rotating device 4, the paint pipe 5 and the trigger 6.

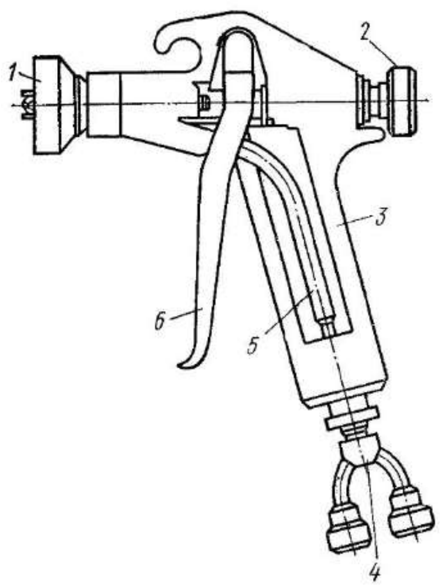


Fig. 8 – Scheme of paint sprayer of high pressure

During airless spray painting without heating a paint-and-lacquer material at 18-23°C is supplied to the spraying device under the pressure of 10-25 MPa.

All basic groups of paint-and-lacquer materials can be applied by the method of airless spraying without heating (analogous to pneumatic spraying) with working viscosity up to 50c for B3-4 at 18-23°C and receive coatings with thickness up to 35-40 mkm per one technological operation.

Painting in electric field of high voltage. The method of electric painting is based on transferring charged particles of painting materials in electric field of high voltage which is formed between two electrodes, one of which is a crone-shaped paint spraying device, and the other – a painted product. High voltage (usually marked "-") is supplied to the paint sprayer, and the product is grounded. A paint material is sent to the crone-shaped border of the paint sprayer device where it takes the charge marked with "-" and it is sprayed by electric powers. Then, charged particles of paint-and-lacquer materials as power lines of the field head to the grounded product and settle on its surface.

The method is usually used for metal product painting of relatively simple configuration on stationary plants and using hand-operated electrospraying devices.

Paint-and-lacquer materials with the specific volume resistance of $P_v=10^6…10^7$ ohm·cm and the dielectric constant of $\varepsilon = 6...10$ are suitable for spraying in the electric field. If the P and ε go beyond these set limits they can be adjusted by adding appropriate solvents diluted to the working viscosity.

Consumption of paint-and-lacquer materials which are normally sprayed in the electric field is 60-80 g/m^2 for paint supply of 1,5-2h per 1cm of the crone-shaped border.

Drying and quality control of paint-and-lacquer coatings

Drying paint-and-lacquer materials is transition from the liquid to glassy state.

Drying paint-and-lacquer coatings can be natural (cold drying) or artificial (baking).

Drying paint-and-lacquer coatings is called natural if it is conducted indoors or outdoors at 15-20ºC. If applied to products paint-and-lacquer materials are dried in drying devices at high temperature, it is called artificial drying. There are three basic methods of artificial drying: convection, thermoradiation and induction.

Using the convection drying method the heat is transmitted to a product during direct contact of the paint film with hot air (Fig. 9); evaporation of the solvent begins from thr coating surface with the formation of the solid external film 1, as a result the volatile product output from the paint lower layers 2 becomes more difficult and this can lead to pores and cracks on coatings. Therefore, the product has to be heated at low speed for uniform evaporation of solvents and obtaining high-quality paint-and-lacquer coatings.

In convection drying chambers simple in design the fresh air heated by a calorifer comes to the chamber, gives a part of heat to the painted surface and is removed from the chamber by fan. During this process the air is used ineffectively, a lot of heat is taken out into the air duct.

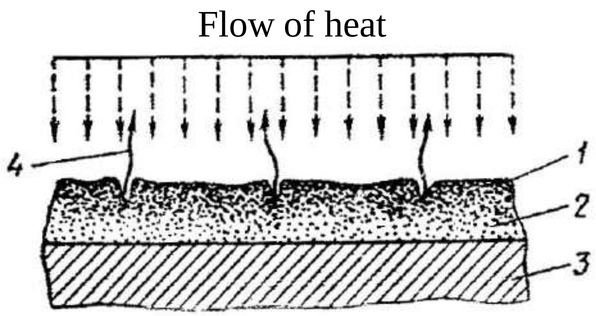


Fig. 9 – Scheme of convection drying method for paint-and-lacquer coatings

1 – solid film;
2 – non-dried out layer;
3 – product;
4 – solvent steam.

Using the thermoradiation drying method a product is heated with infrared rays. Their sources are reflector filament lamps with the capacity of 250 and 500 Wt, as well as tubular and panel-plate radiators. The radiation penetrates into paint-and-lacquer coatings at some depth and contributes to the heat source inside of the coating.

The rate of the heat supply from the source of infrared rays to the surface is large and the heat is barely spent on heating the surrounding air. As the heat is led from the product surface 2 (Fig. 10) to the coating, the temperature of the coating layers contacting the metal surface is higher than the temperature of the outer layer. Therefore, at first the solvent evaporates from the lowest layer 4, which dries out first. When a paint-and-lacquer coating is heated, evaporation at all thickness of solvents is more intense in the upper layers and gradually reaches the outer layer which solidifies last.

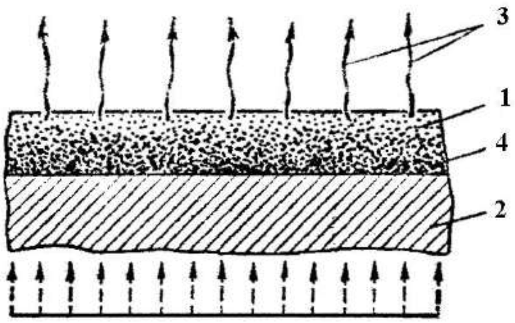


Fig. 10 – Scheme of thermoradiation drying method of paint-and-lacquer coatings:

1 – non-dried out layer;
2 – product;
3 – solvent steam;
4 – lower dried out layer.

The thermoradiation drying method is recommended for both coating enamels and primings which let the energy of infrared radiation pass with the wave length up to 6mkm.

The thermoradiation-convection drying method consists in product heating using thermoradiation and convection methods. It allows drying effectively the external surfaces of the product radiated with infrared rays as well as inaccessible areas for infrared rays of the product surface. This method is also used for simultaneous drying of products of different shapes and dimensions in one chamber.

Using the induction method of drying by high-frequency currents, a metal product is placed into the alternating magnetic field. In this case, the eddy currents are induced in the product and eventually heat it from inside. The paint-and-lacquer layer applied to the product surface is also heated. The drying process of the induction method is conducted as fast as during the thermoradiation method.

Quality control of paint-and-lacquer coatings. The coating quality is controlled due to its outer appearance (gloss, undulation, visible inclusions, etc.) and the coating thickness. A thin layer of paint-and-lacquer coatings can let moisture and gases pass which contribute to premature destruction of the product surface. Too thick layer of paint-and-lacquer coating cracks easily and peels.

To determine the thickness of paint-and-lacquer coatings we use devices whose operation is based on the change of the magnet gravity to the ferromagnetic pad plate (part surface), depending on the thickness of the coating layer.

Lecture № 6
Main methods of worn-part reclamation through welding and surfacing

Classification of component parts of technological (recovery) repair process of parts

Scientific research have shown that there are up to 45% of parts suitable for operation, and up to 50% of parts subjected to restoration in rejected machines. It should be noted that establishment of enterprises to restore parts requires 2-2,5 times less capital investments than to produce spare parts. An important advantage is small steel intensity: it is required 20-30 times less metal than for new spare parts. Worn-part reclamation usually eliminates energy-intensive metallurgical production cycle which is ecologically destructive. Meanwhile, restoration of 1 ton of steel parts saves 180 kW of electricity a year, 0.8 tons of coal, 0.5 tons of limestone, 175 m3 of natural gas. The cost of remanufactured parts is 30-50% of cost of a new part.

The main feature of defects resulting from wear is the need of compensation (restoration) of the worn surface layer. So the whole technological process for its purpose has to consist of three technological parts: compensation (restoration) of theworn surface layer; restoration of dimensionally precise characteristics; strengthening of the restored surface layer.

While defects are being eliminated, which are not related to friction, technological processes are also divided on their conditional assignment (Fig. 1).

Each component of the technological process is classified by technological means. These component parts of technological process and corresponding to them execution methods are often interconnected, but there may be an option when only one component of the process is applied, for example compensation of wear of tractor road wheels by electroslag hard-facing. The sequence of the technological process transition from one part to another for mating parts may be different.

Physical, metallurgical and technological bases of welding. The technological process of obtaining permanent connection of solid materials through interatomic bonds between welding parts is called welding. To do this, it is needed to bring closer atoms of the material of one part to the atoms of the material of another part at the distance of 10-10m, which is approximately equal to the distance between the atoms of the

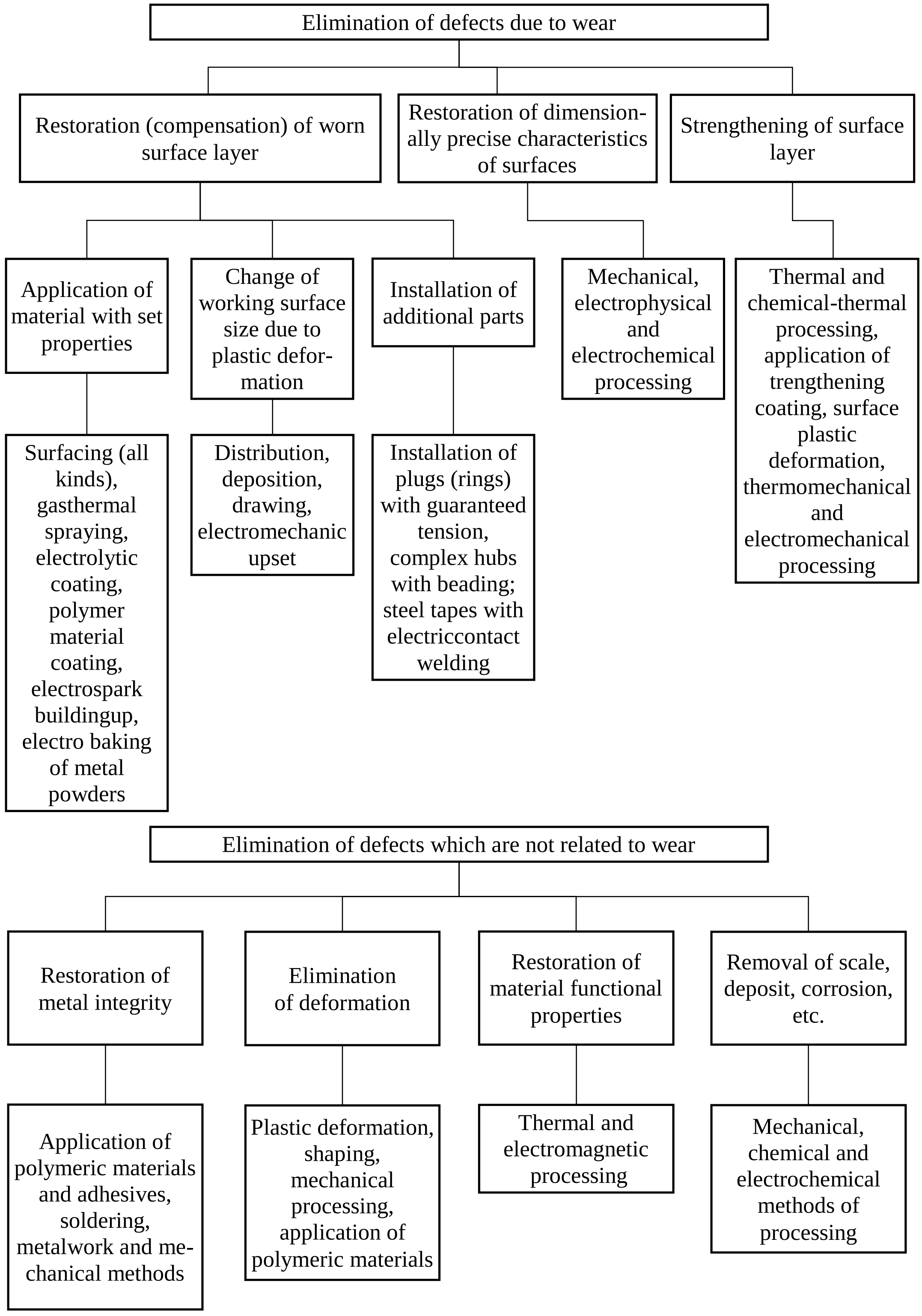


Fig. 1 – Classification of component parts of technological (restoration) repair process of parts.

material of welding parts. In case of such approaching, outer electrons of atoms form a common (collective) electronic system.

At indoor temperature metals do not connect even by compression with significant efforts. Interatomic bounds appear in case of force application of several hundred tons in individual contact points, but they destroy due to the action of elastic forces after removing load. The higher plasticity and the lower material hardness we have, the lower specific pressure at which a part joint is possible becomes.

Metal heating is a common way to reduce hardness and increase plasticity. Metal is heated to the plastic state, precipitated (subjected to plastic deformation) to get a strong welding seam. The process takes place without precipitation due to fusion of volumes of molten metal parts in the common welding pool if the temperature of welding parts is brought to the melting point.

Thus, welding processes can be divided into fusion welding and plastic deformation (pressure) depending on the method of atom approaching.

<u>Surfacing</u> – a kind of welding, which consists in application of the metal layer on the part surface.

Welding and surfacing of metals are classified by physical, technical and technological characteristics.

<u>Physical characteristics</u> describe a shape formed during welding and energy surfacing and provide three classes of welding processes:

- thermal, characterized by supply of thermal energy (arc, gas, high-frequency, thermit, electroslag, plasma, cathode ray and laser);
- thermomechanical – a combination of supply of thermal energy and mechanical energy of pressure (electric-contact, diffusion, gas-pressure, explosion);
- mechanical – using mechanical energy (friction, hypersonic, cold).

<u>Technical features</u> are characterized by the way of protection of the welding area from interaction with the environment, continuity of process and mechanization of supply and moving of the electrode relatively to parts.

<u>Technological features</u> characterize the peculiarities of the technological process of welding (arc, gas, plasma, laser, etc.).

While choosing a way of worn-part reclamation, conditions of work, material properties and processes occuring when a welding joint is formed, have to be taken into consideration.

The changes of chemical composition, structure, material properties of parts and the level of internal stresses and deformations in the joint zone are the most important thing due to the final properties of a product.

Three zones can be defined in a welding joint (Fig. 2). Zones of seam and fusion belong to the zone I where the metal is heated to the melting point when welding is carried out, and then it is stored in the liquid and solid-liquid state. This zone is characterized by the change of chemical composition and construction of material parts because of diffuse processes with the metal of the adding material, interaction with the environment, the flux and peculiarities of crystallization.

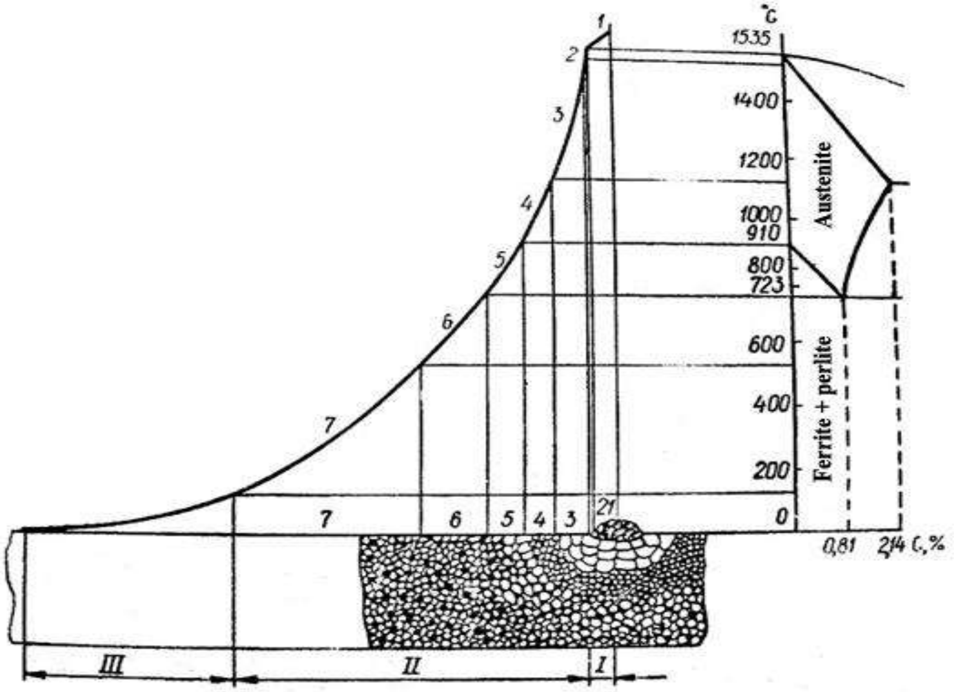


Fig. 2 – Welding joint structure: I – zones of seam and fusion; II – thermal effect zone (overheating, recrystallization and release); III – mechanical or thermomechanical effect zone; 1 – liquid metal state; 2 – solid state; 3 – overheating; 4 – normalization (recrystallization); 5 – partial recrystallization; 6 – recrystallization; 7 – aging

zone II – a zone of thermal effects, includes overheating zones, recrystallization and release. There heating temperature is sufficient for phase transformation and recrystallization of the basic metal. Formation of hardening structures is typical and, therefore, it is inclined to cracking, especially when the content of carbon and alloying elements in metal is significant.

Intercrystalline corrosion acts at the periphery of this zone; it takes place when forming chromium carbides at grain boundaries. Chromium release decreases when it is added titanium, niobium and zirconium into adding wire.

III zone – a zone of the mechanical or thermomechanical effect; The metal temperature is insufficient for the processes of phase transformation and recrystallization. Changes caused by plastic and elastic deformations of the metal under the influence of internal forces take place.

Gas welding and oxyacetylene surfacing

Gas welding and oxyacetylene surfacing are universal ways of component overhaul because it allows to process metals with the thickness of tenths of a millimeter to tens of millimeters. Extended in time, gas welding processes are easily controlled by a welder that allows getting a high enough quality of a seam even at his relatively low qualification. In addition, relatively low heating and cooling speeds of the metal allow reducing welding stress and avoiding cracks when welding is carried out.

Gas welding is often used for welding of low-carbon and medium-carbon steels with the thickness of 3 mm (cabins, facing, casings, etc.) and while parts of cast iron and nonferrous metals are being repaired.

The heat source to heat parts in gas welding is the flame formed by combustion of gas and oxygen mixture. Acetylene (C_2H_2) is often used for welding, propane-butane (C_3H_8+C_4H_{10}) is used rarely. In recent years, application of hydrogen-oxygen mixtures achieved considerable success.

The welding flame consists of three zones (Fig. 3). Zone "A" (the flame center) is limited by a light coating, in the outer layer of which carbon is burning, formed when fuel molecules are decayed. Zone "B" is renewable, or a partial combustion zone. It consists of carbon and hydrogen oxide formed in the first stage of gas combustion. These combustion products deoxidize molten metal, taking away oxygen from its oxides. Zone "C" is a zone of complete combustion (or a plume). It represents a visible volume of gases. In this zone delayed burning of combustion products takes place due to oxygen ejected from the air.

The hydrogen-oxygen flame has another structure, so evaporations of gasoline in small quantities (5-10%) are added to the hydrogen-oxygen mixture to adjust flame composition. Such composition of the gas mixture leads to the absence of zone «B» that in the flame and, therefore, deoxidation of the molten metal does not take place.

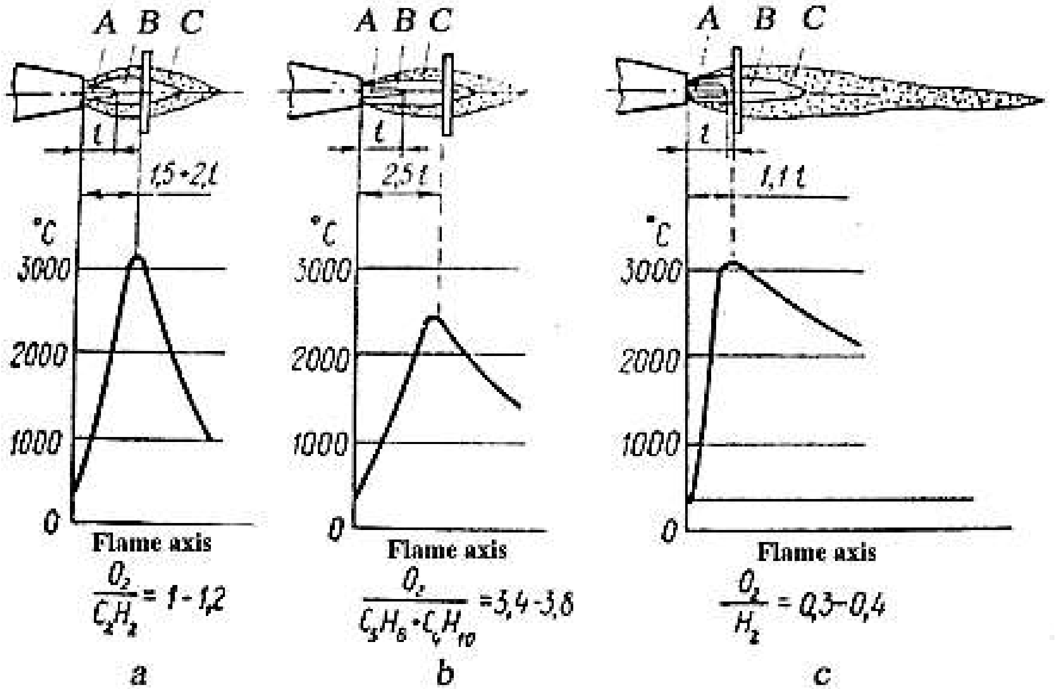


Fig. 3. – Construction of welding flame: a – acetylene-oxygen; b – propane-oxygen; c – hydrogen-oxygen; A – core; B – incomplete combustion zone; C – complete combustion zone; *l* –Length of core

The maximum temperature of the acetylene-oxygen flame is (3150°C) what is much higher than the maximum temperature of the propane-butane-oxygen flame (2400°C). As the research conducted in Kharkiv Petro Vasylenko National Technical University of Agriculture show, the maximum temperature of hydrogen-oxygen flame (3000°C) is close to the temperature of acetylene-oxygen.

The nature of the flame depends on the ratio of gas and oxygen in the fuel mixture. The neutral flame is characterized by the absence of free oxygen and carbon in renewable zone «*B*». For various fuel mixtures neutral flame is reached by the following ratio of oxygen volumes and gas:

acetylene-oxygen flame – $\frac{O_2}{C_2H_2} = 1 - 1{,}2$;

propane-butane-oxygen flame – $\frac{O_2}{C_3H_8 + C_4H_{10}} = 3{,}4 - 3{,}8$;

hydrogen-oxygen flame – $\frac{O_2}{H_2} = 0{,}4 - 0{,}45$

The oxidative flame is obtained at larger values of the ratios given above. Such flame has a higher temperature, however an excess of oxygen promotes iron oxidation. The seam metal is obtained porous and fragile. Thus, in this case you need to use wires of such marks as CB-08ГС and CB-12ГС which contain deoxidation agents – manganese and silicon.

The carbonization flame is characterized by an excess of fuel gas, a low temperature and it promotes saturation of the seam metal with carbon.

The neutral flame is used for welding and surfacing of steel parts which have less than 0.5% of carbon and nonferrous metals; the carbonization flame is used for parts of high-carbon and alloy steels, cast iron, surfacing with hard alloys; the oxidative flame is used for cutting metal.

It should be taken into consideration that the composition changes during interaction of the molten metal with the welding flame. Oxygen, which got into a seam, reduces its strength, impact strength, resistance to corrosion. Hydrogen promotes cracking. Interacting with iron, nitrogen at high temperatures forms nitrides which give the welded metal high hardness and shortness. Silicon, manganese and other alloying material additives of welded parts burn in the process of welding.

The material of the filler wire in its physical and mechanical properties and chemical composition should be the same as the part material, but with an increased number of easily oxidizing components in order not to change the composition of the welded layer.

The wire of low-carbon type Св-08 is an adding material for welding of nonrelevant steel parts. The low alloyed silicon-manganese filler wire Св-08ГС, Св-10ГС etc. is used to increase mechanical properties and seam metal deoxidation. Availability of nickel, chromium etc. in adding material positively influences the quality of seam.

When worn part surfaces are welded, electrodes Нп-40, Нп-50, Нп-30ХГСА, Нп-50Г, Нп-65Г are used and the others which allow to get surfaced layer with high wear resistance.

Fluxes are used to protect the molten metal from harmful effects of oxygen, nitrogen, hydrogen and other elements. They create chemical compounds with metal oxides which emerge on the surface in the form of slag and protect the liquid metal from saturation with gases. The main components of fluxes for black metals are auger $Na_2B_4O_7$, two carbonaceous soda $NaHCO_3$ and boric acid H_3BO_3.

Relatively simple and inexpensive equipment is used for gas welding and oxyacetylene surfacing.

Acetylene is obtained directly at the workplace of a welder in the acetylene generator by calcium carbide interaction with water or is stored in special acetylene containers. In agriculture the most common are movable acetylene generators with the productivity of 0,8-3,2 m^3h, pressure 0,1-0,15 MPa, for example – ASP-1,25, GVR-1,25M4, GNV-1,25 etc.

Oxygen is stored in cylinders of high pressure (15-20 MPa) with the volume of 10-60 liters. Propane-butane is stored in cylinders of medium pressure (1.6 MPa) with the volume of 5-50liters.

Reduction and maintenance within the necessary limits of the working gas pressure is carried out with the help of gas reduction units (e.g., KPP-61, etc.).

Gas and oxygen are delivered by hose pipes to the gas burner where their mixing and batching take place. The burners of low G2-04, medium G3-04 and high G3-05 power are the most common as well as surfacing burners which allow supplying self-fluxing granulated powders GN-2, GN-3 into the surfacing zone etc.

Hydrogen-oxygen gas welding

Equipment for hydrogen-oxygen gas welding is more complex, but it is compensated by significant decrease in the expenses on materials and cylinder transportation.

The hydrogen-oxygen welding flame is obtained during gas burning which is generated in electrolytic sections directly in the workplace of a welder in the way of water decomposition into oxygen and hydrogen with the electric current.

Portable hydrogen-oxygen welding plants designed in Kharkiv Petro Vasylenko National Technical University of Agriculture meet the most needs of agriculture (Fig. 4).

The principle of operation of the electrolytic section is based on the reaction of water dissociation under the action of the constant electric current which passes through the alkaline electrolyte. The electrolytic section consists of a number of series-connected sealed cavities formed by electrodes and sealing rings. Sealing of the package gathered in such a way is carried out by stud bolts. The internal cavity of the gas-separator and the interelectrode cavities are filled with electrolyte. The constant electric current from the power supply is led to the extreme electrodes of the electrolytic section. The hydrogen-oxygen mixture formed while the current passes through the holes at the top of the electrodes gets into the gas-separator, then dries and is supplied through the gate and dresser into the welding burner. The gate is needed to prevent gas explosion inside the generator in case of gas inflammation in hose pipes. The dresser can adjust the character of the welding flame by small additions to the hydrogen-oxygen mixture of gasoline evaporations.

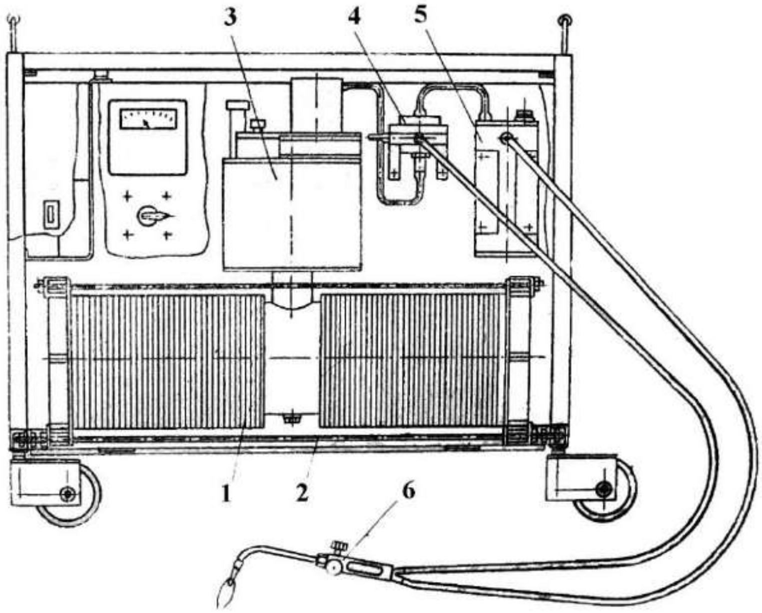


Fig. 4 – Hydrogen-oxygen welding plant, designed in Kharkiv Petro Vasylenko National Technical University of Agriculture: 1 – power source; 2 – constriction stud bolt; 3 – gas-separator; 4 – gate; 5 – dresser; 6 – burner

The low cost of required materials and electricity consumption (2-5 kW/h) allow expecting the spread of this type of welding in manufacturing, especially in agricultural overhault plants.

Gas welding (oxyacetylene surfacing) mode

A gas welding (oxyacetylene surfacing) mode is defined by moving direction and an inclination angle of the burner, power, and the nature of the flame and the filler wire diameter.

Using the left method of welding, the burner is moved from the right to the left, and a filler wire – ahead of the flames. This method is the most common and is used for surfacing and welding of materials with small thickness (Fig. 5).

Using the right method, the burner is moved from the left to the right, and a filler wire – after the burner. This allows to use fully the flame heat and to weld parts with the thickness of over 5-6 mm. The inclination angle of the burner (between the surface of the welding metal and the inclination axis of the burner) is chosen depending on the thickness of welded parts (Fig. 6). The higher it is, the more the thermal impact of the flame on a part becomes.

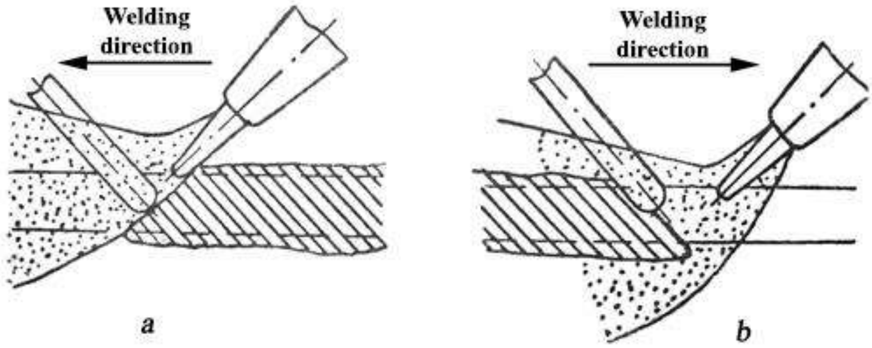


Fig. 5 – Gas welding: a – left; b – right

The flame power is characterized by an hour consumption of acetylene:

$$A = kt,\ \mathrm{dm^3/h}, \quad (1)$$

where k – a coefficient which takes into consideration a material and a welding method, dm^3/ h mm; t – a thickness of welding parts, mm

For steel k = 100-120, aluminum – 60-100, cast iron –110-140.

A number of the burner tip is chosen by acetylene consumption. The power of flame and other gases is defined in much the same way. The nature of the flame (neutral, oxidative, reducing) is taken depending on the material of welding parts.

The diameter of the filler wire is defined depending on the method of welding according to the formulas:

$D = 0,5t + 1$ – for the left method of welding;

$D = 0,5t + 2$ – for the right method of welding;

Gas welding is rationally used for part welding of low thickness. Increasing the thickness of parts there is a sharp drop in the productivity of the process.

During arc welding and surfacing, melting of metal parts and the filler wire takes place due to the heat of the electric arc.

Arc supply is carried out by the alternating or direct current. When welding with the direct current is carried out, we distinguish direct and reverse polarity. When welding at the direct polarity is applied, a welded product is connected to the positive pole of the welding generator and an electrode – to the negative pole. At the reverse polarity – vice versa.

When welding at the reverse polarity is carried out, a part is heated less than at the direct polarity, what is of great practical importance. The electric arc consists of three parts: the cathode and anode regions and the arc column (Fig. 7).

The temperature of the metal in the cathode spot is 2600-3000°C, while in the anode spot is 3500-4000°C. The temperature of the medium in the arc column reaches 6000-7000°C.

Different filler materials, electrodes, fluxes and shielding gases are used while welding and surfacing.

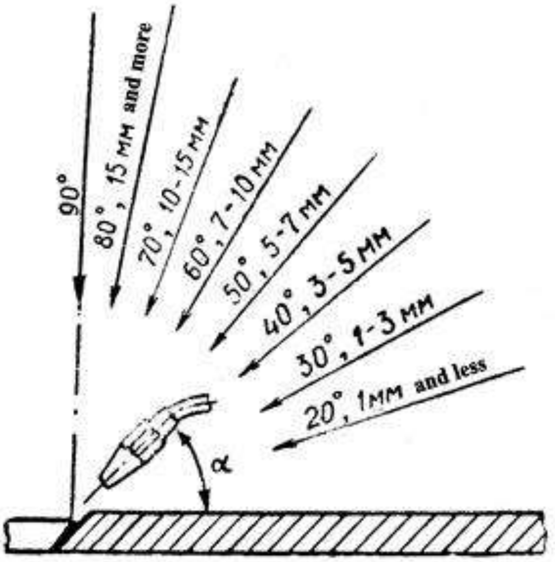


Fig. 6 – Dependence of inclination angle of contactor tube of welding burner on welding metal thickness.

Filler materials are used in a wire and powder form. GOST 2246 involves 77 brands of welding steel wires with the diameter from 0,3 mm to 12 mm. The welding wire is denoted with the letters «Св». According to GOST 10543, 30 brands of wire with the diameter of 0,3-8,0 mm are used for surfacing. A filler wire is denoted with the letters «Нп».

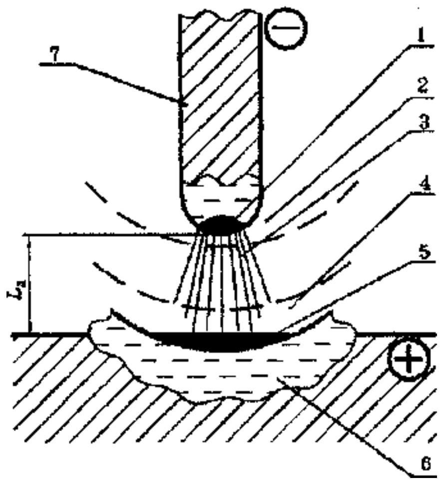


Fig. 7 – Electric arc structure:

1 – cathodic arc spot;
2 – cathode region;
3 – arc column;
4 – anode region;
5 – anodic spot;
6 – molten metal;
7 – electrode;
$L_Д$ –arc length

The filler wire is made of carbon (Нп-30, Нп-45, Нп-50, etc.), alloying (Нп-65Г, Нп-3ОХГСА, Нп-40Х3Г2МФ etc.) and highly alloying (Нп-40Х13, Нп-45Х4В3ГФ, Нп-П3А etc.) steels.

The flux cored wire, which is a steel shell (tube) filled with a powdery charge mixture, consisting of metal and flux components is also used for welding and surfacing.

Welding electrodes, which are divided into types (by the hardness of welded metal) and brands (by chemical composition), are used during manual arc welding. An electrode type is marked by the letter «E» noting the strength of the welding seam metal at tension on the right, MPa. For example, a rod type – E46, a coating brand – UONI-13/55.

The following brands are used as an electrode wire: Св-08, Св-08А, Св-08Г; Св-08ГА, Св-10Г2 etc. Electrodes for surfacing are marked with the letters «EH» and a number indicating the hardness of the surfaced metal without heat treatment.

According to GOST 10051, by a chemical composition electrodes are distinguished in 44 marks (e.g. electrodes Е-16Г2ХМ, Е-110Х14В13Ф2, Е-13Х16Н8М5С5Г4).

Fluxes are used to remove oxides and protect the molten metal from oxidation, they can be divided into three groups: molten (АН-348А, ОСЦ-45, АН-60, АН-10, АН-20, АН-30, designed for welding of carbon and low-carbon steels), nonfusible (e.g. flux АФ-4А, used for welding of aluminum and its alloys) and ceramic (АНК-18, АНК-19, АНК-30, ЖСН-1).

The mode of arc welding and surfacing is caused by the selection of a type, brand and electrode diameter, the welding current power and polarity (during welding with the direct current), the order of roller placing etc.

The type and brand of the electrode is chosen depending on the chemical composition and required mechanical properties of renewable parts. The diameter of the electrode (del mm) is taken depending on the thickness of the welding parts (δ, mm):

$$d_{ел} = 0{,}5\delta + (1 - z), \tag{2}$$

where z – an allowance for further processing.

The strength of the welding current I approximately can be defined by the empirical dependence:

$$I = kd, \tag{3}$$

where k – a coefficient depending on the thickness of welding products, A / mm (25-60 A/mm);

d – a material thickness or a diameter of an electrode rod, mm

Electrodes for welding are selected according to GOST 9466 and GOST 9467.

Welding transformers of the type ТС-300, ТС-500, ТД-300, etc are used as welding equipment while welding with the alternating current is applied.

Welding converters are used while welding with the direct current is carried out: PSO-300-3, PS-500, SAM-300-2 etc.

While semiautomatic welding, the electrode wire is delivered into the welding area using a welding semiautomatic machine, which consists of a rectifier and the wire feeding device. A-580M, OKS-1252M, A-765, A-1197, etc belong to these semiautomatic machines.

Special plants are used during worn-part reclamation with the shape of rotary body as rotators: UD-133, UD-140, UD-143, UD-144, UD-209, UD-233, UD-299, UD-302, UD-651, OKS-11200, OKS - 11236, OKS-11238, OKS-14408, OKS-27432 etc.

Peculiarities of welding of cast iron parts

When cast iron parts are restored by welding, the features of cast iron which complicate welding, should be taken into consideration:

- Internal stresses which cause cracks in the seam and heat-affected zone due to local heating and rapid cooling;
- as the result of the high cooling rate of molten cast iron its whitening takes place, as carbon does not have time to separate in the form of graphite and converts to cement Fe_3C. Chilled cast iron has high hardness, fragility and poor mechanical processing;
- carbon burnout takes place during the welding process, it is accompanied by intensive gas emission from the welding pool what leads to pores in the seam metal;
- difficulties to keep the molten metal from runout and seam formation appear due to increased cast iron castability.

Two basic types of cast iron welding are used: hot and cold.

Hot welding is used for the parts of complex shape previously heated to 600-650°C at the rate of 120-150°C/hin heating furnaces.

Hot welding is carried out with the oxygene-acetylene flame with a slight excess of acetylene. Cast iron twigs of A or B brand with high silicon content to 3.0-3.5% or brass wire L63 can serve as adding materials.

Welding is carried out using fluxes based on borax. The following compositions of fluxes are recommended: borax ($Na_2B_4O_7$) – 100%; borax – 50%, sodium bicarbonate ($NaHCO_3$) – 47%, SiO_2 – 3%; borax – 56%, sodium carbonate (Na_2CO_3) – 22%, K_2CO_3 – 22%. Flux ФСЧ-1 is also used.

Low-temperature annealing is carried out after welding, i.e. part heating to 650-700°C and its cooling along with a heating furnace.

Hot cast iron welding provides a high quality of the seam, however it requires high energy and labor expenditures.

Cold arc welding of parts made of gray cast iron is carried out by special electrodes of ОЗЧ-1, МНЧ-1, ЖНБ-1, ЦЧ-4 types etc with fluoric calcium coatings of УОНИ-13/55 type.

ОЗЧ-1 rod electrode is made of M-2 or M-3 copper. Monel metal (63% Ni, 37% Cu) is used for МНЧ-1 electrode, an alloy containing 55% Ni and 45% Fe is used for ЖНБ-1 electrode.

Welding using these electrodes (with the diameter of 3-4mm) is carried out with the direct current of the reverse polarity (voltage of 20-25V, amperage of 120-150A) and small (20-30 mm) areas carried out by a short arc with peening each site and welding restoration after seam cooling to 50-60°C.

Semiautomatic welding of gray cast iron can be carried out by ПАНЧ-11 and ПАНЧ-12 self-clinching electrode wires on the base of nickel, developed by E.O. Paton Institute of Electric Welding.

А-547-У welding semiautomatic machine is applied for welding by this wire. A wire diameter is 1,4 mm. Welding mode: amperage 100-140A, voltage of 14-18V, welding speed 0,09-0,15 m/min.

Ways to restore parts of aluminum alloys

The main difficulties of worn-part reclamation by welding of aluminum alloys are in the fact that aluminum while welding oxidizes intensely and a refractory film of Al_2O_3 oxide with the melting temperature of 2160°C appears on its surface, while the melting temperature of aluminum is 659ºC.

The oxide film prevents fusion of the base and deposited metal and contaminates the seam. In addition, the high coefficient of the linear expansion (2 times higher than in steel) and high thermal conductivity (3 times higher than in steel) cause significant residual stresses in welding parts and cracking on the seam or around the seam area. High hydrogen solubility in the molten metal forms pores in it.

Worn-part reclamation by welding of aluminum alloys is carried out by one of the following ways: argon-arc welding, manual arc welding with fusible and infusible electrodes, gas welding with the use of fluxes.

Argon-arc welding with infusible tungsten electrode on the plants of UDAR-500, UDG-301, UDG-501 types is widely spread.

Argon-arc welding is based on the use of the heat released when the electric arc burns between the basic metal of the product 1 (Fig. 8) and the tungsten electrode 2; the melting temperature is about 3500°C in the protective medium of argon inert gas.

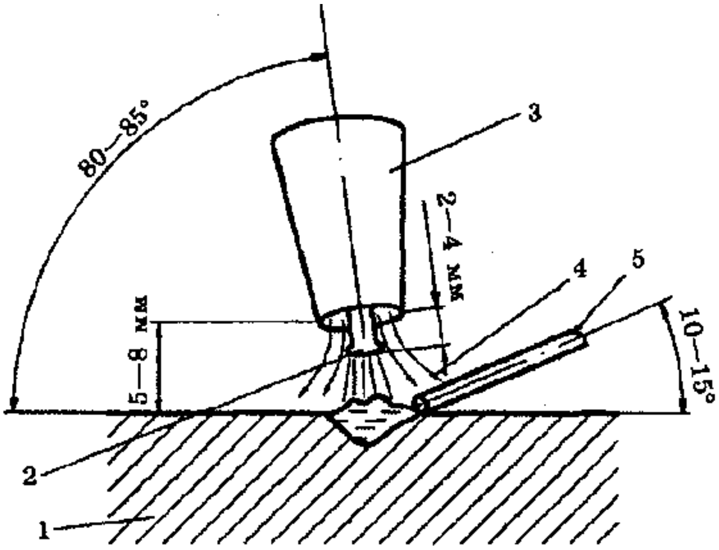


Fig. 8 – Burning scheme in protective argon gas:

1 – part;
2 – tungsten electrode;
3 – burner;
4 – protective gas;
5 – filler wire

An aluminum wire containing 5-6% of silicon and as well as the Св-АК5 or Св-АК10 wire can be used as a filler material. Welding is often carried out with the alternating current or direct current of the reverse polarity.

The burners of GRAD-200 and GRAD-400 type are used to fix the tungsten electrode and supply the protective gas in the arc burning area. Argon-arc welding provides increasing productivity 3-4 times as compared with acetylene-oxygen welding.

Oxyacetylene surfacing is carried out with the neutral flame using АФ-4А, АН-4А fluxes and others, using as a filler material wire of the same composition as the basic metal. The burner power is chosen 00-20 l/h of the fuel gas per 1 mm of the metal thickness.

Part welding of aluminum alloys with the use of ultrasound, which destroys an oxide film, has also become widespread.

In some cases, silumin parts are heated before welding to t = 200-

250°C, what prevents grooving and cracking. After being welded, parts are subjected to annealing at t = 300-350°C, to remove internal stress and improve the structure of the deposited metal.

Surfacing under flux layer

While welding and surfacing of parts under the flux layer are applied, unlike open arc welding the electric arc burns under the layer of molten flux, creating a slag crust on the surface of a seam. Meanwhile, there occur overpressure of gases in the welding area; they prevent the air to get to the liquid metal along with the molten flux (Fig. 9).

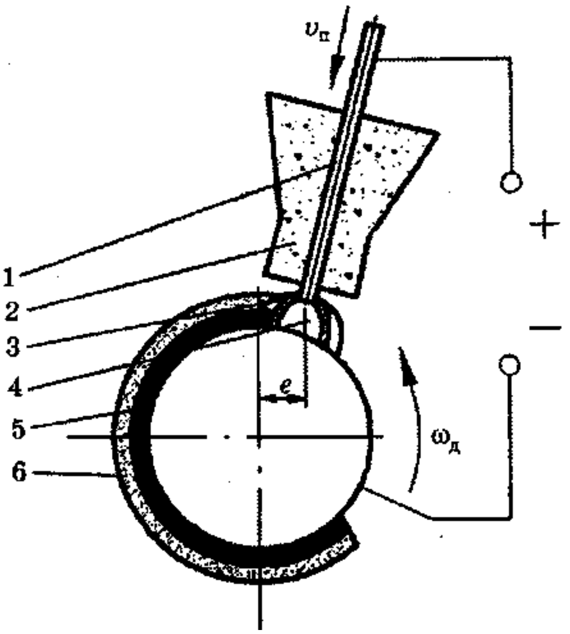


Fig. 9 – Scheme of surfacing under flux layer:

1 – electrode;
2 – hopper with flux;
3 – shell of molten flux;
4 – gas bubble;
5 – weld metal;
6 – slag crust;
e – electrode shift from zenith;
$v_п$ – wire feed speed;
$ω_д$ – angular frequency of part rotation

Surfacing under the flux layer provides the highest quality of the deposited metal, as the welding pool is protected from harmful effects of air oxygen and nitrogen. In addition, slow cooling of metal under the flux layer promotes the most complete removal of gases from the molten metal and slag impurities, what also improves the seam quality.

Automatic surfacing under the flux layer is characterized by high productivity of the process. The metal deposit factor $α_н$ is 1,5 times higher than during manual welding, and it is 14-15 g/A·h. The process poductivity ranges between 1,5-10,0 kg/h depending on the value of the welding current. The thickness of the deposited metal layer can be obtained within 0,5-5,0 mm depending on the mode.

We use Нп-30, Нп-40, Нп-50, Нп-65 carbon wire or (Нп-30ХГСА) low alloyed steel wire for surfacing of parts made of carbon steels 30, 40, 45. We use Нп-2Х14, Нп-3Х13, Нп-30ХТСА wire and others for surfacing of critical parts with high surface hardness.

The most common fluxes are: molten АН-348А; АН-20; АН-30; ОСЦ-45, or ceramic fluxes АНК-18; АНК-19.

Automatic surfacing with a flux cored wire under the flux layer or an open arc without additional protection is recommended to use for surfacing of parts with high wear. The following wire brands are recommended: ПП-АН106; ПП-АН124; ПП-3Х5Г2М-0; ПП-3Х13-0; ПП-25Х5ФМС-0.

A surfacing mode significantly affects the physical and mechanical properties of the surfacing material. It is defined by the following parameters: the electrode diameter, the arc voltage, the welding current power, the surfacing velocity, the wire feed speed, the stick-out distance, the surfacing pitch, the electrode shift from the zenith.

The electrode wire diameter is chosen depending on the diameter of the surfaed part. The wire with the diameter of 1,6-2,5 mm is used while surfacing of automobile parts is carried out.

Amperage (I, A) is chosen depending on the electrode diameter (d_e, mm) according to the tables or approximately by the following formula:

$$I = 110 \cdot d_e + 10 \cdot d_e^2 . \quad (4)$$

The direct current of the reverse polarity with the voltage of 25-35 V is used during worn-part reclamation.

The surfacing velocity ($v_н$, m/h) is chosen within 12-45 m/h, or determined by the following formula:

$$v_н = \frac{\alpha_н I}{G}, \quad (5)$$

where G – a mass of 1 m of surfacing, g.

The width of the surfacing roller and the depth of the weld penetration decreases with increasing the surfacing velocity.

The wire feed speed (vn, m / h or m / min) is chosen depending on the electrode diameter and amperage or is defined by the following formula:

$$v_п = \frac{4\alpha_н I}{\pi d_e^2 \gamma} \text{ or } v_п = \frac{4\alpha_н I}{15\pi d_e^2 \gamma}, \quad (6)$$

where γ – a density of the deposited metal, g/cm^3.

For an electrode wire d_e = 1,6-2,0 mm at the amperage of I = 140-

360 A and $\alpha_н$ = 14-16 g/A·h, the wire feed speed varies withing 75-180 m/h.

The stick-out distance depends on amperage and is assumed to be 10-25 mm.

The surfacing pitch s within 3-6 mm is chosen depending on the required layer thickness h, amperage and voltage.

The electrode shift e from the zenith towwards the opposite direction of part revolution is set depending on the part diameter: for the part with the diameter 50-150 mm, f = 3.8 mm.

Rotation frequency of a part

$$n = 250\frac{v_п d_e^2}{hsD}\eta, \quad (7)$$

where $v_п$ – an electrode wire feed speed, m / min;

h – the thickness of the surfaced layer, mm;

s – a surfacing pitch, mm / rev;

D – a diameter of a part, mm;

η – a transition coefficient of the electrode metal to the basic metal. We can take η = 1,0 for surfacing under the flux.

Automatic surfacing under the flux layer is carried out on special plants U-651, 652, U-653 or by deposition devices of A-580M, PAU-1, UANF-3 NIIAT type and others. The direct current converters PSO-500 (a completed device A-580M) or PSU-500 (a completed device PAU-1) are used to supply surfacing plants. Welding heads A-580M and PAU-1 are set on the support of the re-equipped turning machine furnished with a reduction unit to decrease the rotation frequency of a part.

E.O. Paton Institute of Electric Welding has developed special welding plants: U-465 – for surfacing of cylinder and spline surfaces; U-427 – for surfacing of crankshaft necks; U-425 – for surfacing of inner and outer surfaces.

The main advantages of this worn-part reclamation method are as follows: a high process productivity (6-8 times higher as compared to the manual surfacing) and a metal deposit factor, a possibility to obtain the metal layer of high thickness (1,5-5,0 mm), high quality of the deposited metal.

Surfacing in the medium of shielding gases

The point of the welding method in the medium of shielding gases lies in the following: the shielding gas is supplied under pressure into the combustion zone of the electric arc. Pushing air aside, it protects the molten metal of the welding pool from harmful influence of oxygen and nitrogen.

Welding in shielding gases can be carried out by fusible and infusible electrodes (carbon or tungsten). While welding and surfacing with the fusible electrode is carried out, the electrode wire is fed into the arc combustion zone through the special gas-arc burner. The electric current, shielding gas (argon, helium, carbon acid, hydrogen, water vapor, and their mixtures) are led to it. The most common shielding gases are carbon acid (CO_2) and argon (Fig. 10).

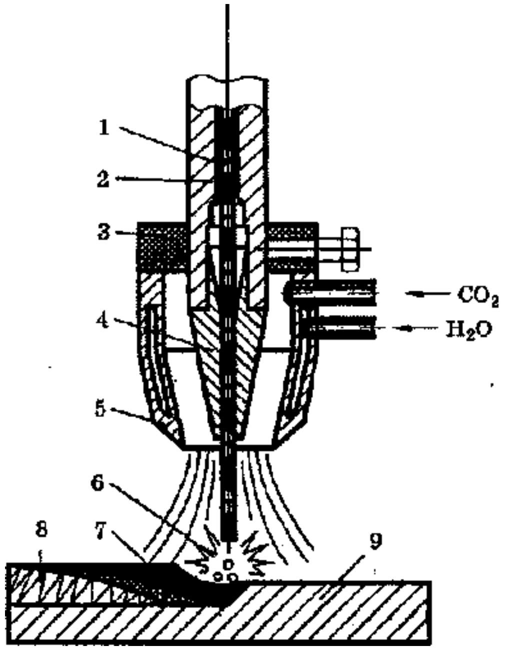


Fig. 10 – Surfacing scheme in the medium of carbonic acid (gas):

1 – contactor tube;
2 – electrode wire;
3 – burner;
4 – nozzle;
5 – burner nozzle;
6 – electric arc;
7 – welding pool;
8 – deposited metal;
9 – renewable part

Welding and surfacing in the medium of CO_2 is usually carried out with the direct current of the reverse polarity. This ensures good stability of the process. Carbon acid supply is carried out according to the scheme: cylinder – heater – drier – lowering reduction unit – flowmeter – filler head (1 cylinder of carbon acid (25 liters) gives 10-12 m^3 of CO_2, 509 liters are produced from 1 kg CO_2).

The wire with the diameter of 0,5-2,0 mm of the following brands is used for welding and surfacing: Св-08ГС, Св-08Г2СА, Св-10ГС, Св-12ГС, Св-18ХГСА, Св-30ХГСА, Нп-30ХГСА. Besides, wires of ПП-Р18Т, ПП-Р9Т, ПП-Х2В8Т brands etc are also used.

Semiautomatic machines are widely used for semiautomatic welding in the medium of CO2: A-537, A-547, A-547U, A-547R, A-1035M, PDG-301, PDPG-500 etc.

A re-equipped unit A-580, which is produced for surfacing under the flux layer, and welding heads are usually used as surfacing plants: OKS-6569; VKB-1252A and PAU-1, completed with the current source PSU-500.

Dip-transfer part surfacing

The process of dip-transfer surfacing is a kind of automatic metal surfacing with ha vibrating electrode in a coolant jet; it was firstly introduced by an engineer R.P. Klekovkin in 1950-1952 (Fig. 11).

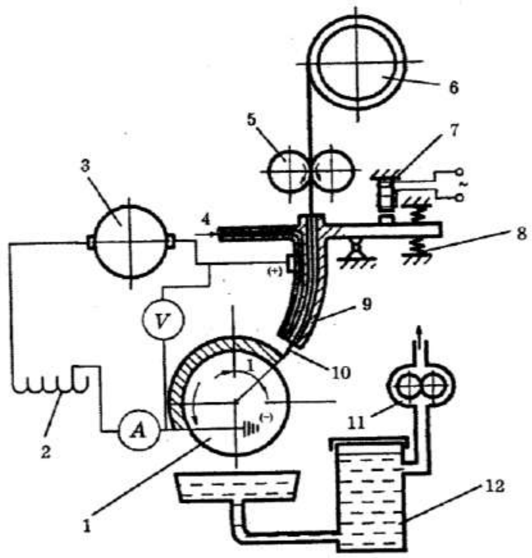


Fig. 11 – Scheme of a unit for dip-transfer part surfacing

The scheme of the unit for dip-transfer part surfacing is presented in Fig. 5. The point of the surfacing process is in the following. The electrode wire 10 is fed to the surfacing surface of the rotating part 1 by the rollers 5 from the cassette 6 through the vibrating contractor tube 9. Vibration of the contractor tube with the rate of 50-100 Hz is carried out with the electromagnetic vibrator 7 and the spring 8. As the result of vibration the welding circuit locks and unlocks between the electrode wire and a part and we observe wasted motion.

The electric current from the power source 3 is fed to parts through a sliding contact. The inductive resistance 2 is included into the welding circuit to increase stability and durability of the arc discharge. The coolant from the gravitation filter 12 is supplied into the deposited metal zone through the channel 4 with the pump 11, resulting in hardening the deposited metal. It is recommended to use 4-6% soda ash solution or 10-20% aqueous solution of technical glycerine as a coolant.

Lecture № 7
Gas-thermal (hot) spraying of parts

Classification of gas-thermal coatings

Gas-thermal spraying (GTS) of coatings is the most important branch of modern surface engineering. The beginning of its history dates back to 1909, when Max Ulrich Schoop, the first inventor of the method of metal spraying on a surface, received coatings on various materials, having sprayed lead and used a stationary crucible plant (Fig. 1).

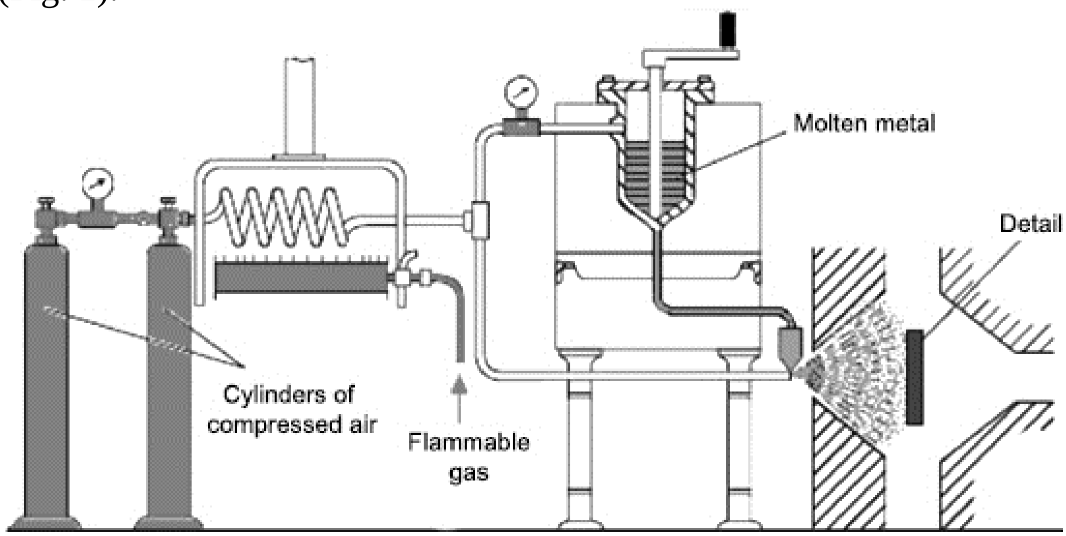


Fig. 1 – Crucible spraying plant

A metallization plant based on his technology was opened in Zurich in 1909. In 1913 M.U. Schoop patented the design of his gas-flame sprayer where the sprayed material was fed to the flame of the gas burner in the form of the wire.

Gas-thermal coatings are classified by the following features: 1. Functional (service) purposes; 2. Composition; 3. Coating macrostructure (structure); 4. Coating macrogeometry (special macrorelief); 5. The method of gas-thermal spraying, by which the coating was received; 6. The type of an outgoing material for coating spraying; 7. The group of coatings by thickness; 8. The group of coatings by porosity; 9. The group of coatings by the bound strength with the base; 10. Technological features which characterize the coating treatment; 11. Additional features.

Significant attention is currently paid to the classification of gas-thermal coatings on functional purpose (Fig. 1).

This classification of gas-thermal coatings (GTC) is needed not only for engineers and scientists, but also to organize the process of marketing management of gas-thermal coatings.

Such classification was first developed by METKO company.

According to GOST 28076 the classification of gas-thermal coatings on the functional purpose is as follows:

1. Rubber coating
2. Thermostable coating
3. Cork coating
4. Protective coating: wear-, erosion-, corrosion resistant.
5. Thermoregulating coating: thermal protective coating.

The classification of gas-thermal coatings on energy features (GOST 28076):

1. Gas-flame spraying
2. Detonation spraying
3. Arc spraying
4. Plasma spraying:

4.1. Arc-plasma spraying

4.2. High-frequency plasma spraying

The main idea of the processes of gas-thermal spraying of coatings consists in forming a directed flow of disperse particles of the sprayed material, which provides their transportation to the surface of a processing product with optimal values of the temperature and speed to form a coating layer (Fig. 2).

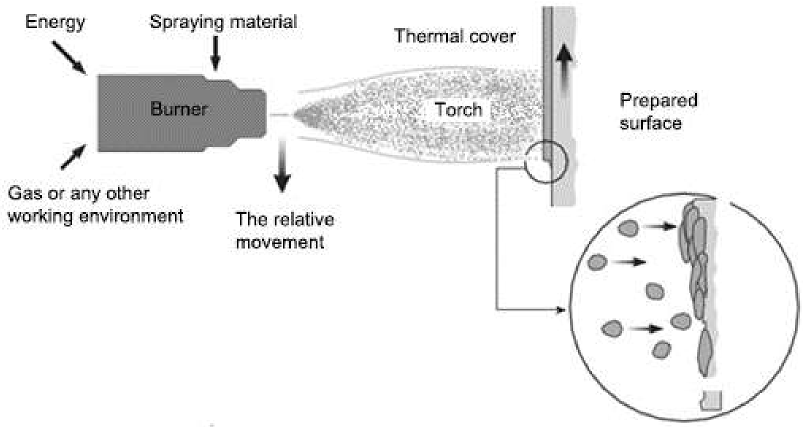


Fig. 2 – Scheme of gas-thermal spraying processes

Gas-flame spraying

The metal (powder material or wire) is melted by the gas mixture flame (acetylene, propane-butane, etc.) and oxygen and sprayed by compressed air or inert gas. Powder material supply to the flame zone can be carried out with the carrier gas (Fig. 3, 4) or directly from the hopper through the tube under the gravity force. Powder transportation with the help of inert gases reduces oxidation of molten metal particles. The advantage of powder injection by compressed air is in simplicity of the equipment and the absence of need in the carrier gas, but in this case we observe more intensive interaction of powder particles with the environment.

Preliminary spraying is used to increase the strength of spraying metal adhesion with part surfaces, i.e the underlayer is created. While spraying the underlayer, for example – from the nickel and aluminum mixture (if one of them is used as a wrapper in powder or flux cored wire, and the second is used as a filling compound). An exothermic reaction (with heat release) takes place between them and their temperature reaches 1450°C in the moment of particle impact on the part surface. As a result, a particle (drop) consisting of nickel, aluminum and their oxides, firmly welds to the surface and creates roughness for secure adhesion of the next (basic) layer with the set mechanical properties.

The speed of particles of the sprayed metal depends on the ratio of oxygen and fuel gas in the mixture, the amount of the gas which blows the flame, the distance from the nozzle section, the amount of the powder blown into the flame, its density, granulometric composition and other components; it is within 20-80 m/s.

It is recommended for powder material spraying: metals, alloys, compositions and oxides (Fig. 3) and metal wire coatings, flexible cords, ties (Fig. 4).

Before coating application, it is sometimes recommended to conduct preheating of a part to 90-180°C to remove adsorbed moisture and increase adhesion strength of coatings in a drying chamber or by the flame of a spraying device without powder supply (in a small part sizes).

Powders resistant to wear based on nickel or cheap iron-based alloys which have high operation and technological properties are used to restore parts working in friction conditions.

The chemical composition of powders based on nickel, % nickel – 80 chrome – 12-15, boron – 1,5-4, silicon – 0,5-4, carbon – 0,3-1,0 iron – 5. Powder brands are marked, for example ПГ–ХН80СР2 (Х – chrome, Н – nickel, С – silicon, Р – boron), where the last figure (2, 3 or 4) describes the percentage composition of all elements, except of nickel or iron.

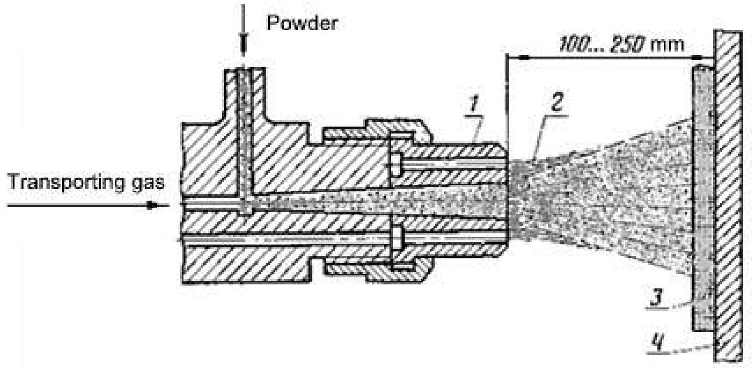


Fig. 3 – Scheme of gas-thermal powder spraying process

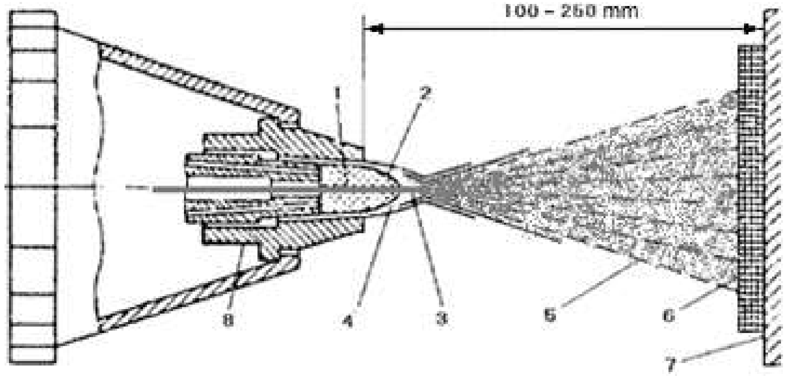


Fig. 4 – Scheme of gas-thermal wire spraying process

The chemical composition of powders based on nickel, % nickel – 80 chrome – 12-15, boron – 1,5-4, silicon – 0,5-4, carbon – 0,3-1,0 iron – 5. Powder brands are marked, for example ПГ–ХН80СР2 (Х – chrome, Н – nickel, С – silicon, Р – boron), where the last figure (2, 3 or 4) describes the percentage composition of all elements, except of nickel or iron.

Powder nickel-based alloys have a low melting temperature (950-1050°C), adjustable hardness (35-60 NRS), castability, high wear resistance and self-fluxing properties. Boron (Р) and silicon (С) actively remove oxygen from oxides in these alloys. The main disadvantage of these alloys is their high cost.

Powder alloys based on iron with a high content of carbon have low cost, high wear resistance, but they are more refractory (melting temperature of 1250-1300°C) and they are not self-fluxing. These alloys contain ferrochrome and boron carbides (e.g, alloy FBH-6-2), providing hardness HRC 56-63. Composite powder alloy mixtures based on nickel and iron are also used. For example, the composition of PS-1 is a mixture of powders in equal proportions: based on nickel – ПГ-ХН80СР3 and on iron – ПГ-У30Х28Н4С4 (hard sormite alloy).

Gas-flame spraying of powders can be used with or without fusion and with fusion of the sprayed layer. In the latter case the adhesion strength with the basic metal significantly increases as well as stability relatively to alternating loads on parts on-stream.

Detonation spraying

The method of detonation spraying of coatings uses the energy of gas mixture explosion (Fig. 5). Using this method, coatings of any type with low porosity can be applied.

In the chamber 1 of the barrel of ∅25 mm is fed oxygen and acetylene in strictly defined quantities; the barrel is surfaced on the processing part 2. The powder of the surfaced material is supplied through the hole 3 in the chamber. The gas mixture is ignited by an electric spark from the igniter 4.

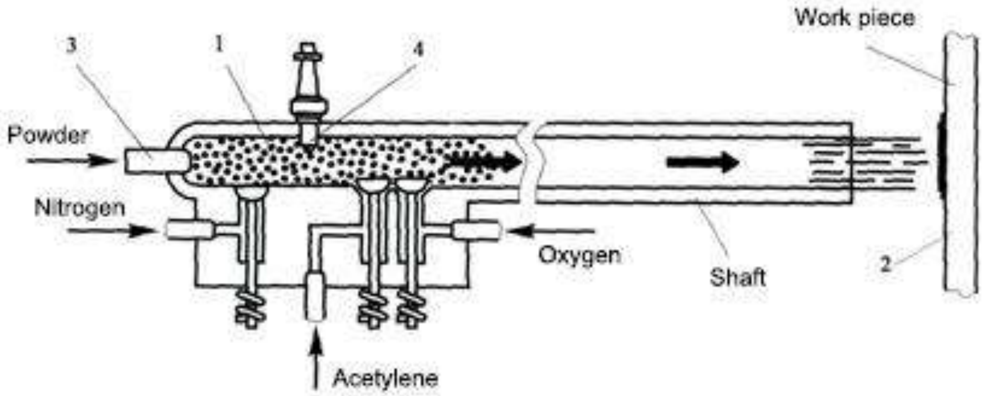


Fig. 5 – Scheme of denotation spraying process

As the result of the mixture explosion there takes place heat release; it forms a shock wave which heats and dissipates powder particles. Their speed at the distance of 75 mm from the shank cut can reach 820 m/s. The large amount of thermal energy releases when particles get on a part and the temperature of the spraying powder increases to 4000°C. As a result, the coating is formed on the part 2.

After explosion of the fuel gas mixture, the shank is blown with nitrogen to remove combustion products. The process is adjusted so that it repeats 3-4 times per second.

Detonation spraying is mainly used to produce solid wear-resistant carbide coatings, which contain small amounts of metal additives, as well as various oxides and their mixtures.

The plant works to achieve required coating thickness, which is usually 0,25-0,3 mm in practice. Coatings received by detonation spraying differ in high density and high adhesion strength with the base.

Arc spraying

During arc spraying (Fig. 6), two spraying metal wires with the diameter of 1-2 mm connected with the electric power source, are continuously fed through the feeding mechanism by guiding tips. There is an electric arc at the points of their approach; it melts the metal. The latter is transferred to the surface at the speed of 100-300 m/s in the form of particles with the size of 3-300 mkm by compressed air or inert gas supplied through metallizer channels (gas-thermal spraying in literature is often called metallization).

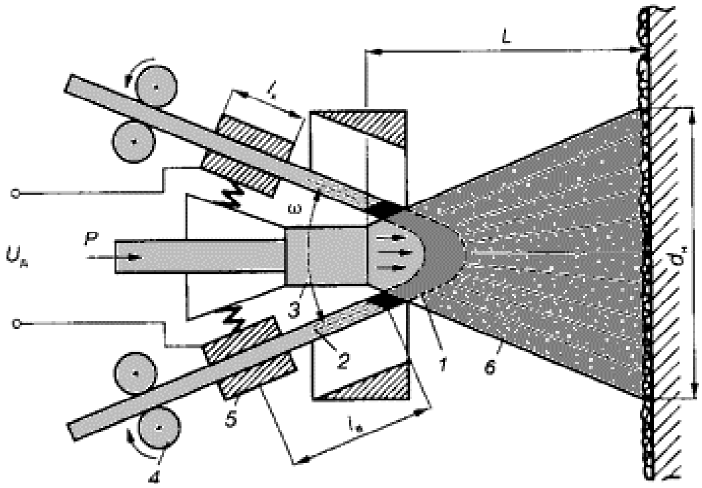


Fig. 6 – Scheme of arc spraying process: 1 – electric arc; 2 – wire; 3 – nozzle; 4 – wire feeding mechanism; 5 – contact devices; 6 – spraying material jet; lv – the length of wire overhang; Ud – voltage

Metal particles get an oxide film interacting with the environment during their flight. In case a part impacts on the surface, this film destroys due to the kinetic energy of particles forming a continuous layered coating with the big amount of pores and oxides on the surface. Particle adhesion to the surface takes place due to adhesion and mechanical cohesion with the rough surface.

Нп-30, Нп-30ХГСА, Нп-30Х13 wires with the diameter of 1,2-2,5 mm are used for arc spraying.

An approximate process mode: voltage 25-40 V, amperage 80-160 A, wire feed speed 0,6-1,5 m/min, air pressure 0,4-0,6 MPa, a distance from the nozzle to the part 80-100 mm. Manual (EM-3 EM-9) and stationary (EMC-1, EM-12) metallizers are used.

The main characteristics of arc spraying are a high process productivity, which can reach 50 kg/h and a high spraying energy efficiency, which can be equal to 0,7-0,9. Disadvantages include the need to use only wire materials for spraying, burning alloying elements, and decreasing the fatigue strength.

Plasma spraying

A plasma sprayer was developed in 1956 by Gianini Corp. and UC companies on the base of Smith`s works (Pat. 2157498, 1939), who introduced a device for coating application comprising a cathode in the form of a rod and an anode in the form a nozzle.

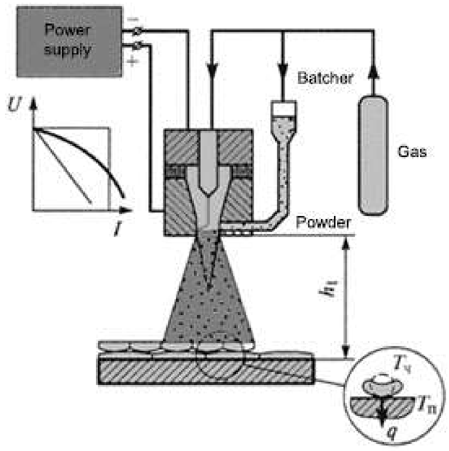


Fig. 7 – Scheme of plasma spraying process

The process of plasma spraying is carried out according to the scheme represented in Fig. 7 where h_l – a distance from the nozzle cut to the spraying surface; $T_ч$ – a particle temperature; $T_п$ – a sub plate temperature; q – a heat current supplied into the sub plate.

Arc-plasma spraying

Arc-plasma spraying lies in the following: the metal molten by the plasma jet is sprayed and applied to the renewable surface by the same gases which are used to form and protect the plasma. The plasma jet is obtained by the gas passing through the arc discharge in the narrow channel of the plasma burner which is cooled by water.

Plasma spraying is carried out by the plasma jet. The plasma temperature in the core is 20 000-30 000°C, the jet velocity is 300-2000 m/s. High-current electric arc is ignited from the power supply between the water-cooled cathode and anode. The value of the current can be adjusted from 80 to 600 A.

Orifice gas (argon, nitrogen, AgN_2 mixture, air, etc.) is fed to the span of the arc. Contacting with the arc, the gas heats and, accelerating, leaves the nozzle in the form of a low-temperature plasma jet. The jet temperature is from $2 \cdot 10^3$ to $15 \cdot 10^{3}$°K. The jet speed is from 200 to $2 - 3 \cdot 10^3$ m/s (Fig. 8).

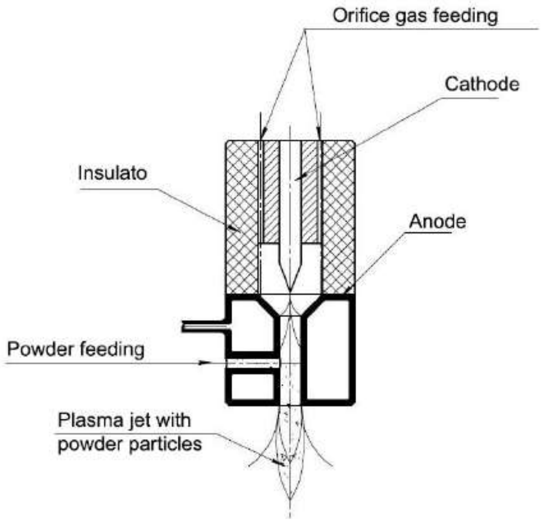


Fig. 8 – Scheme of plasma sprayer.

Powder is supplied from the special feeder into the jet; it accelerates, melts and deposits on the sub plate, forming a coating. Plasma coatings have high density and adhesion strength with the base metal.

Using a plasma jet with a high temperature, any refractory materials, carbides, borides, oxides can be applied with high speed and uniformity. To apply neutral gases, argon, nitrogen and their mixtures for plasma initiation and protection promotes minimum burning of alloying elements and particle oxidation.

The modes of plasma surfacing with different adding materials are presented in Table. 1.

Table 1 – Plasma surfacing modes

Plasma processing type	Current, A	Voltage, V	Orifice gas and its consumption, l/h	Carrier gas and its consumption, l/h	Electrode wire feed speed, m/h	Surfacing speed, m/h	Distance from burner's nozzle to part surface, mm
Surfacing with filler wire	180-260	40-45	Argon 120-180	-	6-24	9,6	10-20
Surfacing of Sormite №1	180-260	40-45	Argon 90	Nitrogen 240-360	-	9,6	10-12
Powder spraying	250-350	80-90	Argon 1500	Argon 1500	-	9,6	120-150
Powder fusion	300-320	80-90	Nitrogen 1500	-	-	9,6-12,0	65-70

Plasma arc surfacing is used to restore parts worn 0,1-1,5 mm and to apply stable anti-friction coatings.

High-frequency plasma spraying

In this case the principle of induction heating is used to melt the adding material; material spraying and its transfer to the working surface of a renewable part is carried out with the compressed gas jet.

Fig. 9 represents the scheme of the high-frequency spray head of a spraying device where a metallic wire is an adding material. The main components of the spray head units include: the inductor 4, its power source is a high-frequency current generator; the current concentrator 3 which provides melting the metal wire on the small area of its length; the cooling system of an inductor; the compressed gas system 5 adjustable within 0,4-0,6 MPa; it helps to spray the molten metal and transfer it to the working surface of the renewable part 1; the metal wire feed system including the guide channel 8; it feeds the wire to the burner by the rollers 7, moving at the rate of 0,46-1,20 m / min using the electric drive.

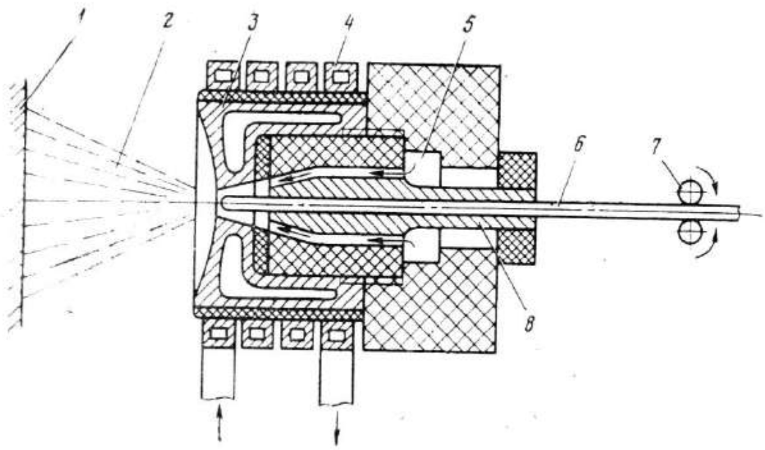


Fig. 9 – Scheme of high-frequency spray head of spraying device

The operating principle of the spray head is the following: the metal wire is fed to the inductor and current concentrator by the feed system. There it is heated and melted by the eddy current which occurs under the influence of the alternating magnetic field created when the high frequency current passes through the inductor coil. The molten metal is sprayed by the air jet and applied to the part being restored. Inert gases are used instead of compressed air when the metal is sprayed and interacts with oxygen. Then spraying process is carried out in the chamber with inert gases.

The advantages of high-frequency spraying include minor metal oxidation due to the opportunity of temperature regulation of heating the metal wire while melting and high mechanical strength of the coating. The disadvantages include a relatively low productivity of the process and the complexity and high cost of the equipment.

To spray coatings, we use general-purpose powders as well as specialized powders with the particle size of 5 to 200 μm.

Specialized powders are often produced of three classes: PS – particularly small; S – small and A – average. The fractional composition of particles within one class varies for different materials. Typically, the PS class includes particles with the diameter of 40-100 μm, S class – 100-280 μm, A class – 280-630 μm.

As one-component powders we use metals as (aluminum, zinc, tungsten, etc.), oxides (AI_2O_3; ZrO_2 etc.), carbides (WC, SiC, etc.), borides (WB, ZrB_2, CrB_2 etc.), nitrides (AlN, ZrN, TiN, HfN, etc.) and silicides ($MoSi_2$, Cr_3Si, $TaSi_2$ etc.). Usually, one-component powders are obtained by meltdown or its restoration. One-component powders are mainly used during gas-thermal spraying, the main advantage of their use is to get the coatings of the uniform chemical composition and structure.

As multicomponent powders we use mechanical mixtures of metals, oxides, alloys, carbides, borides, graphite (diamond), solid lubricants, etc.

The alloys of elements Fe-C, Ni-Al, Ni-Cr, Ni-Al, Cu-Sn became widely used. The particle structure can be homogeneous as well as heterogeneous.

Recently the methods of powder production, which provide each particle with all output components, have dramatically developed. So, all powder particles have the same: mass, chemical composition, density, thermal conductivity etc. To achieve this the technologies to get the powders of plate and conglomerate structure have been developed. These powders are called composite.

Composite powders are divided into two groups: exothermically reacting and thermoneutral. They consist of two or more components of different properties, divided by the clear boundary.

Electrospark building-up

The energy of pulsed spark discharges between electrodes in the gaseous or liquid medium is used while electrospark processing of metal surfaces is carried out. The essence of coating application and surface strengthening is the following: a spark discharge destroys the tool material (cathode) and the products of its erosion are transferred on the work material (anode) in the gaseous environment. Metal transferring on the blank surface forms the coating of the chemical composition close to the composition of the electrode material. The coating has stronger adhesion to the surface because its formation is accompanied by diffusion processes at high temperatures.

The coating consists of three layers. The first layer – a thermodiffusion zone of the coating and basic metal. Complex chemical compounds, nitrides and carbonitrides are formed in the layer. The second, which is not etched (white) layer is a solid solution of alloying or carbide-forming elements comprising the electrode material. The third – the outer layer formed from fragments of the solidified metal and oxides.

Application of hard wear-resistant coatings with the thickness to 0,1 mm relates to strengthening, but application of any coatings of greater thickness – to surfacing. A coating can be applied with the thickness of 0,25 mm, and on the surface of immovable joints – to 1,5 mm while the surfaces involved in friction are restored.

With electrictrospark processing, worn parts are restored and tool cutting borders (cutters, milling cutters, punches, etc.) are strengthened by application of hard alloys, also the properties of part surfaces change as they are provided with anticorrosive, heat-resistant, friction and antifriction properties. Shaft necks and axles are restored, hole surfaces for bearings are strengthened by friction surfaces instead of heat treatment. The method became widespread when we restore parts of fuel equipment of diesels and sliding pistons of hydraulic control valves made of 15X steel with the hardness of 56-63 HRC. Stability of the cutting part of tools increases up to two times as the result of strengthening. Durability of parts 3-8 times increases after electrospark strengthening.

For electrospark strengthening we use the following materials (electrodes): metal ceramic hard alloys ВК6-ОМ, ВК-8, Т15К6, ТТ15К10-МУ, Т30К4, Т60К4, ТН-20 of a round and rectangular overcut; copper wire; bronze Бр.АЖ10-3, Бр.АЖМц10-3-1,5, Бр.АЖН10-4-4, ВБр.5М etc; analog relit ДКВ; Aluminium-tin-copper alloy АСА; alloys ВЖЛ-2, ВЖЛ-2М, ВЖЛ-13, ВЖЛ-17, В56, ЖСН-Л; Steels 65Г, 20Х13, 95Х18, ШХ-15 etc. Sormite, stellite and tungsten are also applied.

Coatings are applied with a condensing plants, such as «Elitron-344» with electromagnetic vibrators, providing a periodic contact of tools and blanks (Fig. 10).

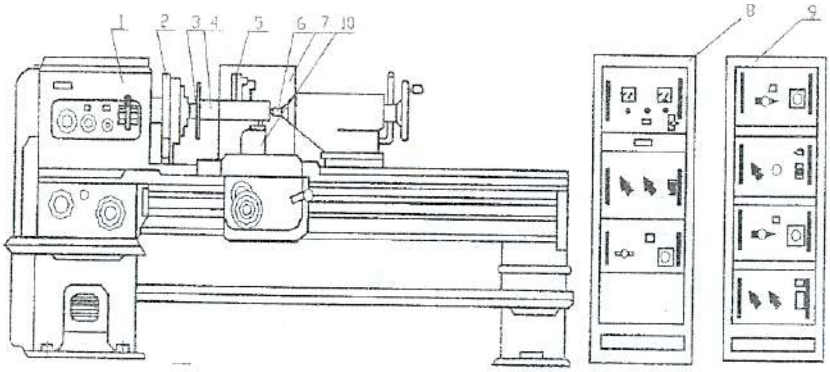


Fig. 10 – Scheme of «Elitron-344» plant: 1 – turning machine 1K62; 2 – three-jaw holder with current collector; 3 – mandrel; 4 – processing part; 5 – machining head; 6 – center; 7 – screen; 8, 9 – generators; 10 – running-in

Modes of coating application are set in Table. 2.

The most widely used are the plants of models EΦI-46A, -23M, -25M, -54A. Modernized portable devices such as «Elitron» are used: «Elitron-22A», «Elitron-22B», «Elitron-22BM», «Elitron-52BM» and two plant models «Westron»: «Westron-005» and «Westron-006» are used.

Table 2 – Electrospark processing modes

Mode	Operating current strength, A	Short-circuit current strength, A	Voltage, V
Finish-ing	0,5-0,7	2,5	15
	0,8-1,2	3,0	25
Average	1,2-1,5	3,5	45
	1,6-2,0	4,5	75
Rough	2,0-2,5	4,8	140
	2,6-3,0	5,0	200

Technological transportations of tools are carried out manually as well as with the use of mechanized means. In both cases, an electrode position, processing durability, modes on current, amplitude and vibration frequency of the electrode are selected so that the coating had maximum continuity, a uniform thickness and a smooth surface that reflects the light.

Lection № 8
Electrolytic augmentation of parts and polymeric materials application in production and component overhaul

Electroplating process of metal sedimentation and its main characteristics

Electrolysis is called as chemical processes that occur on electrodes while the electric current is going through electrolytes (Fig. 1). Electrolytes are acids, lyes and salts dissolved in water that dissociate into positive and negative ions. Water (H_2O) is a weak electrolyte and dissociates into hydrogen ($2H^+$) and hydroxyl (OH^-) ions. During dissociation of ions metals and hydrogen they obtain a positive charge (cation) and, moving to the surface of cathode (an electrode connected to the negative pole of the current source) during electrolysis, are refilled with electrons, that is, they are restored (electroreduction) and become neutral atoms.

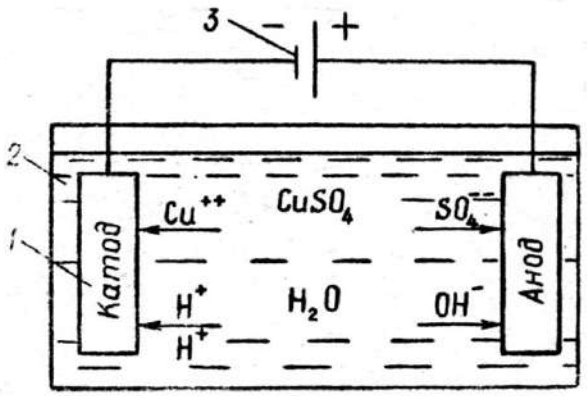


Fig. 1 – Scheme of metal electroplating plant:

1 – part;
2 – electrolyte;
3 – current source

The main process taking place on a cathode during electrolysis is metal release accompanied by hydrogen release. On an anode, oxygen releases. A cathode is an article being coated, and an anode is metal plates, rods or other metal construction forms. Metal electrolysis may be carried out with dissoluble (in case of metal plating, for instance) or indissoluble (in case of chrome plating) electrodes.

Parameters characterising electrolysis are based on Faraday's laws and define the main technological modes of electrolytic surfaces.

Influence of electrolysis conditions on the structure and surface properties

Since, simultaneously with metal sediment, hydrogen releases, and other restoration processes (without release of any matters) consuming a part of the current can be going on, the actual mass of the metal sediment will be lesser than estimated by Faraday's formula. The ratio of the actual quantity of matter ($m_Д$) to theoretical ($m_Т$) is called as the current output (η) or the efficiency coefficient of the bath expressed as a percantage:

$$\eta = \frac{m_Д}{m_Т}100. \qquad (1)$$

During calculating technological models of electrolytic processes a specific parameter is used – the current density that is determined as a ratio between current intensity to the coated surface area of a part (cathode).

$$Dк = \frac{I}{S_к}, \qquad (2)$$

where: $D_к$ – cathodic current density A/dm^2;

I – current intensity, A;

$S_к$ – surface area of a cathode.

In the same way it is also possible to calculate anodic current density $D_{a.}$

To determine thickness of approximately proportional precipitated metal coating, we express its mass in volume and metal specific weight (γ):

$$m_ф = S_к h\gamma. \qquad (3)$$

Using ratios (1), (2) and (3), we obtain the dependence to calculate thickness of metal sediment:

$$h = \frac{cD_к t\eta}{1000\gamma}. \qquad (4)$$

Dimension parameters: c, г/A·hour; $D_к$, A/dm^2; t, hour; η, %; γ, г/sm^3; h, mm.

The average thickness of the metal coating is determined according to the formula (4), as in fact most electrolytes make uneven sediments, i.e. have limited dissipating ability, which is understood as a special feature of cathodes to support evenness by thickness of surface on irregular shaped cathodes (parts), which elementary surfaces are situated on different distance of an anode, (Fig. 2).

Preparing components to electrolytic augmentation includes machining, degreasing, etching processes.

Machining of parts is performed to remove tear and wear traces, give the surface a regular geometrical form and prepare necessary roughness (not lower than R_z=10 μm) for which such kinds of surfacing as filing, reseating, polishing are used.

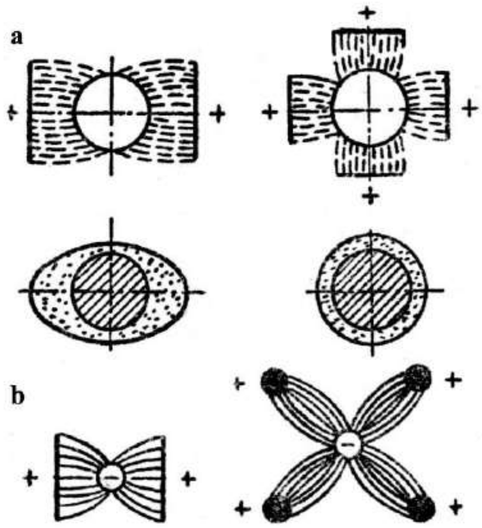


Fig. 2 – Influence of anode placement (a) and their shape (b) on the mode of lines of force and even augmentation of the coating.

Degreasing is performed after machining in organic solvents (petrol and petroleum spirit), and then the areas that are not subjected to be coated by acid-proof materials (perchlorovynyl film or lacquer, glue BF-2, etc).

Polishing is performed to remove the oxidative film and reveal the crystal structure of the part's surface that gives durable coating adherence with the basis metal. Components are subjected to chemical and electrolytic etching.

Metal-plating has a number of advantages over other processes of metal electroplating due to use of cheap and widespread materials (Fig. 3). Meanwhile, the current output is 80-90%, coating hardness – to 7800 MPa. There's a possibility of sediments up to 2 mm thick.

Two types of electrolytes are used in galvanic iron sedimentation. They differ in process temperature – cold and hot.

Hot electrolytes (above than 50°C) require more energy consumption to maintain high temperature, their frequent adjustment, removal of effluviums etc. However, they are widely used to restore parts through high productiveness of the process.

Cold electrolytes (less than 50 °C) do not have the specified shortcomings and besides are steadier against oxidation. Hot electrolytes are divided into three groups by their composition: chloride, sulfate and mixed. There is most widely-used chloride electrolyte consisting of chloride iron $FeCl_2\ 4H_2O$ – 200-500 g/l and chloride sodium NaCl – 100 g/l.

Metal-plating on the asymmetric current in cold electrolyte is quite effective and perspective in repair production. It consists of ferric sulfate $FeSO_4\ 7N_2O$ – 200 g/l and ferric chloride – 150-250 g/l.

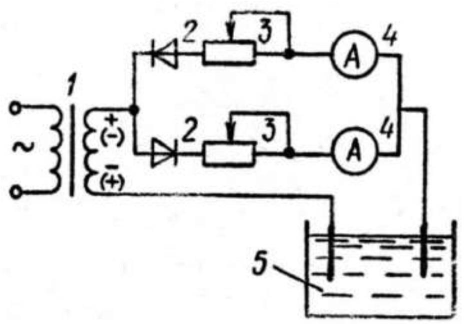


Fig. 3 – Scheme of a metal-plating plant on asymmetric alternating current:
1 – step-down transformer;
2 – diodes VK-50;
3 – rheostats;
4 – amperemeters;
5 – galvanic bath

The major factors that influence the properties of iron sediment from cold chloric electrolytes by using asymmetric alternating current are the cathodic density of current $D_к$ and asymmetry parameter β, in (Fig. 4).

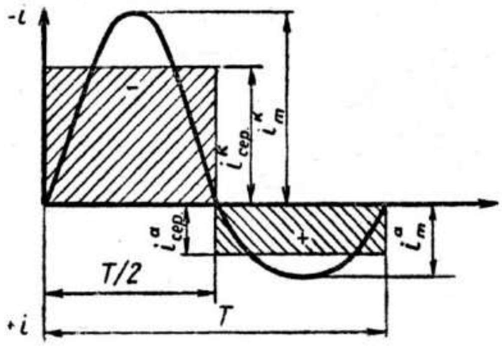


Fig. 4 – The Shape of asymmetric current:
$i^{к}_{сер}, i^{а}_{сер}$ – Average current respectively cathodic and $i^{к}_{m}, i^{а}_{m}$ – amplitude current cathodic and anodic respectively

Dependence of hardness of iron sediments on the asymmetry parameter and current density is given (Fig. 5)

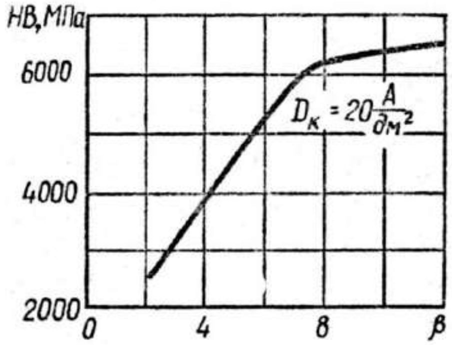


Fig. 5 – Dependence of sediment hardness on asymmetry parameter

Mild steel anodes are used in metal-plating. The anode-area-to-the-surface-part-area (cathode) ratio is accepted as 2:1.

Electrolytic augmentation of worn surfaces of large body parts and complex configuration parts. It is recommended to apply the non-bath way of dry topping to such parts (Fig. 6), which forms a local bath in the coating zone.

For the non-bath way of dry topping (e.g., holes in cast iron case gearbox) it is recommended to use highly concentrated electrolyte composition: 700 g/l of $FeCl_2 \cdot 4H_2O$ and 50 g/l of $MnCl_2 \cdot H_2O$, to conduct the process on the asymmetric alternating current on the mode: $T_k = 120$

c, T_a = 12 c, D_k = Da 40-60 A/dm^2, t = 80°C. Under these conditions we receive a qualitative coating with thickness up to 1,3 mm with an average metal sedimentation rate of 0,30-0,32 mm/hour.

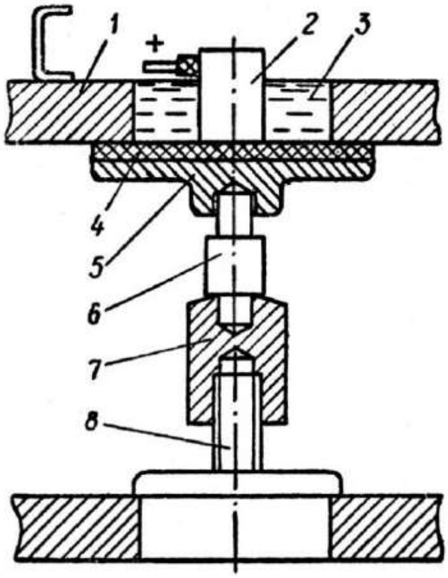


Fig. 6 – Augmentation scheme of the hole surface by the non-bath way of dry topping:

1 – part;
2 – anode
3 – electrolyte;
4 – rubber gasket;
5 – disk;
6 – persistent rod;
7 – nut;
8 – screw

Chromium-plating makes parts resistant against wear, corrosion, and also ensures good appearance. However, chromium plating process is inefficient and also has a high cost price.

For chromium plating we often apply electrolytes that consist of chromic anhydride CrO_3 and sulfuric acid H_2SO_4 dissolved in distilled water. From universal electrolyte, changing the current density and temperature, it is possible to receive shiny, milky and matte (grey) sediments.

Shiny sediments are received at t = 55°C and D_k = 35-70 A/dm². They are recommended for growing parts at specific loads up to 2,5 MPa (dry friction) and 3,9-4,9 MPa (liquid friction).

Dairy sediment is obtained at t = 60°C and more, D_k = 25-35 A/dm^2. They are characterized by good wettability and sufficient viscosity.

Matte (grey) chromium plating is obtained at high current density, D_k = 70-100 A/dm^2 and temperature, t = 35-50°C. They have high hardness and brittleness, low wear resistance.

Copper plating is used to restore the outer diameter of bronze bushings and form an underlayer during nickel plating etc.

Nickel plating as a primary coating is sometimes used to protect parts from corrosion and for decorative purposes, but often it is used as a sublayer in decorative chrome plating.

Electrolytic metal sedimentation by rubbing is useful when we restore shafts seats and axles and coating bearing holes surface in frame parts as well. The method is that the anode (Fig. 7) is a carbon rod 2, covered with a cotton swab or cloth 3, which is supplied with the electrolyte 4, moves relatively to the stackable surface.

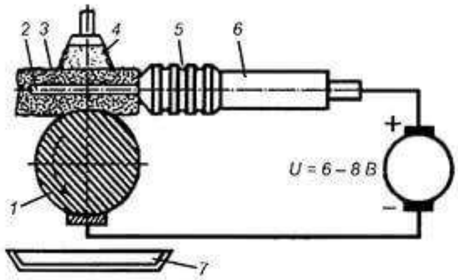


Fig. 7 – Scheme electrolytic deposition of metals rubbing

Polymeric materials in component overhaul

Polymeric materials are divided into two groups: thermoplastic (thermoplastics) and thermosetting (thermosetting plastics).

Thermoplastics melt under heat influence and become hard when cooled during processing. Thus, there occur no chemical reactions. When reheating, they turn into plastic again, but their physical and mechanical properties deteriorate.

Among the thermoplastics, polyamide resins are used in repair production, that work well in terms of friction after being applied to a part surface with a thin layer (up to 0,2-0,7mm). Thermoplastics are used for component overhaul and production.

During processing under heat influence, thermosetting plastics are softened and partially melted at first and then, as a result of chemical reactions, turn into an infusible – solid and insoluble state (irreversible process).

Restoration methods for a worn-out layer by polymeric materials

Application of thin layer coatings in pseudo-compressed layer is used for restoration of worn-out part surfaces of chemical and anticorrosive protection, improving the antifriction properties of frictional areas, creation of electro- and heat insulation and also for decorative purposes. The process is that the part is heated 30-50°C higher than polymer melting temperature, then it is dipped for a while in weighed, so-called a pseudo-compressed layer of polymeric powder (Fig. 8 a, b).

Application of coatings by the gas-flame method is used for alignment of roughness on the cabin parts, plumage and facing of tractors and cars, application of electro- and heat-insulating on the surface of parts, decorative and protective coatings. The method is that the air stream with weighed polymer powder particles in it is passed through a tongue of acetylene flame. At the temperature of 650-700°C and above the polymeric material due to significant speed of passing through the flame zone (20-30m/s), softened to the plastic state and during impact on the prepared surface, parts couple with it, forming a continuous polymeric coating.

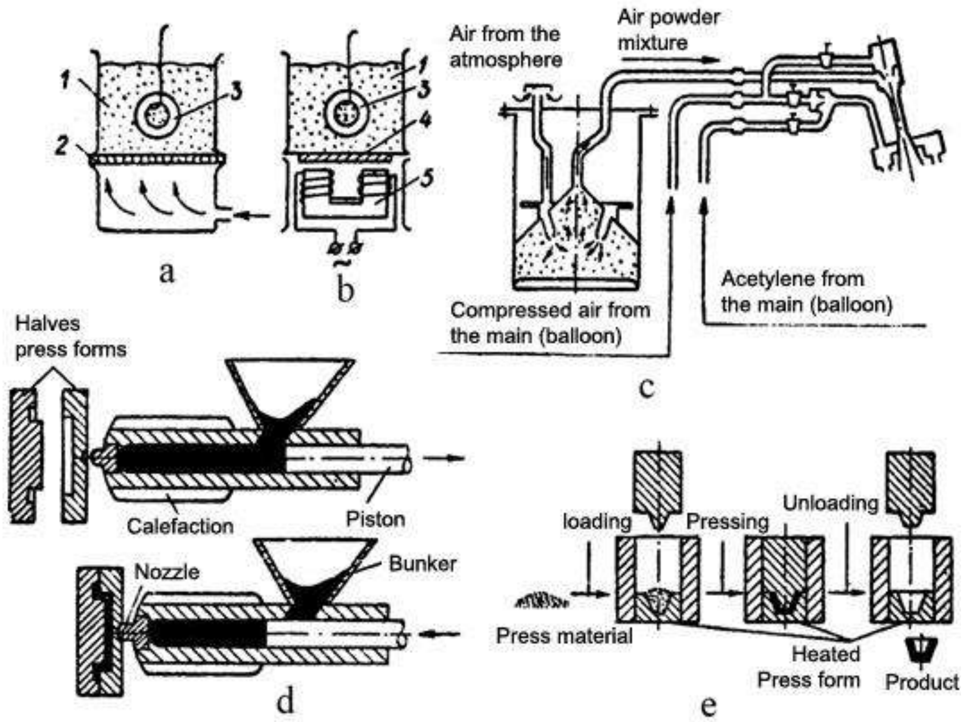


Fig. 8 – Polymeric material application scheme:
a ,b – respectively vortex and vibrational methods of application:
1– chamber with polymer powder; 2 – porous wall; 3 – part; 4 – rubber diaphragm with an iron plate; 5 – solenoid magnet; c – operation scheme of installation for oxyfuel gas spraying of polymeric coatings, d – scheme of casting under pressure, e – processing diagram of thermosetting materials by the compressing method.

Repair and part production from thermoplastic polymeric materials by casting under pressure or compressing is used to receive coatings on the worn-out surface of the part with sufficiently high degree of accuracy, and also to produce new and repaired parts.

Part manufacturing technique by casting under pressure is as follows: the polymeric material melted beforehand and heated at 50–70°C higher than the melting point in the caster injection cylinder, is served by the hydraulic piston or the worm (screw) in generating slots of casting press mold under pressure of 10–20MP.

The process of filling up cracks with polymeric materials is applied for repairing units and cylinder heads, gearboxes, case of rear axles, tanks and other parts (Fig. 9). During this process, we use epoxy resins as ED-16 and ED-20 which harden under the influence of the hardener. To increase the elasticity and the impact toughness of the resin the plasticizers are set into its composition. In addition, the filler is added to the epoxy composition, by means of which physical and mechanical or antifriction properties are improved, heat resistance and thermal conductivity are increased and cost is reduced.

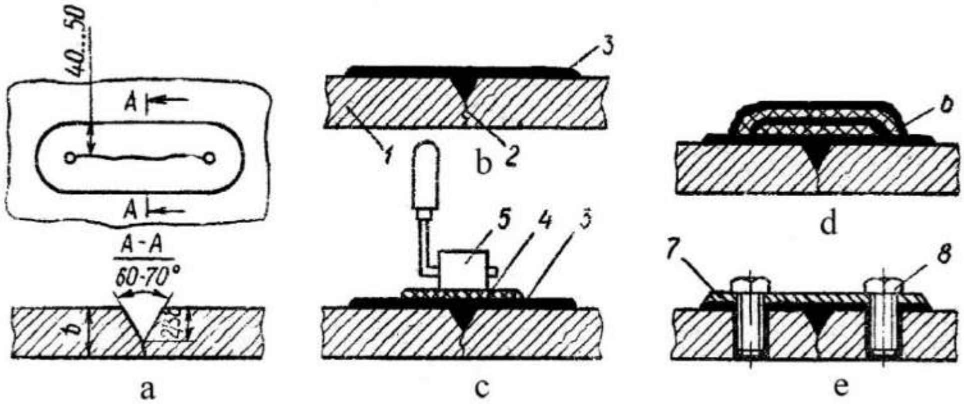


Fig. 9 – Schemes of repairing cracks with epoxy composition:
a – cracks design under the filling with epoxy composition;
b – applying the first layer of epoxy composition; c – applying the plate on a crack and rolling with a roller; d – applying epoxy composition to the second plate; e – filling up the crack with its length more than 150 mm: 1 – part; 2 – crack; 3 – epoxy composition; 6 – plate of glass fabrics; 5 – roller; 7 – metallic plate; 8 – screw.

Application of synthetic adhesives

One of the most well-known technological processes using adhesives is sticking of anti-friction plates on brake pads and clutch discs.

Anaerobic adhesives are one-component materials which harden under room temperature providing the contact with oxygen is absent. The liquid component of curing remains inactive until it is in contact with atmospheric oxygen. If adhesive without access to atmospheric oxygen, e.g. when assembling parts, fast curing takes place, especially in simultaneous contact with the metal. This curing can be explained as follows: when atmospheric oxygen stops yielding, free radicals are formed under the influence of metal ions (Cu, Fe). These free radicals are favourable to start of the polymerization process (Fig. 10).

They are used to seal pores while casting and in welds, flat demountable joints, to fix smooth cylindrical joints (Fig. 11) and for fixing, and sealing threads; they prevent turning off and provide protection from the threaded joint from corrosion (Fig. 12).

Acrylic adhesives. The adhesives are intended for bonding and sealing flat and smooth cylindrical joints. Acrylic adhesives have high rapidity of curing and high strength while tearing.

They are used for bonding different materials: metal, glass, laminated glass, ceramics, plastics.

Elastomers. Elastomers are used to restore a rubber surface, and to eliminate its defects as well. They are polymers possessing good elastic properties under ordinary temperatures, that is, they are capable of tremendous reversible tensile deformations.

Due to their structure, elastomers quickly return to their original state, i.e. have a high elasticity.

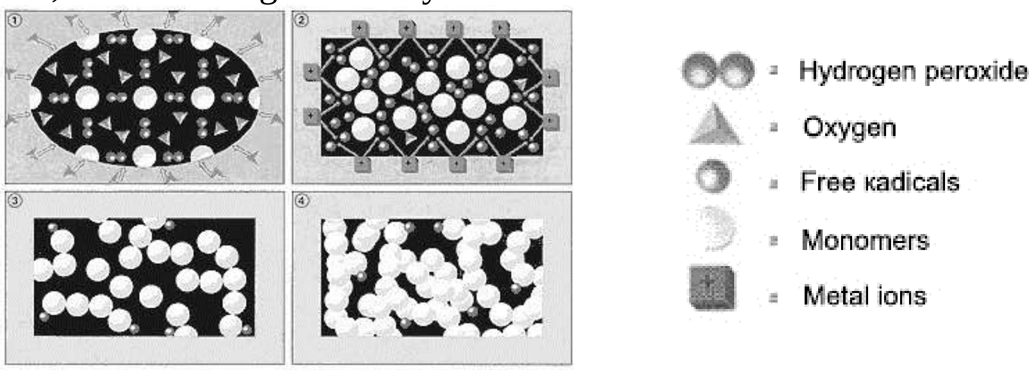


Fig. 10 – Adhesives polymerization under anaerobic reaction

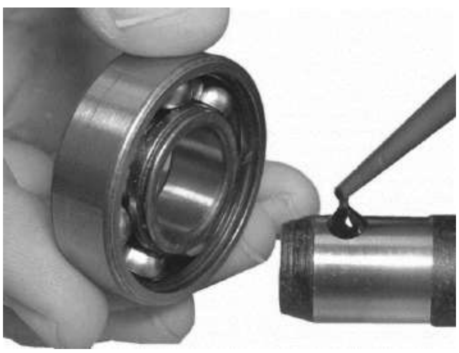


Fig. 11 – Scheme of using anaerobic adhesives for mounting seats

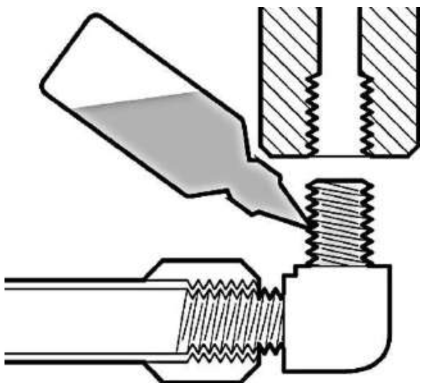


Fig. 12 – Scheme of using anaerobic adhesives for screw joints

Lecture № 9
Basic methods of restoration and strengthening of parts

Worn-part reclamation by plastic deformation

Repair (restoration) of parts by plastic deformation is based on the ability of metals to change their shape under pressure. Plastic deformation is possible with and without the part heating process.

Component overhaul by plastic deformation has the following advantages: simple, not labor-consuming, of high-quality and does not require additional materials. The disadvantages of the method include the following: alteration of mechanical properties of parts; costs on heating and heat treatment violation while heating; cracking especially in case parts deform in the cold state and a necessity to produce special punches. In practice we use the following types of component overhaul (recovery) by plastic deformation: distribution, compression, extension, deposition, indentation.

Distribution is used to restore geometrical sizes and shapes of parts when the outer surface is worn. During distribution the direction of the applied force $P_д$ (Fig. 1, *a*) coincides with the direction of the deformation δ. The method is used while parts as bushings, hollow fingers, spline shafts are restored.

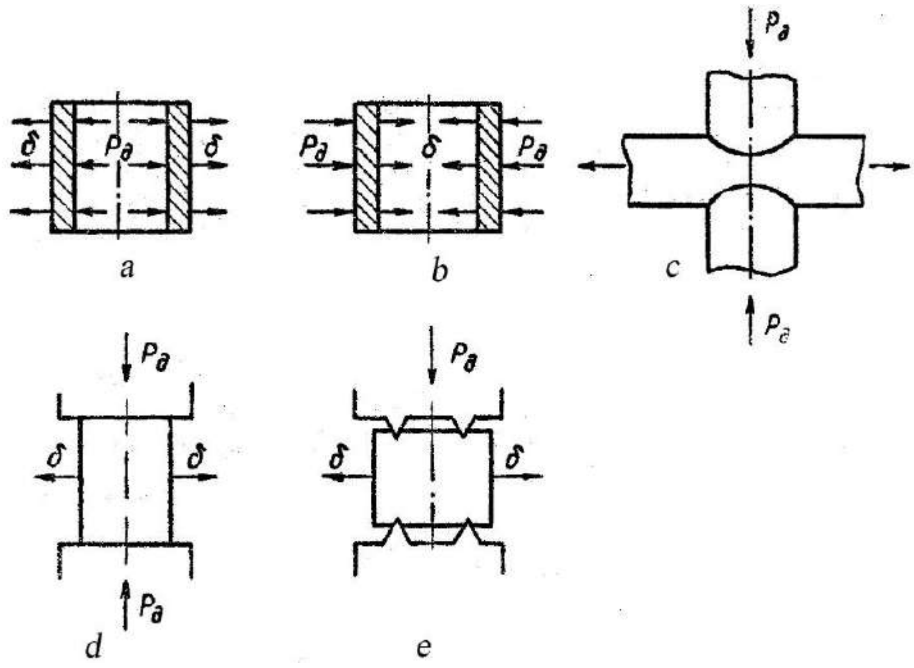


Fig. 1 – Schemes of worn layer compensation by plastic deformation:
a – distribution; *b* – compression; *c* – extension; *d* – deposition;
e – indentation

The technological repair process consists in forcing balls or a special punch through a part hole. This type of plastic deformation is widely used to repair piston fingers of tractor engines. Fingers are subjected to high tempering, and then a punch is forced through the inner finger hole. The diameter of the punch has to be chosen according to the inner diameter of the finger hole and provide an allowance for mechanical processing of the outer finger surface within 0,1 mm. Then the piston finger is tempered and hardened, and if necessary, it is cemented and ground and the hardness is checked. Cracks are determined by magnetic crack detection.

Thin-walled piston fingers, bushings, and parts of nonferrous metals are distributed without tempering, but the quality of repair is controlled, the absence of cracks is obligatory checked.

Compression is different from distribution by the direction of the applied force and deformation (Fig. 1, *b*) and is used to compensate the worn layer of the inner part surface.

The method of plastic deformation by compression is used while parts are repaired, when reduction of external sizes is inessential or when repairing parts whose outer surface is subjected to restoration by other methods.

Extension is based on noncoincidence of the direction of the applied force and deformation (Fig. 1, *c*). Extension is used to lengthen rods, pivots, bars and other parts. Part length compensation is carried out by its cross-section reduction.

Extension or blacksmith stretching is widely used to repair worn surfaces of working units of tillage machines. Extension is usually carried out with heating parts to 800-1200°C.

Deposition by the direction of the applied force and deformation is similar to extension (Fig. 1, *d*). This type of plastic deformation is used to repair parts with worn outer and inner surfaces. Wear compensation is carried out due to reduction of the part length.

During indentation the directions of the applied force and deformation do not coincide (Fig. 1, *e*), as during deposition, but the part length does not change because metal replacement takes place from the non-working part section towards the worn one.

Worn-part reclamation by surface plastic deformation

During surface plastic deformation (SPD) it is formed a cold-hardening, i.e surface strengthening of the metal (Fig. 2). Metal grains are extended in the direction of deformation, crystal lattices are bended, and as the result the structure and properties of the surface layer are changed, ductility and the impact strength decrease, but favorable compressive stresses are formed, the fatigue strength increases (30-70%); hardness and wear resistance grow (1,5-2 times). During SPD the height of microroughnesses decreases (0,04μm) and a surface with a new microshape is ctreated.

Bead blasting processing (Fig. 2, *a*) is used to strengthen carriage springs, springs, shafts, gear wheels, welding seams etc.

The cold-hardened layer with the depth of 0,5-0,7 mm is created due to the kinetic energy of a shot flow, which flies with the speed of 30-90 m/s at the angle of 70°. For that we use bead blasting plants as follows: pneumatic (the air in the nozzle is compressed to 0,5-0,6 MPa) and mechanical (with a centrifugal bead blasting wheel).

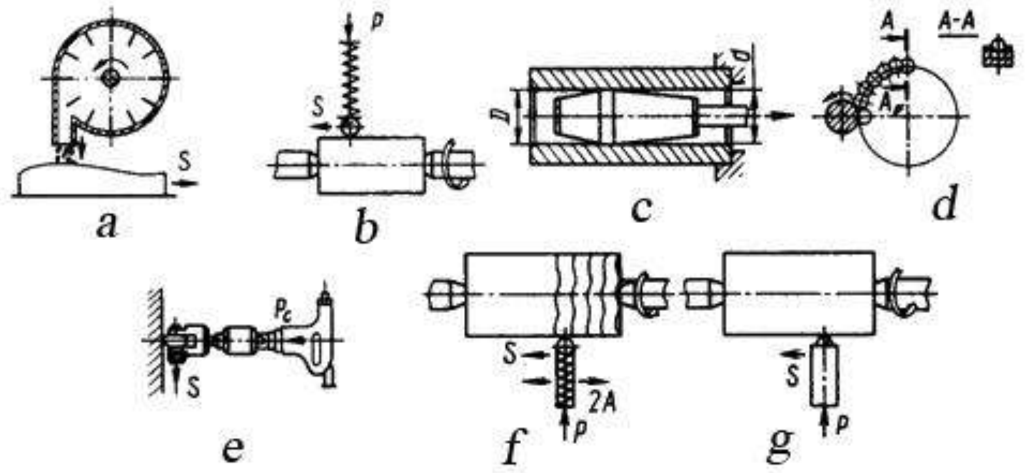


Fig. 2 – Scheme of surface plastic deformation (SPD).

The size and material of the shot are chosen depending on the processing sizes. A shot is produced of bleached cast iron and steel spring wire, which are used to process steel parts. An aluminum shot is used for nonferrous parts.

Test run and beading by balls and rollers (Fig. 2,*b*) process cylindrical surfaces, grooves, hollow chamfers, areas, shaped surfaces etc. The peculiarity of processing by balls is the absence of the forced rotation axis and their self-adjustment relatively to the processed surface, simplicity and versatility of devices, an ability to achieve high contact pressures at relatively little efforts, improvement of surface roughness.

Rolling (beading) by balls and rollers is carried out using special devices (knurling tools or tube expanders) which are fixed in the tool carrier of a turning machine or another metal-cutting machine tool. The pressure during rolling (beading) can be created by the calibrate spring as well as by the pneumatic or hydraulic power mechanism. These methods of SPD are recommended to be carried out with the use of lubricating-cooling fluids (LCF) – industrial oil or its mixture with 2-3% oleic acid.

The allowance for surface strengthening is determined depending on the initial roughness and taken approximately equal to the height of unevenness or determined by the following formula:

$$\delta = 1{,}35(R'_z - R_z), \tag{1}$$

where R'_z i R_z – microroughnesses before and after the test-run, μm.

The efforts of processing depend on the hardness, ductility and metal structure, surface roughness, design of a part and a tool. Small efforts do not provide complete elimination of microroughnesses and large ones cause overstress and surface destruction, part deformation and tool service life reduction.

Test-run efforts (beading) *P* are determined empirically or by the following formula:

during deformation by balls

$$P = \left(\frac{dq}{0{,}54E}\right)^2 q; \tag{2}$$

where *d* – a diameter of a roller or a ball, mm;

q – a maximum specific pressure, MPa (q = (1,8-2,1) σt);

E – a modulus of elasticity of the processed material, MPa.

The line feed of the ball is 0,1-0,3 mm/v, and the roller with a cylindrical land – 0,2-0,6 mm/rev.

The surface roughness depends on the number of tool's passes and improves with its increase.

Test-run (development) allows to improve the roughness significantly (from R_a= 2,5-0,63 μm to R_a = 0,32-0,08 μm) at a single run and increase the degree of a cold-hardening up to 50%, and depth – within 2-3 mm.

Burnishing (Fig. 2, *c*) is one of SPD ways to strengthen and increase physical and mechanical properties of bushing holes (hydraulic pumps, turbocompressors, connecting rods, pins, etc.), caps, cups.

The essence of the process is in extension of a ball or mandrel relatively to the surface of the hole with a negative allowance, resulting in metal plastic deformation, which leads to changes in the shape and sizes of a hole and strengthening of the surface layer. A negative allowance is the main technological parameter of burnishing.

$$i = d_i - D_o, \tag{3}$$

where d_i, D_o – diameters of a hole and a tool before burnishing and a relative negative allowance i/D_o, efforts and the burnishing speed, geometric characteristics of the mandrel and the bushing thickness.

By intended use the surface burnishing can be smoothing, calibrating and strengthening.

There are two types of hole burnishing: with a small negative allowance and a big one. While burnishing with a small negative allowance is carried out, the plastic deformation area extends to a slight depth. In this case, the surface roughness and the defect of form reduce by 25-35%. While burnishing with a big negative allowance is applied, the plastic deformation area covers the entire part, resulting in increasing the hole diameters and the outer surface and simultaneously reducing the part size along the axis of the processed hole.

Holes for burnishing are preprocessed by fine boring and deployment at 8-10 accuracy quality classes with the roughness of R_a = 2,5-1,25 μm.

While burnishing is carried, we use oil (for high-strength steels) or refined glycerol (cast iron parts).

Burnishing provides a high quality of processed surfaces, (D_o = 1,25-0,1 μm), increases durability of parts in the conditions of alternating loads.

Mandrels (single and multiunit, continuous and complex) or balls are tools for burnishing. Complex mandrels are made of hard alloy BK8 or BK15M, continuous, of steels ХВГ, ШХ15, 9ХС with the hardness of NRC 62-64. Burnishing is carried out on presses, horizontal and vertical broaching machines.

Impact centrifugal surfacing (Fig. 2, *d*) is carried out by the kinetic energy of steel balls located at the periphery of the disk rotation. While the disk is rotating, the balls are thrown to the periphery of the rim under the centrifugal force, interact with the processed surface and are thrown into the center of the jack. The surface processing by the impact centrifugal tools are easily carried out on turning, grinder, planer and other machines. Impact centrifugal tools are used during dimensional-finishing as well as strengthening processing. The tool circular velocity, the part circular velocity, the allowance value, the line feed, the number of passes, the number of deform elements in the tool, the diameter of a ball or a roller have a big impact on the roughness of the processing surface and physical and mechanical properties of the cold-hardened layer.

The circular velocity is the most important factor influencing the roughness, the degree and the depth of the cold-hardening and the residual stresses. Usually the circular velocity is taken within 12-25 m/s, while hardened and hard steel processing is carried out with a higher circular velocity than soft steel and nonferrous metal processing. The circular velocity of parts is taken within 0.5-1.5 m/s, and to obtain a surface with small roughness, a lower circular velocity should be set. The qualitative characteristics of the processed surface depend on the negative allowance, with its increase the impact force on the product increases. For different processing conditions the negative allowance can vary within 0,05-0,3 mm. The line feed on the part turn is taken within 0,02-0,2 mm/rev.

Chasing (Fig. 2, *e*) is carried out by an impact action on the processed surface by special firing-pins. In conditions of repair production, it is used to strengthen hollow chamfers of crankshafts, slot cavities, large-size parts and to improve physical and mechanical properties of welding seams and deposited metals. Chasing comparing to rolling and centrifugal processing provides a greater depth (up to 3-4 mm) and a high level of strengthening. After chasing the roughness of the processed surface increases that requires additional grinding.

Chasing is performed using spherical, elliptic, or firing-pins of special shapes of high-strength tool steel or superhard material which perform back-and-forth motion. The frequency of impacts is within 10-50 Hts.

The diameter of the firing-pin working surface D (the diameter of the depressed sphere) is chosen according to the set strengthening depth:

$$h / h_1 \le D \le 2{,}2h \, , \qquad (4)$$

where h_1 – a depth of cup (hole).

The deformation level is taken into consideration: ε = d / D, where d –a diameter of cup. It is necessary that $0{,}7 \ge \varepsilon \ge 0{,}3$.

Besides devices where a spring-loaded firing pin is moved by the cam mechanism while impact chasing, we use vibratory eccentric gaskets as well as multiple-head pneumatic tools.

Multiple-head tool processing provides the depth of the cold-hardened layer to 3mm and increases the fatigue resistance of the welding joint at 80%, and the strength of the welding joint after processing is determined by the metal strength.

Vibration knurling (vibration smoothing) (Fig.2, *f*) of surfaces promotes reducing duration of the coupled surface running-in, the heat transfer efficiency, reducing labor-consumption of manufacturing parts of high accuracy etc.

The essence of vibation knurling is as follows: besides the axial advance S (as during rolling or smoothing), the tool (a ball with a diameter $d_к$), pressed to the processing surface with the force P, is given back-and-forth (oscillating) motion with the frequency f, which is equal to the rotation frequency of the electric motor shaft, and the amplitude l along the part axis rotating at the frequency n. In case a diamond smoother with the radius $R_в$ is used, the process is called vibration smoothing because it takes place in the conditions of sliding friction.

While test-running and smoothing, the tool squeezes a groove on the surface (while vibration knurling – a sinusoidal one).

The microrelief, obtained during vibration knurling, is divided into four types by the nature and density of sinusoidal channels. The variation of shapes, sizes and placement of microroughnesses on part surfaces is reached by the change of processing mode parameters.

The system of vibration smoothing channels (grooves) forms oil pockets, where the lubricant remains and evenly spreads over the surface, what significantly improves friction conditions.

The lubricant remained in the uniform labyrinth of grooves creates an oil wedge. In this case, deposited abrasive particles and wear products are carried out of the friction area under the pressure of fluid in grooves.

During dry friction grooves act as traps, delaying wear products, dust and abrasive particles, because of that their abrasive effect is localized and all physical and mechanical properties of the surface layer significantly improved.

Parts of ferrous and nonferrous metals and alloys with the hardness to NRC 65 are subjected to vibration knurling (vibration smoothing).

Processing efforts vary within 50-200 N what allows to process small-stiff parts. The microhardness of the finished surface is 25-30% higher than the outer one. Residual stresses after vibration knurling are 1,3-1,7 times higher than while rolling without vibration under the same modes. Part strengthening by vibration knurling 1,6-2,2 times reduces the friction coefficient and twice or more increases the wear resistance.

Hardened steel balls and spherical nozzles (smoothers) of natural and synthetic diamonds, hard alloys are used during vibration knurling. The choice of the material depends on the hardness of the processed surface and its characteristic properties.

For vibration knurling we use vibrators which have a drive to create back-and-forth motion of the tool from a separate electric motor. Rotational motion of the electric motor is converted into back-and-forth motion of the bar using eccentrics placed on the electric motor shaft. There is a ball on one end of the bar; it is attached by a collet hub and a nut. The second end of the bar is joined by a pin with a hub which moves along with the bar. The power torque spring with a scale is set on the hub in the frame. The device is installed with an angle bar on the cutter-holder of the support of the screw-cutting lathe.

Diamond smoothing (Fig. 2, *g*) is widely used to increase operation properties of outer and inner surfaces of machine parts as the finish operation during restoration.

Its essence lies in surface plastic deformation of parts with a sliding tool on the surface. Its working element is a diamond or superhard materials of boron nitride (geksanit P, kubonit borazon materials etc.) with high hardness, a low coefficient of friction on metals and low roughness (Ra = 0,02-0,04 mkm). Due to a small radius of the tool working part (R_{alm} = 0,5-3,5 mm) and relatively small efforts of smoothing (150-300 N) we can process parts of low hardness made of soft hardened to NRS 60-65 steels and alloys as the result of high pressure on the contact area.

The diamond radius is chosen taking into consideration the hardness of the processed surface. For materials with the hardness HB < 300 it is 2,5-3,5 mm, with NRC 35-60 – 1-2,5 mm and NRC 50-65 – 1-2 mm.

To process nonhardening steels, nonferrous metals and alloys the initial roughness has to be Ra < 2,5 µm. It is rationally to make smooth hardened steels at the initial roughness of Ra = 0,32-1,25 µm.

A universal burnisher consists of a mandrel and a diamond. It is put in a special device installed in the tool carrier of the plant. Smoothing is carried out in the conditions of sliding friction which distinguishes this process from rolling. The characteristics of the smoothing mode are approximately the same as of rolling.

Optimal efforts $P_{опт}$ are taken the same when the lowest surface roughness is achieved.

The line feed for hardened steels is 0,02-0,05 mm/v (R_{alm} = 1-2 mm), nonhardening steels and nonferrous alloys – 0,03-0,07 mm/v (R_{alm} = 2,5-3,5 mm). The smoothing speed (20-120 m/min) has almost no impact on the surface quality.

Basic metal deformation takes place after the first tool pass. With the increase of a pass number, the surface roughness isn't changed considerably.

While smoothing, industrial oil I-20A is used as MOP for black metals, kerosene – for nonferrous metals and alloys.

Diamond smoothing allows to get a part surface with the roughness not lower than Ra = 0,04-0,08 μm, increase the strength at 25-30%, the wear resistance at 40-60% and the fatigue strength at 30-60%.

Thermomechanical processing of metals

Thermomechanical processing of metals (TPM) – a set of plastic deformation operations, heating and cooling resulting in formation of the final structure of the alloy, and hence its properties; it takes place in the conditions of the increased number of crystal imperfections created by plastic deformation. TPM relates to strengthening technologies.

There are high temperature (HTMP) and low temperature (LTMP) thermomechanical processing.

HTMP of steel consists of hot working under pressure within austenite temperature stability. LTMP consists of deformation within austenite temperature instability (lower than critical points of change) (Fig. 3). During further hardening martensite of special structure is received from this austenite; it provides a very high strength limit (up to 3000 MPa).

Worn-part reclamation technologies using TPM were developed in the Department of Repair Technological Systems at Kharkiv Petro Vasylenko National Technical University of Agriculture: in the first variant surfacing is used in the carbon dioxide medium, combined with LTMP, and in the second one – surfacing and LTMP are fulfilled with the following turning and vibration smoothing.

Part heating for TPM is provided by the heat released while surfacing necessary to build up the worn surface layer.

During HTMP the deposited metal is processed by two deforming rollers (Fig. 4, a); immediately after applying the metal layer on the surface at t = 900-950°C and the pressure of P_1 = 1000-5000 H followed by natural cooling. During LTMP (Fig. 4, b) the deposited metal is initially deformed at the temperature of HTMP, and then deformed again within 350-700°C at P2 = 5000-15000 H with cooling using a sprayer.

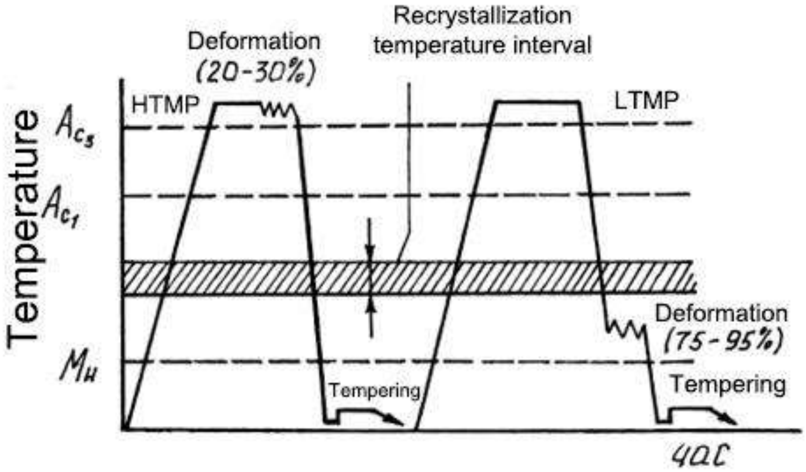
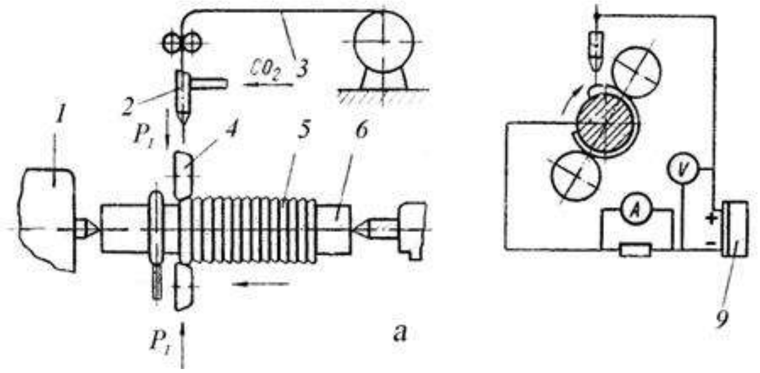


Fig. 3 – Control charts of thermomechanical steel processing



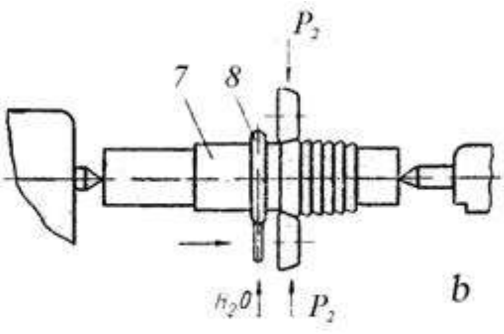


Fig. 4 – Scheme of HTMP (a) during part surfacing and LTMP (b) after its termination:

1 – plant; 2 – overlaying head; 3 – welding wire; 4 – deforming roller; 5 – deposited metal after HTMP; 6 – part; 7 – deposited metal after LTMP; 8 – sprayer; 9 – current source.

TPM tightens and smoothes the deposited surface, thus promotes the elimination of such metallurgical defects as pores, cracks, discontinuity flaws; reduces the allowance for mechanical processing and its labor-consumption; provides surface roughness of Ra = 1,25-0,32 μm; increases the hardness and resource of the restored part more than 30%.

Electromechanical processing

Electromechanical processing (EMP) represents a kind of high temperature mechanical processing when the local surface is heated in the contact area of a tool and part powered by the electric current. The EMP method is applied for strengthening as well as for restoration of dimensionally precise characteristics of parts with small wear (0,4 mm). EMP is used to restore the outer surface of movable and immovable joints.

The essence of the process is as follows: the contact point of two current conductive surfaces (part – working tool) releases heat, under action of which the part surface is heated and at the same time subjected to the tool pressure, it is deformed and cooled due to heat rejection into the cold part.

As the volume of high-temperature heating is very small comparing to the part mass then cooling of the heated metal (due to heat rejection into a part) takes place at a high speed, causing hardening in the local volume.

Restoration of mounting surfaces of worn parts consists of two operations: metal deposition and smoothing to a certain size; a lamellar tool is used here.

Fig. 5 represents a schematic diagram of the plant for EMP. Current 350-1300 A and voltage of 2-6 V are fed in the contact area (part – tool). Passing through a small contact area the current of great power and low voltage instantly heats the metal up to 800-900 C in the contact area. The part metal deposits or smoothes under the tool pressure depending on its cross-section.

Material release takes place when the tool is immersed into the part surface. The part diameter D_2 increases to D_1, and the surface takes the form of thread. Replacing the upsetting plate by the smoothing one we receive the necessary diameter D_0, which does not require further processing by cutting.

The diameters of mating parts are measured before processing, and then the actual joint gap is set. The diameter can be increased no more than 0,4mm for parts which were not hardened and 0,2 mm – for hardened ones. Release is carried out at a few passages only by means of the lead screw. Otherwise cross-section cutting can take place. Efforts to release nonhardening steel are 700-800 H, hardened steel – 900-1200 H.

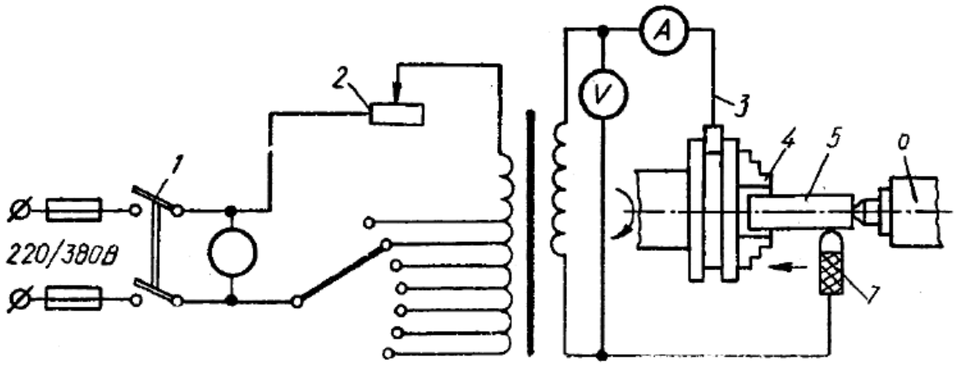


Fig. 5 – Schematic diagram of the plant for electromechanical processing: 1 – knife switch; 2 – rheostat; 3 – secondary winding wire; 4 – pulling head; 5 – part; 6 – tail block; 7 – processing tool

The hardness of the strengthened layer after EMP increases 1,5-2,5 times. Hard alloys BK and TK, P18 can be used as the material for a working tool.

Screw-cutting lathes and horizontal milling machines are used for EMO. A step-down transformer with the capacity of 25 kVA is a source of the alternating current.

Strengthening of part surfaces by thermal and chemicothermal processing

Thermal and chemicothermal processing refers to the operations which provide the set physical and mechanical properties of materials and parts.

There are low (without phase recrystallizations) and high temperature (with phase recrystallization) modes of thermal and chemicothermal processing.

A large number of machine parts produced in machine-building plants are subjected to high-temperature thermal processing to provide necessary properties: strength, ductility, toughness, hardness, wear resistance.

In terms of repair production using high-temperature methods of thermal and chemicothermal processing is limited and possible only in the conditions of specialized repair production. In this case, to improve ductility and strength it is used improvement, normalization and hardening with heating above Ac_3 and tempering (500-650°C), and to increase the hardness of the working surface – microwave hardening. In some cases, chemicothermal processing is used to strengthen the working surface and anticorrosion resistance: cementation (carbon saturation at 920-950°C) in the solid carburizing material; nitriding (nitrogen saturation, heating in ammonia or liquid mediums at 500-571°C); cyanidation in molten layers NaCN (20-25%), NaCl (25-50%), Na_2CO_3 (25-50%) at 820-860°C; carbonitriding in the gas medium (carbonaceous gas and ammonia at 850-860°C).

A strengthened layer with the depth of no less than 2-4 mm and hardness to 50-60HRC depending on the strengthening material are provided during all types of surface hardening.

Chemicothermal processing within heating parameters allows to obtain a diffusion layer from 0,5 to 2,0 mm with the hardness of 52-62 HRC.

The most common heat treatment is annealing of I and II type.

Depending on the initial state of steel or alloy, annealing of I type includes the processes of homogenization (obtaining the uniform structure), recrystallization and removal of residual stresses. Depending on the purpose, it is carried out at temperatures above or below phase recrystallization. This type of processing eliminates chemical or physical inhomogeneity created by preprocessing (surfacing, baking and other types).

Diffusion homogenizing annealing is carried out at 1100-1200°C. In this case, balancing processes of chemical composition and properties are carried out the most fully. But this processing promotes the increase of the grain size and reduction of the strength and ductility level. Thus, normalization or improvement has to be carried out after homogenizing annealing.

Annealing is used for parts after processing of which (surfacing, mechanical processing, casting, etc.) residual stresses appear. The annealing temperature is within 200-700°C depending on the material and the level of stresses. The dwell time is 1-3 hours. Slow cooling to 300°C is carried out after soaking.

Annealing of II type is carried out at 30-50°C, higher than Ac_3 or Ac_1 to get a balanced structure of the metal. Annealing of I and II type provide strengthening of the working surface of renewable parts due to stabilization of the structure, its uniformity, removal of stresses. All of that reduce crumbling and cracking.

Special thermal furnaces are used for thermal and chemicothermal processing, in some cases with controlled atmosphere and adjusting temperature parameters of heating and cooling as well as hardening baths.

The main controlled quality parameters are physical and mechanical properties, a metal structure, a depth of the hardened layer and its phase composition.

Mechanical processing of parts

Mechanical processing is one of main operations of dimensionally precise characteristics of parts while being restored. It is widely used as preparatory and final processing. Besides that, parts are restored to their repair sizes when mechanical processing is carried out.

During mechanical processing it is important to provide necessary precision and roughness of the surface, which are reached by the right choice of the processing type, fits and technological bases and forming the minimum admissible allowance at any kind of building-up. Minimum allowances for mechanical processing while manual surfacing are 2-3 mm, after surfacing under the flux layer are 1-2 mm, for gas-thermal spraying are 0,3-0,4 mm.

There are all kinds of mechanical processing (turning, milling operation, thread cutting, honing, burnishing, lapping, polishing, etc.) at overhaul plants. They are used in machine-building plants. However, preprocessing of worn and spliced part surfaces has its peculiarities which considerably make mechanical processing more complicated when they are restored comparing to processing when a new part is manufactured.

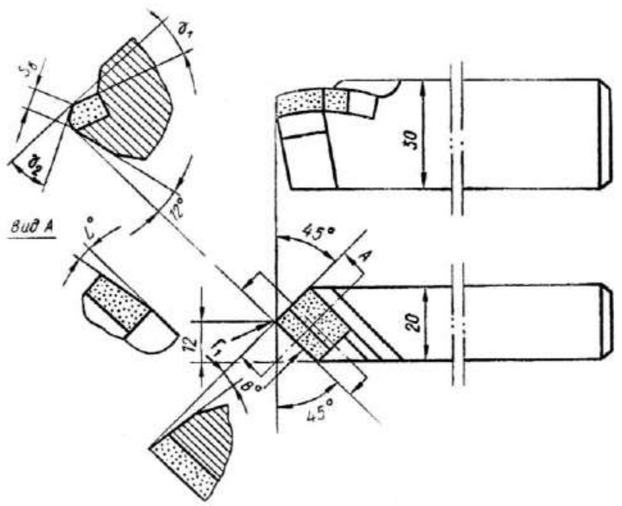


Fig. 6 – Geometry of cutting part of cutter while turning of deposited metals

Dimensionally precise characteristics of parts which were repaired by different types of surfacing are restored by turning. The cutting tool part is made of hard alloys T5K10 and T15K6 with the hardness HRC of the surfaced layer less than 40 and BK8, BK6 at HRC over 40.

For hardened steels we use cutters with a negative front angle γ_2 = -10 ... -15° (Fig. 6). Processing is carried out using coolants (5-8% emulsion, 0,2% technical soda ash, the rest – water). Cutters of superhard materials (synthetic diamond of balas type, el'bor borazon material-P, geksanit borazon material-P, etc.) are widely used while restored surfaces are turned.

Cutters of synthetic diamonds of balas type (DSB) ensure stability of linear part sizes, necessary surface roughness, high-productive cutting. Resistance of DSB cutters during turning is 2-3 times higher comparing to the cutters of hard alloys.

Elbor-P (cubic boron nitride) has high thermal stability and chemical inertness to iron. This all allows using it widely for hard processing steels and alloys, especially in the hardened condition.

Geksanit-R (one of boron nitride types) – polycrystalline material received at high pulsed pressures is effectively used for cold processing of surfaced and hardened steels, cast irons, hard alloys.

Leucosapphire is a ruby-like, synthetic single crystal Al_2O_3 as α-modification, but in contrast to it almost without additives. It is used to manufacture of cutters, grinding wheels and pastes.

For turning materials surfaced by electric-contact welding we use cutters of leucosapphire on the mode: turning speed υ = 50 m/min, feed S = 0,05 mm/rev, cutting depth t = 0,1 mm.

While turning of electrolytic iron depositions in the cutting zone, a high temperature (1000-1050°C) is created. It promotes intensive wear of a cutting tool. While turning of soft depositions, the temperature is 1,2-1,7 times higher than while turning hard coatings. The best results are shown by cutters from hard alloy T30K4. During turning of electrolytic iron depositions, it is used the following mode: cutting speed υ = 56 m/min, feed S = 0,12 mm/rev, cutting depth t = 0,2 mm, front cutter angle γ = 0°, rear angle – α = 10°; major cutting edge angle φ = 60°, side-cutting edge angle φ_1 = 30°.

Grinding is used to restore dimensionally precise characteristics of parts surfaced with hard powder materials or electrolytic coatings. Grinding is also used as the finishing operation after turning and to restore a crankshaft to repair sizes.

The processing by grinding of surfaces restored by surfacing or wear resistant powder spraying is considered to be very complicated. Grinding with abrasive (including diamond) tools, as well as through electrophysical and electrochemical methods of processing are most effective for their processing.

The highest results of powder surfacing processing such as – sormite УС-25, ФБХ-6-2, ПГХНСПЗ) are achieved during dry grinding.

It is rationally to fulfill preprocessing of sormite with a grinding wheel of chrome fused corundum 34A40CM16K and processing of УС-25, ФБХ-6-2 with a grinding wheel of silicon carbide 64C25CM16K.

The main modes of rough grinding are as follows: circular velocity Vc = 35 m/s part circular velocity υd = 11 m/min, the rate of metal removal Qm (for sormite is 7 sm^3/min for УС25 – 4, for ФБХ -6-2 - 4, 5, for ПГХН80СРЗ – 3 sm^3/min).

Finishing grinding is recommended to carry out at the minute feed $S_{tм}$ which does not exceed 0,15mm / min.

To restore parts built up by electrolytic coatings it is used wheels from synthetic diamonds of АСП25К6-50 brand with diamond concentration of 50% in a wheel.

Optimal grinding modes of electrolytic coatings with wheels of synthetic diamonds are as follows: circular velocity of the wheel υk = 30 m/s, circular velocity of renewable parts – υd = 20-25 m/min, line feed S = 1-1,5 mm/v, grinding depth t = 0,01-0,02 mm/move.

During grinding it is used the lubricating-cooling liquid – 3-5% emulsol solution in soda water.

Accuracy of 6-8 quality classes and surface roughness of Ra = 0,5-0,2 μm is obtained by grinding.

Honing is used for final polishing of inner surfaces to improve roughness characteristics such as processing of cylinder barrels, lower heads of connecting rods etc.

Preliminary honing is carried out by bars of silicon carbide or fused corundum with the gritness of 16-12 μm, finishing honing is carried out with bars with the gritness of 4-3 μm. The honing sleeve circular velocity is 8-20m / min under the specific pressure of 0,6-1,4 MPa.

Diamond bars AC15250/200-M1-100 with the hundred-percent concentration of diamond in the bar are also used for preliminary honing, for finishing honing – ACM28/20-M1-100. The lubricating-cooling liquid is the mix of kerosene with up to 40% of machine oil is used during honing in overhault plants. But it is flammable and toxic, thus oily liquid OCM-I (the flash point is no less than 94°C) is recommended to use for it. The surface roughness after honing is Ka = 0,16-0,025 μm, processing accuracy is of 5-7 quality classes.

Diamond tape polishing is used to get a high quality roughness of surfaces of cylindrical, eccentric and curved parts. It is carried out at turning or circular grinding machines. For example, it is polished bearings and hollow chamfers of crankshafts.

The device for part polishing with the endless diamond tape such as bodies of rotation is fitted on the longitudinal support of the machine through the plate 11 (Fig. 7)

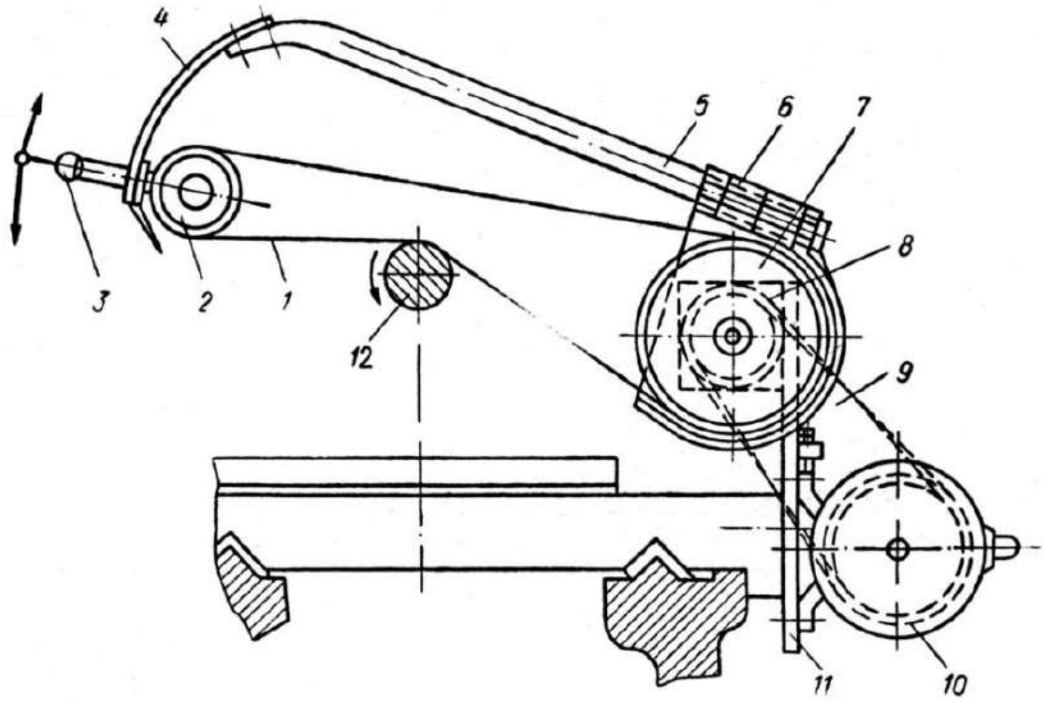


Fig. 7 – Scheme of device for part polishing with endless tape:
1 – endless tape; 2 – roller; 3 – handle; 4 – elastic plate; 5 – rod;
6 – bracket; 7 – pulley; 8 – vibrator; 9 – V-belt transmission;
10 – electric motor; 11 – plate; 12 – part

The tape with the length of 1500-2200 mm and the width of 60 mm is used for part processing. It is used a diamond tape of ACO 100%-P9 type with the gritness of 80/63-40/23 μm. The speed of tape movement is 35 m/s, transverse oscillating motion with the amplitude of 2-6 mm and the frequency of 300-900 oscillations per minute under rotational motion of the part and the line feed of the tape from the machine.

While processing, the surface roughness Ra of 0,32-0,05 μm and the processing precision of 5-7 quality classes are received.

Paste lapping allows to obtain the surface roughness within Ra 0,08-0,025 μm and accuracy within 1-3 μm. It is used as the finishing operation to get tightness of valves, pump elements, fitting one part to another.

Application of soldering when parts are repaired

Soldering is the process of obtaining permanent connection of parts or pieces of destroyed parts by entering the molten intermediate metal or alloy – solder (after cooling it forms a strong bond) – in the clearance between them.

The melting temperature of the solder has to be lower than the melting temperature of the part material.

While soldering, parts are heated to the temperature close to the melting temperature of the solder, and then the solder is melted and the clearance is filled with it. Metal diffusion takes place in the brazed seam – liquid solder atoms interact with the atoms of the solid base material. Depending on the chemical activity of the solder relatively to the part material, intermetallic bonds can be formed on their boundaries or liquid and solid solutions. The ratio of melting temperatures of the solder and part material, duration of the soldering process, a way of part heating, etc influence the processes mentioned above.

Solders are conventionally divided into two groups depending on the purpose and working conditions: soft and hard. Soft solders have the melting temperature of 400°C and low mechanical strength. Solid solders have the melting temperature of more than 550°C and allow obtaining the joint similar in strength to the part material.

Soft solders are the alloys on the base of tin, lead, antimony, bismuth, cadmium, etc.

Solid solders have a relatively high melting temperature and are used to produce a durable layer. They can operate at high temperatures. Solders of the second group include copper, silver, nickel and alloys on their base.

While soldering, we use fluxes which are designed to protect the surfaces of the base metal and the solder from oxidation, dissolution and removal of the oxide film, improve wetting conditions of the part surface by the solder. The melting temperature of the flux has to be lower than the melting temperature of the solder.

Fluxes can be aqueous solutions of zinc chloride ($ZnCl_2$) and ammonium chloride (NH_4Cl) while soft-soldering. Colophony is used to solder copper, for example wires.

While hard-soldering, we use borax and the borax mixture with boric acid and boric anhydride as fluxes. For aluminum soldering it is used F5, F134 fluxes etc.

The surfaces of fittings are thoroughly cleaned from dirt, oxides and grease films by mechanical or chemical means (etching in the solution of sulfuric acid) before soldering.

Soft-soldering is carried out by manual soldering irons. Surfaces are wetted by flux, and then a thin layer of solder is uniformly applied with a soldering iron.

While hard-soldering, parts are heated by the flame of the gas burner or it is used muffle furnaces, hearths or other heat sources, heated to the melting temperature of the part surface solder is sprinkled by the flux. Then the clearance between the parts is filled with the solder.

Electric erosion machining

The electric erosion method of part processing relates to the group of electrophysical processes and consists in electrical erosion during a spark discharge. When a spark passes between electrodes, the flow of electrons moving with a high speed instantly heats a part of the anode surface to 10 000-15 000°C, metal melts and even transfers into the gaseous state, resulting in an explosion (Fig. 8). Particles of the separated molten anode metal are ejected into the interelectrode space and depending on its environment (gaseous or liquid) reach the cathode and deposit on it or dissipate. The part is the anode. The tool is provided with oscillating motion of the vibrator to lock and unlock the chain and to get a spark discharge. The choice and fit of the necessary mode is achieved using variable resistance and constant or changeable capacity of adjustable capacitors but there are plants without capacitors.

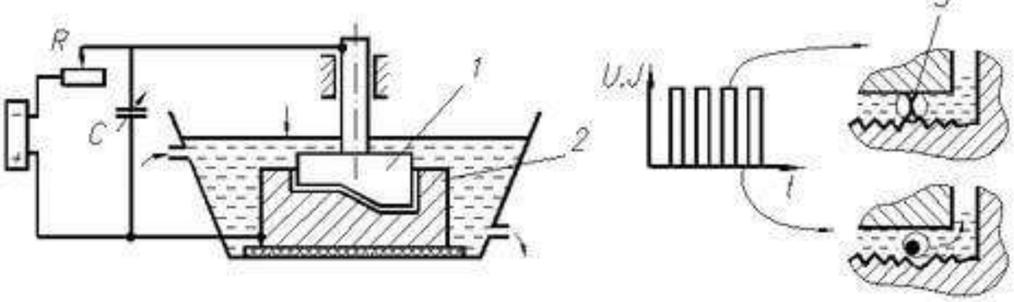


Fig. 8 – Scheme of plant for electric erosion machining: 1 – tool; 2 – part; 3 – pass of spark

Electric erosion machining modes are divided into three groups: rough – the current is more than 10 A (maximum productivity but high surface roughness – R_Z 160-320 μm); middle – the current is from 1 to 10 A (roughness R_Z 40-160 μm); finishing – the current is less than 1 A (roughness R_a to 0,16 μm but low productivity).

Electric erosion machining is used for rough cut of parts after hard alloy surfacing; removal of broken drills, taps, stud pins, studs; cutting of grooves and internal push broaching of any shape in the metal of any hardness.

They produce a tool made of copper and its alloys of the necessary cross-section form, and it is connected to the cathode to make cutting of grooves and internal push broaching. It is better to carry out the process in the liquid medium (gas, mineral oil and other liquids which do not carry the current) to eliminate building-up of a tool (cathode).

Anode-mechanical machining

The anode-mechanical method is used to process hardened, made of hard alloys and restored by surfacing parts which have a significant surface hardness, thus it is difficult or even impossible to process them by cutting.

In the action zone of the processing tool is injected an electrolyte jet consisting of the aqueous solution of liquid glass (with the density of 1,36-1,38 h/cm^3) or another liquid containing silicic acid compounds. The solution is subjected to electrolysis, while the direct current is passing and it is created the dense film of silicic acid compounds on the anode. This film is removed by the mechanical action of the cathode (cast iron, steel, copper disk or abrasive wheel).

Fig. 9 represents a diagram of anode-mechanical machining for cutting of work materials, grinding and clean finishing of part, modes: Free running voltage – 6-24 V; working stroke voltage – 5-28 V; current density – 0,005-5,0 A/mm^2.

In case we use the current of low density, the electrochemical effect appears and microscopic asperities dissolve on the part surface. A film on the anode surface is formed due to sodium silicate dissociation. Consecutive peeling of the film by the cathode and dissolution of microasperities on the anode lead to gradual surface smoothing.

To obtain a high surface purity, the cathode does not carry out the functions of the tool; it is only a negative conductive electrode. The film is removed by a fine-grained abrasive bar or a wheel.

While surface finishing of parts is applied, working fluids are aqueous solutions of phosphate (NaH_2PO_4), nitrate ($NaNO_3$), chloride

(NaCl), and sulfur (NaS) sodium. To get these solutions, correspondently 31, 16, 11 and 16 grams of these salts are dissolved in 1 liter of water.

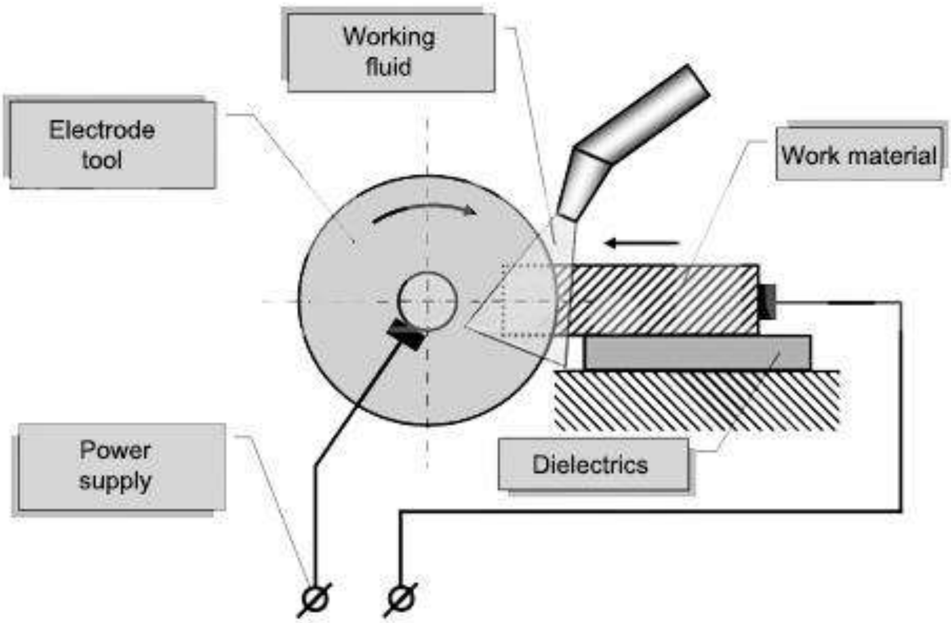


Fig. 9 – Scheme of anode-mechanical machining

Worn-part reclamation by laser

The use of laser technology for worn-part reclamation can provide metal building-up, welding of defects with the depth to 0,5 mm, thermal processing, internal push broaching, welding.

It is effective for local surfacing of the area 50-100mm^2 with the layer thickness of 0,8-1,2mm, thermostrengthening of critical parts of flat part surfaces as well as cylindrical and geometrically-complex ones with the radius of curvature no more than 25mm. The heat affected zone depends on the mass of parts and must not exceed 0,4 mm while laser surfacing is applied.

The essence of laser technology is the following: the laser beam creates light powers of very high density – about 10^{9}Vt / cm^2 and more. Meanwhile, the size and position of the light beam are easily regulated using reflectors and focusing lenses.

The diameter of the focused beam can vary from 0,01 to 10 mm, also it can move along the programmed trajectories of any complexity. The basic parameter of laser technologies is power density (P). If P <10^{5}Vt / cm^2, it is used for heat processing; 10^5 <P <I0^7 – for welding and surfacing; P> 10^8 W / cm^2 – for cutting and internal push broaching.

To strengthen and build-up worn cylindrical surfaces it is mainly used the scheme shown in Fig. 10. Processing of the cylindrical surface with a greater length than the diameter of the beam is carried out by rolling spiraling and a flat one – as a zigzag.

Laser surfacing can be carried out in two ways: by the way of powder feeding through a dispenser into the beam zone and application of the powder of necessary composition on the part in the form of coating (glue-binding compound – water solution osietylcellulose – OEC or carboxymethylcellulose – CMC at the rate of 8-20 g/l at t = 75°C). Powder consumption at the first method is 5-6 times higher and the level of physical and mechanical properties of the coating is lower than at the second method of layer building-up.

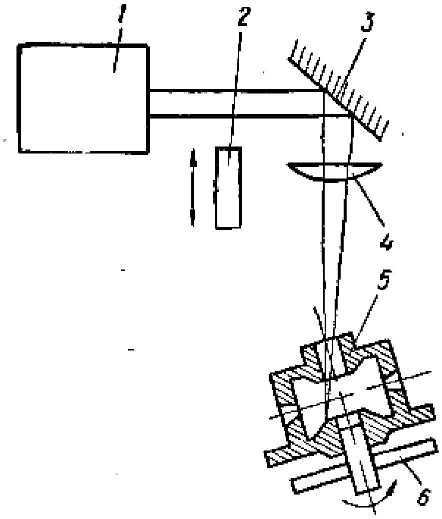


Fig. 10 – Scheme of laser plant to strengthen cylindrical surfaces:

1 – laser;
2 – power measuring instrument;
3 – reflectors;
4 – focusing lens;
5 – part;
6 – rotation device

Lasers are divided into solid-state and gas – CO_2. Solid-state lasers are used during auxiliary operations, as well as during processing of small-sized parts. Active mediums are solid bodies: rubies, special glass, yttrium aluminum garnet etc. Their energy efficiency does not exceed 3%. The continuous action efficiency is 5-10% in gas lasers.

The optical system of beam formation and transmission into laser plants includes reflectors and lenses.

The basic criteria of quality are the strengthening depth, its uniformity, the strength of transition zone during building-up, the microhardness level and distribution along the working layer cross-section. The maximum depth of the hardened layer is reached when the temperature on the part surface corresponds to the melting temperature. It is provided by the intensity of the heat source, rotation speed and part movement while being processed.

The hardness and depth of the hardened area increase with the increase of carbon concentration. Increased concentration of carbide-forming alloying elements (Cr, W, V, Mo) leads to the hardness increase of the strengthened zone and austenite-forming elements (Mi, Mn, Cu) – to its decrease. Thermal strengthening (hardening) of steel parts with carbon content from 0,006 to 0,78% provides the depth of the hardened layer without surface fusion to 0,5-0,6 mm, and of high-strength cast iron – up to 1 mm.

When parts are restored by laser surfacing, the working layer hardness is 60-63 HRC and the adhesion strength with the base metal is 250 MPa.

Restoration by setting additional repair parts

Restoration of the working surface worn layer and its dimensionally precise characteristics is often carried out by setting additional repair parts (ARP) produced as solid bushes, rings, barrels as well as composite bushings.

Setting solid bushes and rings is applied for parts where the mounting surfaces are worn.

The process flow of component overhaul using ARP consists of three main parts:

- mechanical processing of the worn mounting surface for an additional part;
- pressing-in or press fit of the bushing on the mounting surface;
- mechanical processing of bushings to the normal size (the size set in the working draft to produce a part).

The ARP material has to correspond to the renewable part material. Bushings are made of steel only for cast iron parts. ARP immobility of the basic part is provided by the guaranteed negative allowance in this assembly or by the use of glue, pins, welding. Combinations of these methods are possible.

To fit a bushing without a guaranteed negative allowance, mechanical processing of the mounting (working) surface to its normal size is carried out, while it is manufactured. Otherwise, while a bushing is produced, it is anticipated an allowance to process the working surface to its normal size after pressing-in.

Fit reliability with a guaranteed negative allowance depends on the basic part material; material, diameter and thickness of the bushing;

the height of microasperities of the matching surface as well as the pressing-in method. Bushings are produced with the thickness of 2-5 mm.

The real negative allowance in the fixed joint with the set fit is different from the tabular and determined by calculations according to the following dependence:

$$\delta_{\text{p}} = \delta_{\text{T}} - 1{,}2(R_{z_1} - R_{z_2}), \tag{5}$$

where δt – a tabular negative allowance, μm;

R_{z_1} i R_{z_2}, – an asperity height of the matching surface, μm.

It is recommend to use the disulfide molybdenum lubricant or machine oil for surface lubricating while a bushing is pressed in without heating. It facilitates pressing-in and protects surfaces from scoring.

To facilitate pressing-in of bushings and increase the joint strength, the basic part if its design allows it, is rationally to preheat (or to cool ARP) as at this the medium negative allowance doubles because asperities of the matching surfaces practically are not smooth out and the fit strength increases threefold.

Lecture № 10
Principles of technological processes unification

Classification of agricultural machinery parts

Low series manufacture is typical for overhaul plants, i.e. having a large assortment of parts subjected to restoration (there are several thousand names), a number of parts of one name can be only a few hundreds a year. But many agricultural machinery parts have similar geometric shape, constructs, defects, material etc. Thus, you can choose a number of parts similar in constructively technological characteristics for which you can use the same restoration optimal technology (unified technology). Technological unification is carried out in two directions: typification of technological processes and the batch method.

Typification of technological processes consists in developing repair (restoration) processes of part groups with common structural and technological features.

The batch method, thoroughly developed by professor S. P. Mitrofanov is a further development of the ideas of typification of technological processes. In terms of individual and small-scale industries typical for repair production, there is widely used the batch method. It consists in developing repair (restoration) processes of part groups with different structural but common technological features.

For the further study of the typical worn-part reclamation technology, it is used the classification developed at the Department of Repair Technological Systems at Kharkiv Petro Vasylenko National Technical University of Agriculture (Tab. 1).

The classification is based on the following constructively technological features: geometric part forms; structural characteristics of renewable elements; types and frequency of defects; dimensional and weight characteristics; sizes of renewable constructs, characteristics and values of wears; part materials and durability requirements; accuracy characteristics.

Taking into consideration the given features, all agricultural machinery parts can be divided into 12 classes, and each class can be divided into several subclasses. The value and limits of measurement of dimensionally precise characteristics of parts of tractors, combines, cars and agricultural machinery relatively to the biggest subclasses are given in Tab. 2.

Table 1 – Classification of agricultural machinery parts

Class	Subclass	Main technological tasks of restoration
01. Round bars	01.1. Smooth and stepped shafts	Restoration of external rotation elements, mainly cylindrical
	01.2. Spline hafts	Restoration of the spline part and cylindrical surfaces of rotation, necessity of heat treatment
	01.3. Crankshafts	Restoration of eccentrically placed surfaces
	01.4. Distribution shafts	Restoration of the required cam profile
02. Hollow cylinders	02.1. Cartridges, hubs, bushings	Restoration of external, inner and butt-end surfaces of rotation
	02.2. Cylinder sleeves	Restoration of inner and external cylindrical surfaces
03. Disks	03.1. Disks, flywheels, pulleys	Restoration of external, inner and butt-end surfaces which differ in their large diametric sizes; necessity to balance most parts
	03.2. Rolls, guide wheels	The same as 03.1, but big surface wear require special restoration methods (pouring of liquid metal, band fitting, electroslag surfacing etc.)
04. Small parts	04.1. Piston pins	Restoration of external cylindrical surfaces by specific methods (by hydrothermal distribution, hot flattening-out etc.)
	04.2. Rollers of fans and pushers, axles of pinion gears	Restoration of external surfaces with minor wear (mainly by galvanic methods)
05. Gear wheels	05.1. Pinion gears	Restoration of ring gear
	05.2. Sprockets	Restoration of cogs and sprocket cavities
06. Levers	06.1. Connecting rods	Restoration of lower and upper connecting rod heads and big end caps with high accuracy of processing and mutual placement
	06.2. Pull bars, levers	Restoration of holes and butt ends of heads with given precision of their mutual placement
07. Frame parts	07.1. Cylinder blocks	Restoration of cracks in crosspieces between clearances for bush sleeves, surfaces and axis misalignment for bushings
	07.2. Heads of a cylinder block	Restoration of valve pockets, abutment surface to the block
	07.3. Frames	Restoration of cylindrical and flat surfaces with high requirements for precision of their processing and geometrical arrangement, filling of cracks
08. Thin-walled dimensional parts	08.1. Lids, casings, housings	Restoration of flat surfaces, filling of cracks, restoration of smooth and threaded openings
	08.2. Thin-walled part facing	Dents elimination, filling of cracks
09. Flat parts	09.1. Shifter fork	Restoration of flat working surfaces
10. Cross-section parts	10.1. Share lifters, lug supports, colter blades	Restoration of blades and part design geometry
11. Springs, carriage springs	11.1. Springs 11.2. Carriage springs	
12. Custom parts	12.1 Radiators, track links etc.	Parts have specific restoration technology

Table 2 – Quantity value of parts

Subclass	Part weight, kg	Part overall size, mm		External mounting surfaces, mm		Inner mounting surfaces, mm		Diameter of auxiliary holes, mm	Permissible surface wears, mm		Accuracy of renewable surfaces, quality class	Roughness, µm
		width (diameter), mm	length, mm	diameter	length	diameter	length		external	inner		
01-1 smooth shafts	0,17-24	15-220	100-1600	15-140	10-430	–	–	8-50	0,02-0,70	–	7-11	0,25-40
01-2 Spline shafts	1,2-17,3	24-300	200-1590	20-110	10-100	–	–	–	0,02-0,80	–	7-10	0,50-20
02-2 Cartridges, hubs, bushings	0,37-17,5	70-350	30-200	52-240	8-150	35-150	10-100	8,5-25	0,015-0,54	0,015-0,074	7-10	0,25-5,0
03-1 Flywheels, pulleys, disks	0,74-51	100-518	15-162	55-500	–	16-205	10-100	5-30	0,04-0,80	0,03-0,86	7-12	0,25-20
0.6-2 Pull bars, levers	0,1-5	–	50-550	–	–	–	–	8-50	0,12-3,0	0,03-2,15	7-14	0,8-6,3
0.7-2 Frames	8,4-231,6	109-527	340-1614	–	–	50-298	10-150	10-150	–	0,03-0,23	7-10	0,40
09 Flat parts	0,3-2	25-258	80-300	–	–		–	15-22	0,1-2,0	0,072-0,37	8-14	0,8-6,3

The development of the unified technology is carried out in the following order:

- classification of parts which have to be restored, combining parts in groups, pre-selection of typical representatives;
- quantitative evaluation of part groups, determination of the annual restoration program and determination of a unification degree of technological processes (single, common, group);
- analysis of defect recurrence, determination of reasonability of all defect elimination especially those with the low frequency requiring special elimination methods or equipment;
- selection of the most advanced methods of defect elimination

taking into consideration wears which provide minimal allowances for processing, and orientation on the existing equipment or those which you can purchase or produce;

- ➢ establishment of technological bases which provide accuracy and reliability of location. Typically, the least worn surface or those which are used during part production are chosen as the bases;
- ➢ creation of processing production flows: it is developed an integrated part or a complex route (Fig. 1) and determined a sequence of operations and configuration. Choosing the types and dimension types of equipment it is necessary that equipment specifications correspond to the precise dimensional parameters of renewable parts;

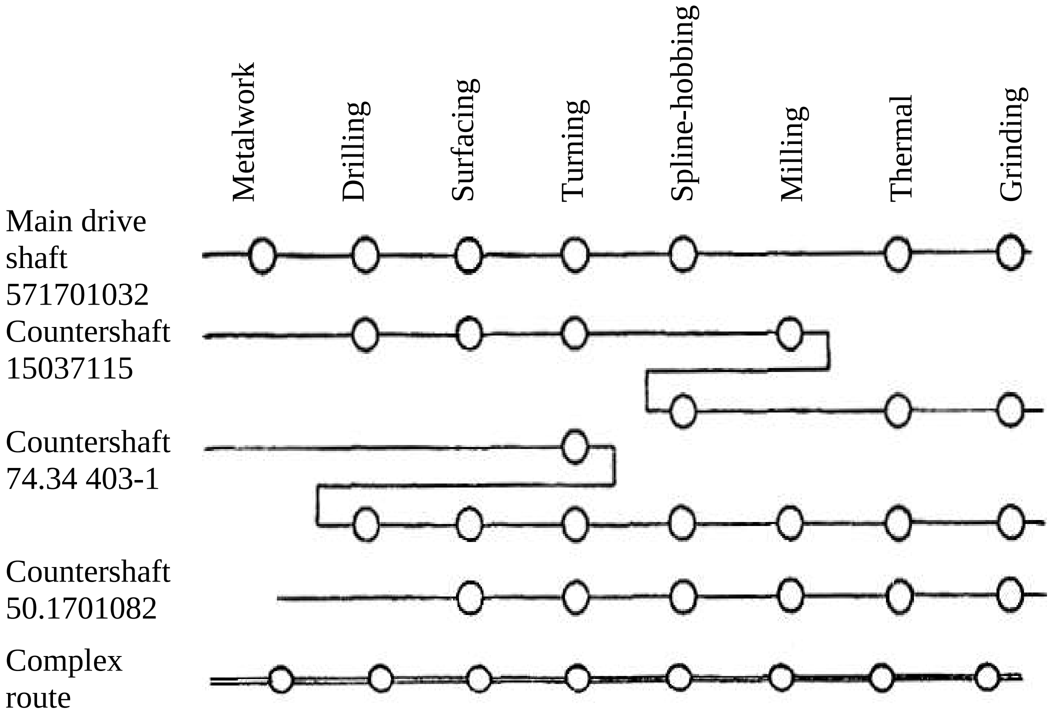


Fig. 1 – Scheme of complex process flow

- ➢ development of technological operations, choosing their structure, designing or selecting universal revamped equipment, fitting a rational transition, standardization of operations.

Component overhaul of «Round bars» class

<u>Smooth and stepped shafts (subclass 01.1.)</u> are the bodies of rotation with smooth or stepped outer surfaces and in some cases (7% of parts) with a flange.

Shafts are mostly made of carbon steels (45, 35, 50), about 25%

of part names – of alloy steels 40Х, 25ХГТ, 50Г, 18ХГТ and 4% of ordinary quality steels (mostly parts of combines).

About 70% of parts have the length up to 600mm and the diameter up to 85 mm, and only 3% of parts – constructs with the diameter of 155-220 mm. The length of the majority of renewable surfaces does not exceed 80 mm. Key grooves are 6-10 mm wide.

The allowable nonparallelity of axles is 10% of parts, radial runout (0,03-0,10 mm) – 30% of parts, face runout – 5% of parts.

The mounting surface with the strength of HRC_e 40 have 10% of parts of this subclass. Part defects of «Smooth and stepped shafts» subclass are shown in Fig. 2.

Defects of outer cylindrical surfaces are controlled with a micrometer (division value is 0,01mm), part bending and flange beating – with an indicator (0,01mm) on a tripod, wear of conical, curved and threaded surfaces – with patterns and calibers.

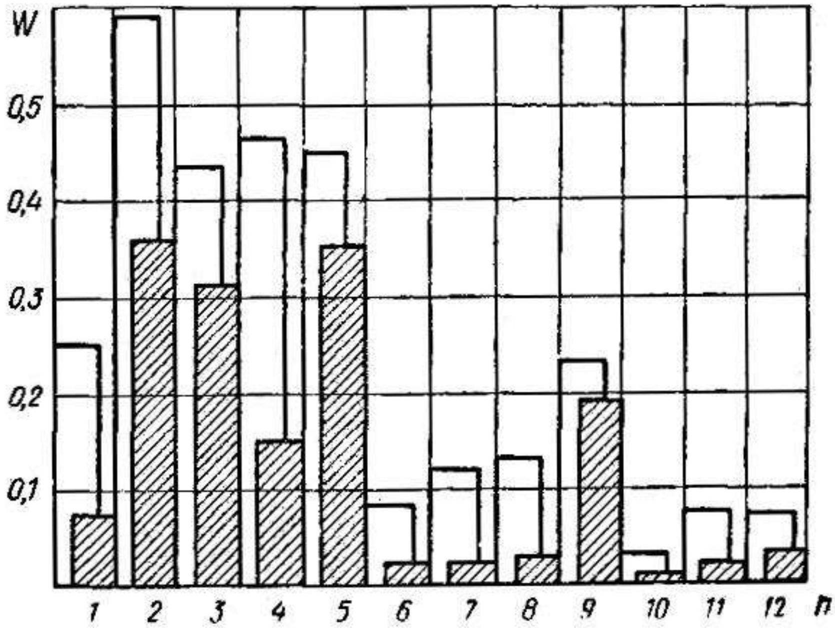


Fig. 2 – Defect characteristic of «Smooth and stepped shafts» subclass: *n* – defect name; *W* – average defect recurrence; 1 – part bending, 2 – surface wear in rolling bearings; 3 – surface wear in plain bearings; 4 – wear, outer thread damage; 5 – wear in key grooves; 6 – wear, threaded openings damage; 7 – wear in axial bores; 8 – wear in auxiliary holes; 9 – surface wear of fixed joints; 10 – flange beating; 11 – cracks in welded seams; 12 – lining wear

The highest defect recurrence is in outer cylindrical surfaces, in addition, from 60% of parts two need restoring and in some parts 3-4 and even 5 cylindrical surfaces. Quite often shafts have defects of key grooves and external threads.

Permissible wear of sites for rolling bearings (bearing parts) does not exceed 0,07 mm and it can reach 0,5-0,8 mm for gaskets and sleeve gaskets. The limiting wear of key grooves is the 15% increase of its width.

Technological bases of parts of this class are center holes. Before restoration center holes are checked (visually) and if necessary they are mended with a center drill or a chamfer bit or a cutter on a turning machine (a part is based by the least worn surface). In case there is no center hole, bases are the least worn surfaces.

Process flow. After repair determination and classification, the center holes are mended (a vertical or radial drilling machine with devices).

Shafts with a bending are mended on a press. After mending, threaded parts, cylindrical surfaces are surfaced, key grooves are welded up. For this we use surfacing with carbonic (Нп-30, Нп-40), alloying (Нп-30ХГСА, Нп-65Г) or high alloying (Нп-30ХН1З, Нп-40ХН13) wire with the diameter of 1,2-1,8 mm in the medium of carbonic gas (nitrogen, argon, helium). Sometimes we use powdered electrode ППАН-122, ППАН-125) with the diameter of 2,6-3,2 mm.

It can also be used gas flame or plasma spraying or surfacing, dry topping in a bath or rubbing, steel belt welding. In case we restore mounting surfaces of smooth shafts by steel belt welding, they are initially ground and then the belt is welded and again ground to the size of the drawing.

The surfaced shafts are normalized at 880-920°C on the SHF (superhigh frequency) plant, then cooled in the air. Normalization improves the metal microstructure, reduces its strength to 250HB and internal stresses and improves workability with an edge tool.

It is carried out turning and milling mechanical processing. Then it is fulfilled surface hardening on the SHF plant, mending on a press, grinding, metalwork processing, purification and conservation.

To increase the strength of the surface layer and part resource it is rationally to apply the following methods of the strengthening technology: diamond burnishing, vibration knurling, laser strengthening.

In some cases, thread damages can also be removed by the following:

- screw die using a screw threading die (tap);
- turning (boring) of the worn thread followed by cutting the repair size thread;
- dip-transfer surfacing without coolant; turning and thread cutting set in the drawing.

A key groove can be restored by milling to get an increased repair size and stepped key production; or by groove milling of the normal size in a new place.

<u>Spline shafts (subclass 01.2).</u> The peculiarity of spline shafts is availability of one (to 70% of parts) or several outer spline surfaces.

Besides slots, these parts have 1-5 cylindrical surfaces, 50% of parts have threaded surfaces.

The part length varies significantly but 60% of parts have the length of up to 500 mm, the biggest diameter of 80% of parts does not exceed 100 mm.

The spline part is mainly to 100mm long and the diameter is within 30-40 mm or 50-60 mm. The spline width is 6-14 mm.

Up to 60% of spline shafts are made of alloy steels (40X, 38XC, 18XГT, 20XHP etc.), the rest – of quality carbon steels 45, 40, 35.

The requirements for the strength of spline surfaces are within 38≤HRC≤52.

Part defects of «Spline shafts» subclass are shown in Fig. 3.

Wear control of spline surfaces is carried out with a micrometer (0,01 mm) and a caliper (0,05 mm or 0,1 mm).

35-75% of parts from the repair fund have spline wear in thickness, 15-65% - in the cone and almost every part has defects of cylindrical surfaces.

Permissible spline surface wears in thickness are within 0,05-2 mm with an average value of 0,55 mm. No more than 10% of parts have spline wear over 1 mm. Spline wear on the outer diameter is 0,1-0,2 mm.

The process flow of defect elimination includes the following: washing, repair determination, center hole correction, grinding, surfacing (of splines, sites, threads, key grooves), SHF normalization, grinding, mechanical processing, SHF hardening with tempering in a furnace, grinding (of sites, splines by the outer diameter) benchwork, washing, controlling, conservation.

Spline surfaces are restored by surfacing, welding the adding material with the following deposition and plastic deformation of splines.

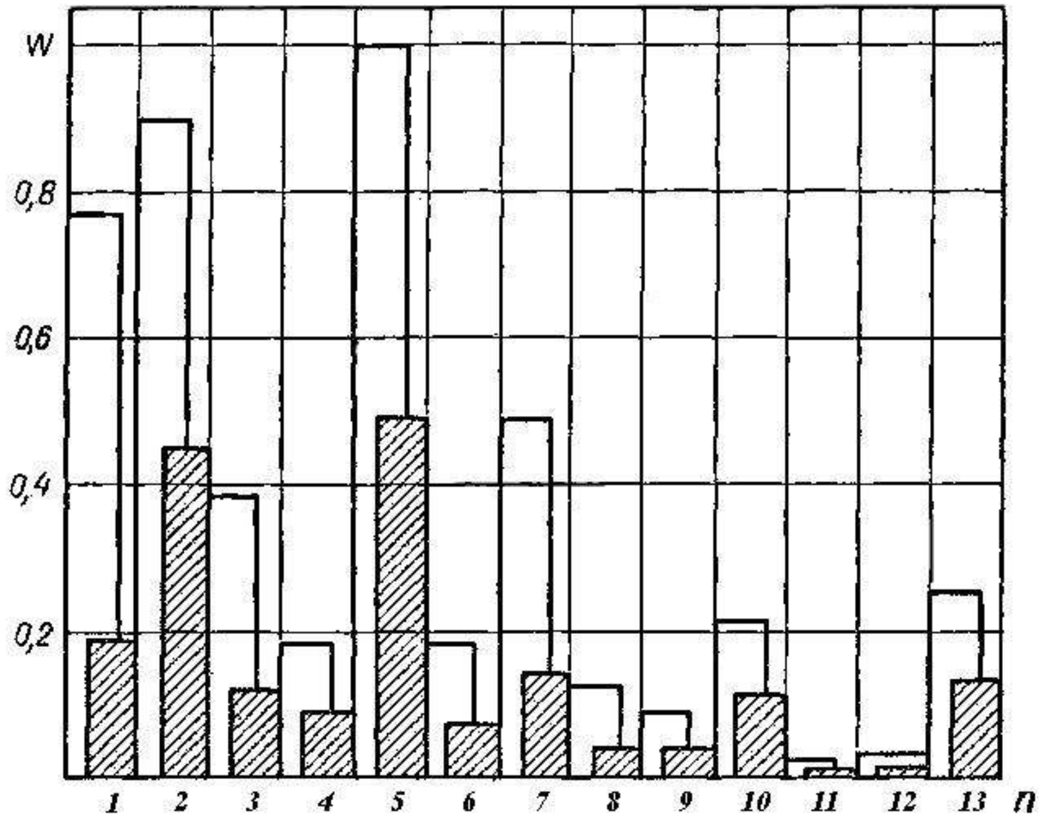


Fig. 3 – Part defect characteristic of «Spline shafts» subclass: *n* – defect name; *W* – average defect recurrence; 1 – part bending; 2 – surface wear in rolling bearings, 3 – surface wear in gaskets, sleeve gaskets; 4 – surface wear of fixed joints; 5, 6 – spline wear respectively by thickness and on cone; 7 – outer thread wear; 8 – wear, damage of threaded openings; 9 – wear in axle holes; 10 – wear, damage of gear teeth; 11 – inner surface wear in bearings; 12 – wear in axle threaded openings; 13 – inner spline wear.

Compensation of the worn layer of splines by mechanized surfacing is carried out with Нп-30ХГСА or Нп-65Г wire under (АН-60, АН-348А) flux layer in the carbon dioxide medium. Surfacing can be carried out on the helical line or along the side spline surface. After turning splines are milled on a spline mill. Kharkiv Petro Vasylenko National Technical University of Agriculture developed a method by which a shaft on mounting holes is oriented on the splines on a spline mill so cutting of the deposited metal layer is carried out from the spline working surface on the size which exceeds the wear size. According to this method of processing, the splines work in coupling with the surface of the shaft basic metal.

Welding of plates on the preliminary turned spline surface is carried out with welding rollers by the vibrocontact method with simultaneous deposition and distribution of splines by the width. After that it is carried out turning on the outer diameter and grinding of side surfaces along the generatrix. Although according to this method not high part heating reduces warping but uneven and big wears are hard to remove.

Compensation of spline wear by plastic deformation is carried out with taper rollers (HRC_e 54-56) by spline distribution using the cold method with shaft pushing by the hydraulic press through a special head. Shaft normalization is carried out before distribution (heating to 800-850°C with cooling in the air). The groove created after distribution is surfaced, the splines are calibrated or ground on the outer diameter and side surfaces. The method is effective in case of spline wear with the thickness of no more than 0,7 mm.

Component overhaul of «Hollow cylinders» class

Cylinder sleeves (subclass 02.2.) of agricultural engines have the inner diameter of 100-150 mm, the length of 200-400 mm, the outer diameter 125-180 mm.

They are made of gray (СЧ18-36, СЧ22-44) or special cast iron. Cylinder sleeves ЗІЛ, ЗМЗ have inserted sleeves at the top part. The hardness of the inner surface is HRC_e 40-50.

Cylinder sleeve defects include the following: wear or inner working surface scorings; surface wear of a support clamp of the upper and lower fitting centering face. Permissible wear is 0,3-0,5, and 0,1-0,8 and 0,05-0,07 mm. There can also be cavitation and corrosion damages of the outer surface.

While centering a cylinder sleeve, the technological base is the upper not worn part of the sleeve inner surface. Sleeves are clamped along its outer surface in the special device and centered.

The process flow of defect elimination involves purification, washing, repair determination, elimination of cavitation damages, application of the compensation layer on centering faces, boring and honing of sleeve inner surfaces, clamp cutting, finish honing, controlling.

Purification of the outer surface is carried out with a metallic brush by sandblasting and stone crumbs on a turning machine.

Cavitational damages of sleeve surfaces are eliminated with epoxy glue, contact welding of a steel belt.

Lower and upper fitting centering faces are restored by dry topping with the following processing to get the size of the working drawing. During restoration by welding a steel belt, centering faces are turned or ground to the diameter 0,5 mm smaller than the nominal. The belt of low-carbon steel is welded and ground according to the size of the working drawing.

Inner surfaces of cylinder sleeves are bored to get one of repair sizes increased by 0,7 mm (automobile engines 0,5; 1,0; 1,5 mm) if they are provided. Boring is carried out on diamond boring machines with cutters with plates of hard alloy ВК-6, ВК-2 or synthetic Elbor material.

Sleeve honing is carried out on vertical honing machines using lubricating coolants ОСМ-1. Preliminary (roughing) honing is carried out with bars АКС 250/200-ММ00 К310СПК or diamond bars АС6МI on the mode: circular velocity is 60-80 m/min, back-and-forth speed is 15-25 m/min, pressure on bars is 0,8-1,5 MPa, allowance for honing is 0,05 mm. Final honing is carried out with bars АСО80/63-Р11Р9-50, КЗМ20СМЩ, diamond bars АСМ20МI.

It is developed several ways to compensate a worn layer of inner surfaces of sleeves which went beyond the repair sizes or for which the repair sizes are not provided. The thermal deposition method consists in the following: the inner diameter decreases by continuous microwave heating to 840-880°C and when a sleeve is provided with back-and-forth motion and rotational motions with simultaneous inner cooling by water. The sleeve is subjected to mechanical processing after the temperature form change.

The method of steel belt contact welding is carried out on the 011-1-06 plant with the current strength – 5,7 kA, electrode pressing effort – 1,7-1,9 kN, welding head feeding – 8-10 m/h.

It is worth paying attention on the restoration of the inner surfaces of cylinder sleeve by the combined process of boring and superficial plastic deformation.

The Department of Repair Technological Systems of Kharkiv Petro Vasylenko National Technical University of Agriculture designed, produced and tested the equipment for the combined boring process and surface plastic deformation (SPD) of inner surfaces of cylinder engines D-144. It was designed a special spindle, a combined head and a device for cylinder fixing.

Optimal process mode: boring speed and SPD is 395.64 m/min (1200 rev/min), feed is 0,05 mm/rev, SPD efforts is 2,5 MPa, allowance for SPD is 0,02-0,04 mm.

The designed equipment and selected modes allow 7-8 times increasing the productivity of the process and 1,5 times reducing cylinder wear when strengthening a surface layer, as compared to the cylinders restored by boring with further honing.

Component overhaul of «Disks» class

Disks, flywheels, pulleys, (subclass 03.1.) are bodies of rotation with diametrical sizes which exceed the part length and need restoring outer, inner and butt-end surfaces as well as balancing.

Fig. 4 illustrates part defects. The outer diameter of the parts of this subclass is within 100-520 mm. Most parts have the diameter of 200 mm. External renewable elements can have diameter up to 500 mm. Axial bores have a diameter up to 200 mm and holes on butt-ends – 5-30 mm, a mass of 20% of the parts exceeds 24 kg, thus, working places have to be equipped with the handling equipment. Parts made of gray cast iron (about 50% of part names are СЧ18-36) and 30% of carbon steel of the ordinary quality.

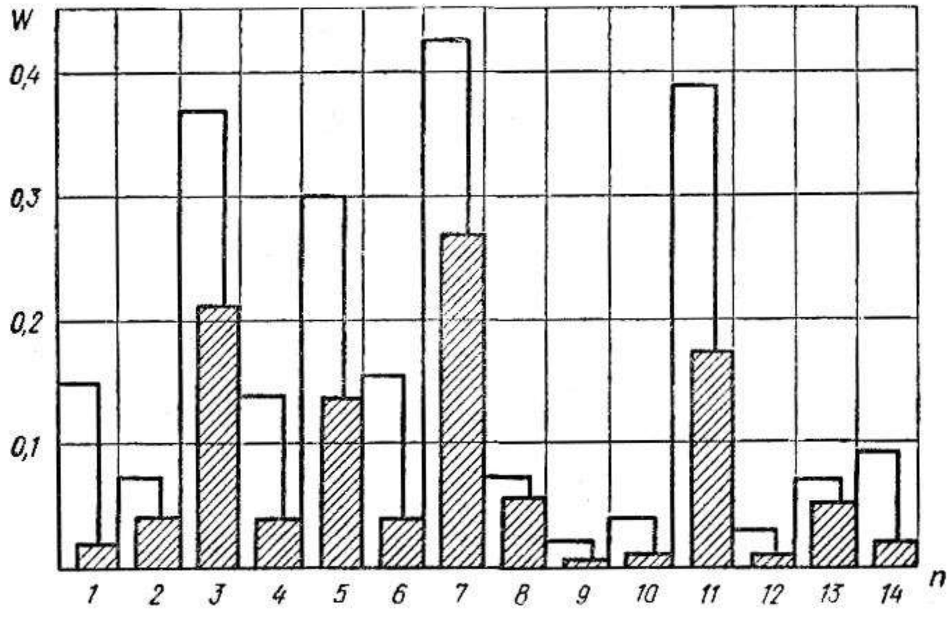


Fig. 4 – Part defect characteristics of «Disks, flywheels, pulleys» subclass: 1 – cracks, fractures; 2 – imbalance; 3, 4, 5 – wear of butt-end working surface, conical surfaces, but end holes respectively: 6 – wear, thread damage; 7 – wear in outer cylindrical surfaces; 8 – wear of studs and slots: 9 – wear, ring gear damage; 10 – outer spline wear:
11, 12 – wear of inner cylindrical and conical surfaces respectively;

13 – wear in key grooves; 14 – inner spline damage

Indicator inside-diameter gages – 0,01 mm, calipers – 0,05-0,1 mm, a ruler and a set of probes are used to control wears.

Defect repetition coefficient is within 0,6-1,0 according to wear of outer, butt-ends working, inner cylindrical, but-end holes, key grooves.

Permissible wear of inner cylindrical surfaces is 0,05-0,50 mm, including 80% with wear of up to 0,2 mm.

Choosing the way of restoration of outer cylindrical surfaces, you should take into consideration that external cylindrical surfaces have wear up to 1mm and 50% – from 1 to 6mm. Permissible wear, grooving, butt-end surface beating are 0,2-2,5 mm, 50% of them are about 1 mm.

When processing is carried out, technological bases are the surface where the metal layer was not building-up. It can be an inner or outer cylindrical surface and a butt-end. If compensation of the worn layer is carried on all surfaces then the first operation is based on the unprocessed outer cylindrical surface, and further – on the processed hole and butt-end.

The process flow of pulley restoration is the following: a hole surface is bored (a screw-cutting lathe); cracks are welded; chips, a key groove, a hole surface are surfaced with ПАНЧ-11 wire; the weld metal is cleaned, the facet is removed, the hole is bored on a screw-cutting lathe; working surfaces are turned to remove traces of wear; the key groove is produced on a slotting machine, the pulley is balanced on a balancing stand (the metal is removed by the Ø15 mm drill for balancing).

Track rollers, guide wheels, bearing rollers (subclass 03.2.) have big (up to 10 mm) wears of outer cylindrical surfaces. It has been developed a number of ways to compensate their metal, what provides a high productivity: pouring with liquid metal, banding, electroslag surfacing.

Pouring with liquid metal. A roller is heated to 500°C in a shaft furnace and kept there for one hour. The outer surface is cleaned and coated with lacquer (KF965), and then slag (АНШ-200) is applied. It is heated in the inductor to 950-1150°C and placed in a mold and poured with molten metal. The hardness of the metal coating is HB 320-390. Mechanical processing is not required. Rim stability is at the level of a new one.

Bending is the easiest way that can be carried out even in small workshops. A ring made of a steel band is press-fitted on the turned rim surface and welded but-ends by arc welding. The resource is almost 60%

of new.

Electroslag surfacing of a wheel rim consists in using heat released when the electric current from the electrode passes to the rim through the molten slag. The electrode wire melts and fuses the rim under the influence of this heat.

Cracks on needles are welded by electrode ОММ-51 with the diameter of 4-5 mm having preliminary removed facets 4×45°.

After processing guide wheels, beating of the hole surface of the hub relatively to butt-end surfaces is no more than 0,25 mm, the outer surface of the hole axis of the hub is no more than 2 mm.

Component overhaul of «Levers» class

Pull bars and levers (subclass 6.2.) are primarily bars with one or several heads with smooth, conic and threaded holes.

The length of parts ranges within 50-550 mm, but the biggest number of levers has the length of about 100 mm with the average weight of 1,2 kg and the maximum – 5 kg. There can be up to 4 restored holes with the diameters from 8 to 50 mm on one part. Processing accuracy is at 7-10 quality classes, the roughness is at Ra 0,8-6,3 level. Material of 80% of subclass parts is quality carbon steel (45, 40, 45L) as well as alloying (40X, 45H, 12XH3A) and of ordinary quality. There are also levers of ductile cast iron (КЧ35-10). The hardness of the most surfaces is HB 170-217.

Wear of smooth holes (80% of parts) is the main defect of the parts of this subclass. Bending or twisting occurs in 20% of parts, wear of inner keys or spline surfaces – in 40%, and outer plane, spherical and curved surfaces – in 27% of parts.

Permissible wear of holes varies widely within 0,12-2 mm and permissible wear of butt-end surfaces – 0,18-3 mm.

Technological bases during restoration are mount (head) butt-ends and holes, sometimes auxiliary bases in the form of milled areas and center holes.

Process flow. Dressing of levers and draws is carried out in the cold state or by local heating to 800°C. Lever holes are unfolded under the increased size or restored by fitting a bushing and its unfolding to the size set in the working drawing. Butt-end wear is compensated by mounting washers or surfacing with electrodes ОЗШ-2 and ЕНУ-2 with the following thermal and mechanical processing. Worn splines or key inner surfaces are welded up, drilled, and then broached.

Component overhaul of «Frame parts» class

Parts of «Frames» subclass (subclass 07.3). have considerable overall sizes – length – up to 1600 mm, width – up to 500 mm, height – up to 750 mm. The weight of 50% is over 50 kg and reaches 233 kg.

Basic structural elements are bearing holes in outer and sometimes in inner walls (some parts have more than 8 of these holes). The diameter of these holes is within 50-298 mm and the length of the generating line – 10-30 mm. They are used with the accuracy of no more than 7 quality classes and the roughness parameter is no more than R_a 40. The diameter of threaded openings ranges from 6 to 20 mm.

Frame parts are made of gray (СЧ 15-32, СЧ 18-36, СЧ 21-40), forgeable (КЧ95-0), high-strength and special cast iron as well as (to 15%) of aluminum alloys (Al9, Al11).

Part defects of «Frames» subclass are shown in Fig. 5.

Wears of mounting surfaces for bearings and damages of threaded openings have the highest coefficient of defect repetition.

Permissible wear of holes vary from 0,01 mm to 0,23 mm with the average value is 0,072 mm, wears of small diameter holes are 0,03-1 mm.

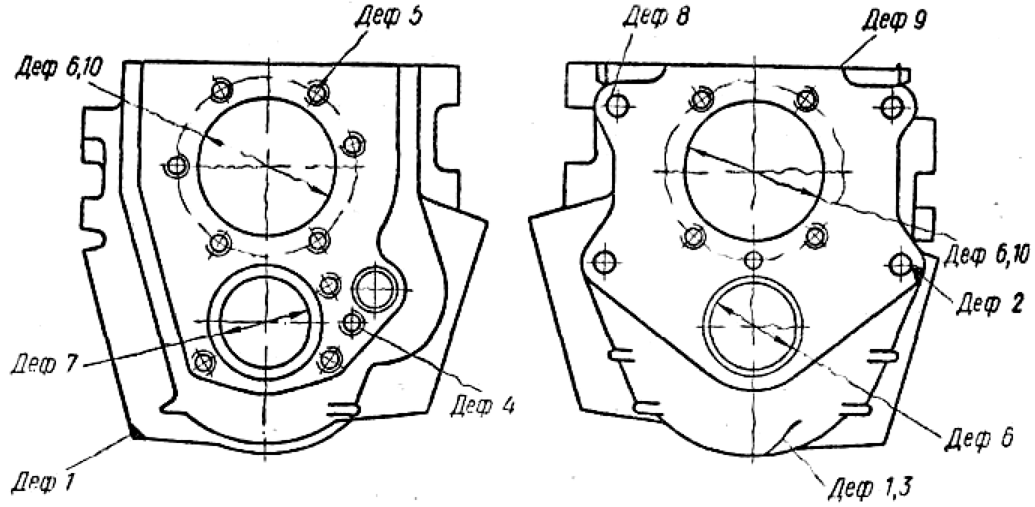
Technological bases are selected to carry out installation on the not worn-out, processed flat surface. Auxiliary bases of two holes are frequently used.

The process flow will be considered on the example of the power-shift transmission frame.

Crack ends are revealed after washing, cleaning of the principal and profile planes from gaskets and dints. Holes with the diameter of 3 mm are bored, cracks are welded, broken off ears and mounts are surfaced, welded seams are cleansed and leak-tested at the distance of 6-10 mm from the visible end.

Broken bolts are bored out, holes with the damaged threaded surface are bored, the facet is countersunk, the thread is cut for spiral inserts, and spiral inserts are fixed. Holes are bored for bearings of primary, secondary and intermediate shafts and the pinion gear axle of reverse movement to install bushings. Bushings are pressed into the bored openings, openings in bushings are bored out to get the size in the working drawing for one fitment keeping the center-to-center distance.

Mounting surfaces for bearings are also restored in frame parts by galvanic coating (local dry topping), when setting rotation rings, using polymeric materials, belt or powder contact welding.



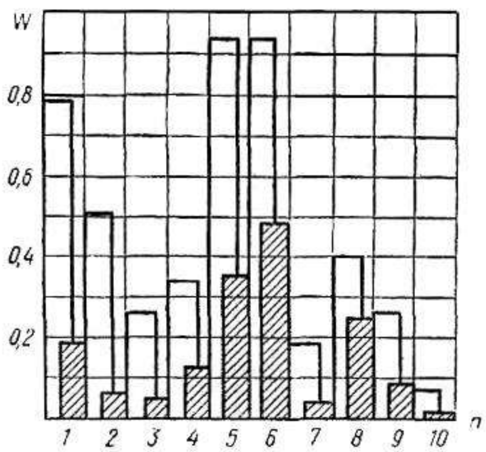


Fig. 5 – Part defect characteristics of «Frames» subclass: n – defect name; W – average defect recurrence; 1, 2 – cracks which do not go beyond and go beyond the processed surface respectively; 3 – breaches on the unprocessed surface; 4 – fractures of bolts or stud pins; 5 – damages of threaded openings; 6 – fitment bore wear in inner walls; 7, 8 – wear of small diameter holes; 9 – nonflatness, nonparallelism, misalignment of flat surfaces; 10 – nonparallelism of hole axles

Defect elimination of threaded holes can also be carried out by welding holes with further threading, setting sealing gaskets, threading of the repair (increased) size.

Adhesive compositions, figure inserts are also used for crack doping.

Radial drilling machine, horizontal boring machine, pneumatic stripping machine are used during mechanical processing of frame parts.

Component overhaul of «Flat parts» class

Shifter forks (subclass 09.1.) are parts with a rectilinear or ring working surface. Constructively they can be made with continuous or split-design holes or rods of round and rectangular cross-section (Fig. 6).

Parts of «Shift fork» have relatively small overall dimensions – about 300 mm long and about 55 mm wide, and if there are rods – about 257 mm. The length of rectilinear renewable parts of fork webs ranges within 25-47 mm and the thickness is about 9 mm. The width of the fork jaw opening is 30-130 mm. A fork head openings can be processed on boring machines because their diameter is of 15-22 mm. The groove width of heads and rods is 14-18 mm. The part mass is within 0.3-2 kg. Parts of this subclass are made of steels 35, 45, 40X, 45X. Part web hardness is HRC_e 42-52 what requires hardening with superhigh frequency heating.

Fork bend, wear of fork jaw opening at width and web surfaces at the thickness of grooves, openings; cracks, fractures, wear of outer cylindrical surfaces; rod wear are considered to be part defects.

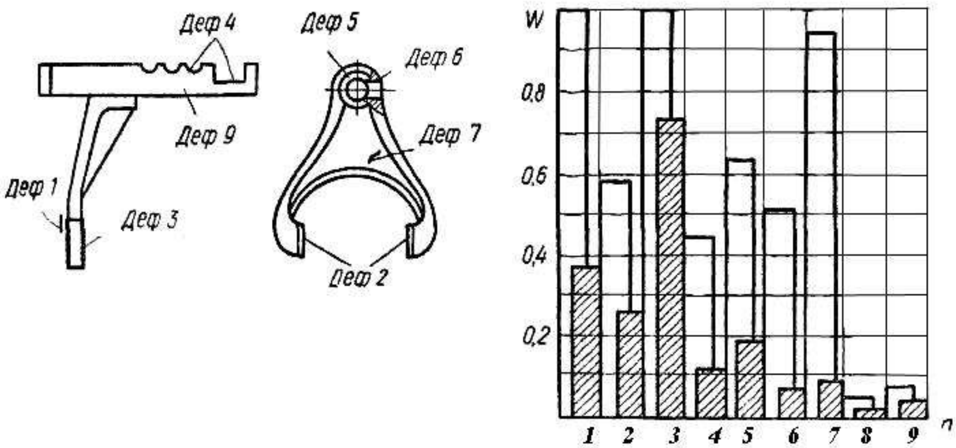


Fig. 6 – Part defect characteristics of «Shift fork» subclass: n – defect name; W – average defect recurrence; 1 – fork bend; 2 – wear of fork jaw opening by width; 3 – wear of web surfaces by thickness; 4, 5 – wear of grooves and openings; 6 – wear of threaded openings; 7 – cracks, fractures; 8, 9 – wear of outer cylindrical surfaces and rods

Average repetition coefficients «web wear» and «fork bend» are respectively 0.7 and 0.4.

Permissible wears of web surfaces at thickness are within 0,1-2,2 mm, openings – 0,072-0,37 mm, grooves – 0,46-1 mm. The permissible fork bend of different kinds varies within 0,03-0,5 mm.

Process flow. Side surfaces of fork webs bent over 6,3-0,5 mm are ground on a plate. Worn side surfaces of webs are surfaced, milled or ground.

Types of technological processes and output information

For different types of technological processes of repairing products used in repair production relevant technological documentation packages are developed and drawn. They consist of separate text and graphic documents. The composition, form and content of technological documents depend on the type and purpose of technological process and have to meet the requirements of standards and other technological normative documentation.

By industrial engineering, technological processes are divided into individual, typical and group.

The individual technological process refers to the products of one name, dimension type and production.

The typical technological process is developed product groups with common structural and technological features. The typical technological processes are also designed operations of one work type: purification and painting of parts and assembly parts, galvanic coatings etc.

The group technological process is developed to restore part groups with different structural but common technological features.

By the degree of the specificated description, technological processes are divided (GOST 3.1109) into the following:

- a route description of a technological process is a brief description of all technological operations in route maps according to the sequence of their execution without indicating transitions and process conditions.
- an operation description of a technological process is a full description of all technological operations in the sequence of their execution indicating transitions and process conditions:
- a flow-process description of a technological process is a brief description of technological operations in the route map according to the sequence of their execution with a full description of some operations in other technological documents.

Output information to develop a technological processes is divided into basic, control and supplemental information.

The basic stages to develop working technological processes for small-scale and commercial repair production and tasks of each stage are given in Table. 3.

Table 3 – Basic stages of development of technological processes

Stages of development of technological processes	Objective of stage
1. Analyzing output data to develop a technological process	Studying design documentation of the product, technical requirements for repair determination, a renewable part or repaired unit, an assembly, a machine. Examination of planning of the corresponding production area on this overhaul plant. Selection of supplemental information
2. Searching an analog of the operating individual, typical (group) technological process	Consideration of documentation for individual, typical (group) technological processes which relate to this product
3. Creating a process flow of restoration a part, unit, assembly, machine disassembly (assembly)	Selection of technological methods used during worn-part reclamation; determination (or elaboration) of the sequence of technological operations in technological analogous processes. Determination (or elaboration) of the store of manufacturing equipment
4. Development of technological operations	Development (or elaboration) of transition sequence in the operation. Selection of technological equipment in the operation (or their elaboration). Definition of output data for calculations and calculation of processing allowances and optimal processing modes
5. Standardization of technological process	Definition of output data necessary to calculate standard time and their computation. Determination of the work category and explanation of executive professions to carry out operations depending on work complexity
6. Calculation of economic efficiency of variants of the technological process	Choosing a variant of the optimal working technological process
7. Design of the operational technological processes	Filling the forms of technological documentation according to ESTD standard requirements and branch technological normative documentation. Normal inspection of technological documentation (GOST 3.1116 ESKD). Approval and adoption

Repair drawing and disassembly/assembly circuit

After first and second stages they develop a repair drawing of a part or a disassembly (assembly) circuit of a product i.e. (assembly part).

Repair drawing of a part. The repair technological normative documentation includes repair drawings (Fig. 7). Repair drawings are drawn by the rules established in DSTU GOST 2.604: 2005 and GSTU: 3-058:2004.

Repair drawings are drawn on the sheets of A3 format. The image of renewable parts, specification, technical requirements and the table of categorial sizes are drawn on the first sheet, and types, sizes, cross-sections, defect tables – on the other sheets. It is allowed to draw repair drawings on the sheets of other formats, but no more than A1 format.

It is suggested if necessary preparatory works to set an additional part in the assembly drawing. It is allowed for additional parts of simple configuration (bushing type) to give data for production and control in the field of the repair drawing.

In repair drawings the surfaces which need to be processed in repair are drawn with a basic continuous thick line, the rest of the image – with a continuous thin line (two to three times thinner than the basic continuous line). Places of defects are numbered according to the number of the defect indicated in the Defect Table given in the repair drawing. In repair drawings they draw profiles, sections and cross-sections and indicate dimensions, limit deviations, permissible errors of mutual placement of axles and surfaces, characteristics of hardness, surface roughness, etc., which have to be implemented and tested in the process of worn-part reclamation.

Numerical values and keys of dimensionally precise characteristics, parameters of hardness and surface roughness have to be the same as in the working drawing.

The scheme of disassembly (assembly) of an assembly part is reasonable (optional) output information to describe the technological process of disassembly (assembly) and can also be used as a standalone technological document at the workplace in repair shops. Taking into consideration the labor content, it is possible to define thoroughly the required workplaces to carry out disassembly-assembly operations at the plant, as the scheme shows the possibility to perform consecutive as well as parallel operations. Disassembly (assembly) of a unit is carried out in the special sequence, depending on its design (see. Lecture 2, Fig. 7).

The process of disassembly (assembly) is shown in the scheme as the straight (vertical or horizontal) line. The rectangles, which represent components of the product (assembly units and parts), adjoin to the line.

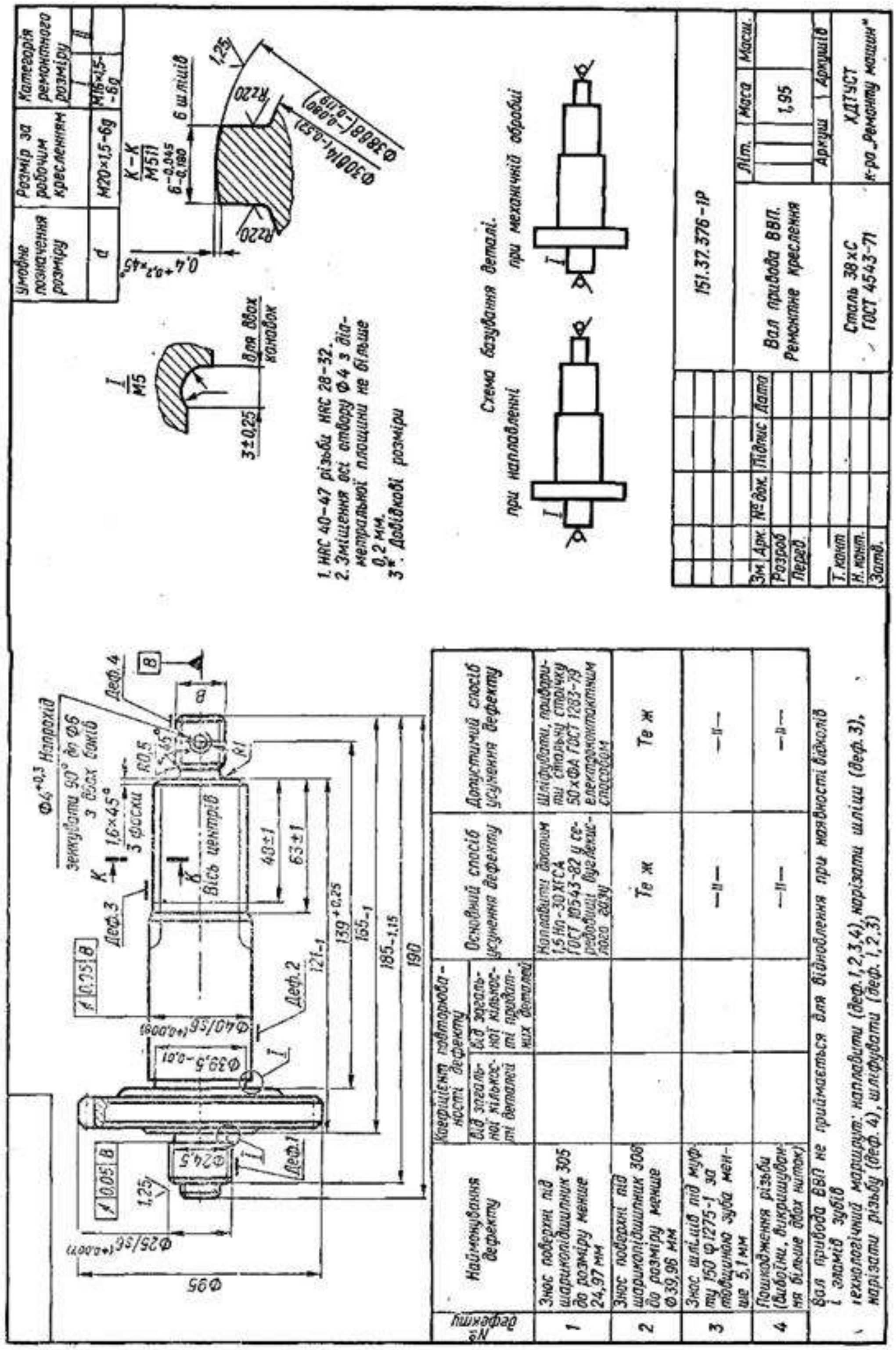


Fig. 7 – Repair drawing

For better clearness the rectangle which schematically depicts an assembly part is drawn by two parallel lines.

In the disassembly scheme rectangles which depict assembly to be removed, are placed to the left along disassembly lines, and some separate parts – to the right.

The beginning for the disassembly scheme is a product (assembly unit), the end – a basic part.

Each rectangle in the scheme is divided into four fields that give the names to a part or an assembly unit, their designation, quantity and position number according to the specification on the basic design drawing of the product.

The disassembly (assembly) scheme is accompanied by the sketch of the assembly unit and its specification. All components of the assembly part are numbered on the sketch according to the numbers of positions stated in the specifications (see. Lecture 2. Fig. 8).

The most appropriate technological methods for these conditions, means and routes of worn-part reclamation as well as created plans of operations have to be chosen as the result of the third and fourth stages of implementation. Table 4 represents the recommended form to create the plan of operations. For example, it is filled with only operation.

Table 4 – Plan of operations for worn-part reclamation

Part: Shaft drive GDP

Designation: 151.37-376-1

Mass: 1,95 kg

Defect 5: Thread damage M20 × 1,5-6

Operation number	Operation name, worn-part reclamation method, equipment, devices, tools	Transition number	Transition content
Surfacing			
005	Setting a part in the centers. Semiautomatic welding machine A-537U. Welding converter PSG-500. Cylinder $CO_2$40-150 DSTU 3245-95. Deposition device (shop). Pattern 23 (shop).	1	To surface threaded surface with wire 1,6 Нп-30ХГСА GOST 3691-98 with the diameter from 20 to 23mm and on the length of 20mm

It is drawn a set of documents which define the technological processes of disassembly, assembly, repair determination and worn-part reclamation for overhaul plants. Thus, there are the following types of technological processes by the level of their detailed description: route description – for disassembly and repair determination, route-operating – for assembly of assembly units and worn-part reclamation.

The technical documentation developed and used in overhaul plants is drawn according to the required standards of ESTD, taking into consideration explanations and limitations listed in GSTU 3-058: 2004 and SOU 29.3-37-186: 2004. Different types of technological documents are provided by these documents: a route map (RM), a map of a typical technological process (MTTP), such as for cleaning or electrolytic operations, an operating map for different types of operations (surfacing, mechanical processing, technical control, etc.), a map of the repair determination technological process (MRDTP), a map of sketches for technological operations (MS), etc. The group list includes: a list of technological documents (LTD) being in the set of documents of technological process, a list of parts for a typical technological process (LTP), a list of tooling (LT) and equipment (LE).

The criteria and methods of choosing a technological process. The comprehensive analysis of types – the interconnected set of various technological methods, equipment and tooling used to repair a product, is different types of technological processes to eliminate some separate defects or repair products, machines, assemblies, parts in general. While developing technological processes as well as methods of management and production connected with them, there is a need of the comprehensive analysis of possible variants and the choice of specific production conditions. The comprehensive analysis of comparable variants of technological processes involves consideration of technical, organizational, social, ecological and economic feasibility of their application.

Lecture № 11
Repair of engines and turbocompressors

Crank mechanism repair

Among assemblies of tractors and motor vehicles an engine is the least durable. Piston rings, pistons, cylinders, valves, crankshaft journals, its crank and main bushes are worn most quickly.

Crankshaft. Peculiarities of crankshaft repair (restoration) are in defect elimination on eccentrically located surfaces (crank and main bearings) made with high accuracy.

Crankshafts are mainly produced of steel (45, 50, 50Г) or high-strength cast iron. The hardness of bearing surfaces is HRC_e 45-62.

Crankshafts may have the following defects: wear of main and crank bearings; cracks, pieces; shaft bend; flange butt-end surface beating; neck wear in a pinion gear and drive pulley hub; wear in a key groove at width; hole wear for bolts of flywheel fastening.

Shaft is fit into the centers with the flange towards the foot block, while polishing the main bearing. The bearings for a pinion gear and the outer diameter of the flange are, basic while you carry out turning of center holes.

The process flow of crankshaft repair: checking for cracks on bearings; welding of key grooves; surfacing of conical surface bearings for the pulley, the front balance and the pinion gear; turning of center holes and pads; grinding of main and crank bearings, pads; boring holes for bushings, pressing the bushing; milling key grooves, rounding of facets and oil channel edges; grinding the main and crank bearings; reaming holes for a pin; pin press-fitting; crankshaft balancing.

Elimination of defects on main and crank bearings is carried out by their regrinding to get one of repair sizes (sizes for different engines are reduced by 0,25; 0,50; 0,75; 1,0; 1,5 mm). Bearings are ground on a circular grinding machine of 3A432 type by a grinding wheel 14A40-ПСМ27К5 35 m/s at 1 kl at modes: wheel rotation speed – 35 m/s, part – 15-25 m/min, cross-feed movement – 0,02-0,03 mm. The radius of hollow chamfers should be kept and the length of crank bearings should not be increased while grinding. At first, crank bearings are ground. For this the shaft is set in central transporters. They provide accordance with the crank radius. Grinding begins from the first bearing.

Bearing surfaces are subjected to polishing to receive the necessary roughness.

Shaft necks which went beyond the last repair size are built up with one of the following variants of technological processes:

- surfacing with Нп-30ХГСА wire under АН-348-А flux, normalization, turning of bearings, microwave hardening, grinding and polishing;
- surfacing with Нп-80 wire, high temperature tempering, turning of bearings, microwave hardening, grinding and polishing;
- surfacing of shaft necks with a spring wire of the second class containing 0,7-0,8% of carbon under the alloying flux (АН-348-А flux – 95,5%, powder graphite – 2,5%, powder ferrochrome – 2%), previous and final grinding and neck polishing.

Shafts made of steel 50Г with the high carbon content (YAMZ-236, YAMZ-238, YAMZ-240), are hard subjected to surfacing under the flux because of forming cracks. Therefore, plasma-arc or gas metallization are more often used for such shafts.

Distribution shafts Distribution shafts are made of high quality carbon steels (steel type 45) or cast iron. Cam profiles need to be restored in the distribution shafts.

Ways of restoration:

- processing to get a repair size by a copier to obtain a cam profile equidistant relatively to a new cam profile. It provides the same valve lift, but the law of its motion changes;
- cam building-up by various ways of surfacing – dip-transfer, electroarc in the medium of carbon dioxide or argon, laser or plasma-jet hard-facing;
- cam building-up by metallization, chromium coating, electric-contact powder baking.

Cams are processed in three stages:

- previous (peeled) grinding by wheels ПП600Х30524А 40-П СМ1-СМ-2 6К5 on the mode: radial feed – 0,05 mm/rev, speed of shaft rotation – 30 m/min, speed of wheel rotation – 40 m/s;
- final grinding by wheels ПП600Х 40х305 24А 25-П СМ1-СМ2 5К8 on the mode: radial feed 0,005 mm/rev, speed of wheel rotation – 35 m/s. Allowance for further polishing has to be 0,005 mm;
- cam polishing by fabric-based abrasive cloths with the gritness of 8-4 on turning or grinding machines using vibration-belt-polishing heads (VBPH). Polishing is carried out with felt or felt wheels using polishing paste ГОI or diamond smoothing.

Cam roughness has to be Ra 0,5-0,32 μm.

Engine cylinder sleeves. Repair of cylinder sleeve is considered in the lecture № 10 «Principles of technological processes unification».

Completing of connecting rod and piston group

Connecting rod sets assembled with covers, bolts and nuts are selected by mass and center-to-center spacing of head openings. The connecting rod mass is marked with three-digit number left on the butt-end of the lower head. The rod metal of connecting rods is sawn at the depth to 1 mm on the dividing line of punches for mass balancing.

The difference of part masses in a set for one engine during its operation leads to appearance of unbalanced inertial forces what causes vibration and accelerates wear of engine parts. The difference of masses in one set for diesel engines SMD and YAMZ must not exceed 10 g and 20 g respectively.

Grooves for rings and openings in bosses wear in pistons. Piston grooves are restored by plasma-arc hard-facing and worn openings in bosses for a piston pin are reamed with a hand-held expansion reamer. Ovality, taper and disalignment of openings in piston bosses must not exceed 0,01 mm. The allowable misalignment of common axle openings of bosses to a piston axle is to 0,03 mm at the length of 100 mm.

Pistons are selected by the size group and mass. The piston mass and size group labels are placed on the bottom.

A piston set is selected beforehand within permissible difference in mass by digital labeling on the bottom, and finally – by results of weighing. Piston set selected by mass has to be of one size group. Pistons with barrels are completed by the clearance between the piston (by skirt) and the bush sleeve are marked with the following letters Б, С, М, (SMD), А, АА, ААА, АААА, ААААА, АААААА, or А, Б, В, Г, Е, Ж(YAMZ) which are put on the bottom of the piston and on the upper end of the barrel. The difference in masses of pistons and connecting rods assembled with pistons in 17 g and 30 g respectively is permissible depending on the brand of the engine.

Oil and compressive rings are selected according the bush sleeve size and the groove height on pistons and checked for elasticity on a special device, which has to be: for compressive rings 15-75 Н, oil-removing – 18-52 Н, for clearance in the joint – 0,3-0,6 mm (depending on the brand of the engine). The allowable warping of end surfaces of piston rings is no more than 0,06 mm. While checking the paint between two plates with the mass of 3 kg of the upper plate, the contact spot has to be at least 75% of the total area of the whole surface for compressive rings and 65% for oil-removing rings. The contact spot has to cover the whole ring; its gap is not allowed to exceed 8 mm in length. A permissible variation of the thickness for one ring is no more than 0,08 mm. It is possible to fit piston rings in height when grinding on a surface-grinding machine with a magnetic holding plate or manually on the plate covered with sandpaper. To check the gap at the joint piston rings are set into the cylinder strictly in the area perpendicular to the axle and checked by a probe. The quality of ring abutment to the cylinder walls is also controlled. The gap between rings and barrels should not exceed 0,02 mm on the arc of 25-30° and 30 mm closer to the joint.

Bushes are selected by the size of connecting rod journals and the height H. In a special device (Fig. 1) bushes are set into the jack with the diameter D which equals to the nominal diameter of the opening of the lower connecting rod head for a bush. One joint sets against the device cog; it is applied a load to the second one. It changes depending on the number of repair size.

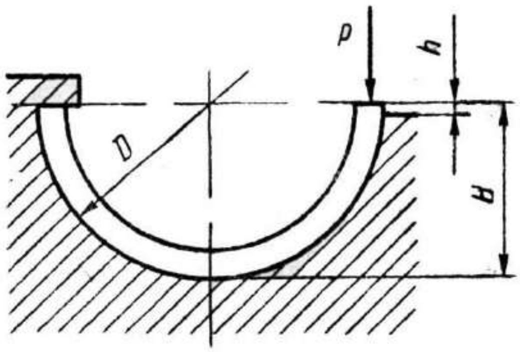


Fig. 1 – Scheme of checking connecting rod bushes for height

When the height of engine bushes is measured, the load is 6-13 kN. With the increase of the bush thickness (repair size number) the load increases. The bush height at this measurement has to be: N = r + h, where r is a radius of the device, which equals half of a diameter D, mm; h – a projecting part of the bush on the joint under a load P which is 0,07-0,12 mm

Piston pins are selected so that they have one size group with openings in piston bosses. Size groups on pistons and piston pins are marked with paint, literal or digital indexes. On pistons the labeling is applied on piston bosses, and on piston pins – on the inner surface or the butt end.

The difference in masses of piston pins which are set on one engine depending on the brand should not exceed 6-10 g, thickness variation – 0,5 mm.

Bushings by the outer diameter are selected according to the diameter of the upper connecting rod head and by the inner diameter – by the diameter of a pin taking into consideration the allowance for processing.

Assembling a connecting rod and piston group begins with press-fitting of the bushing into the upper connecting rod head with the negative allowance of 0,03-0,12 mm for diesels of different brands. The connecting rod is fixed on a diamond-boring machine URB-VP and a bushing is bored with the allowance – 0,04-0,06 mm while flattening-out, 0,08-0,15 mm, while burnishing or 0,05-0,08 mm while reaming relatively to the normal diameter of a piston pin.

Bushings are flattened-out with a pulse roller on a vertical-boring machine, burnished under the press with mechanical drive applying a continuous feed of the mandrel lubricated with diesel oil. It is controlled deviations from parallelism of axle openings in the bushing and lower connecting rod head according to the technical requirements. The lower head is assembled with bushes and bolts. Bolts have to fit into openings with light impacts of a hammer with the mass of 200 g.

Oil channels of connecting rods are washed, blown out with air.

Pistons are heated in the electric equipment cabinet or oil baths to 80-90°C and jointed with a connecting rod by a piston pin in piston clams, having fitted beforehand a closing ring in one of bosses using special gables. Then the second closing ring is put into the groove of a boss opening. Pins have to fit into piston openings freely. Rings are set on the piston by means of a special device (Fig. 2). They have to move freely in grooves.

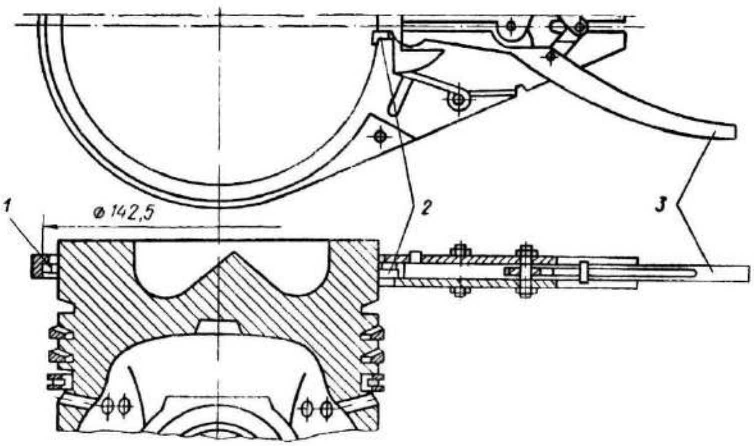


Fig. 2 – Device to remove and set piston rings: 1 – piston ring; 2 – sponges; 3 – handle

Rings are set on a piston with the smaller diameter the way up (compressive - recess is up). While assembly takes place, there is paid attention on the correct placement of a connecting rod by the instruction of the manufacturing plant.

Repair of gas distribution mechanism

The main defects of the head of a cylinder block are cracks and breaches, warping of the parting plane with the cylinder block; wear and burning of facets of valve pockets (seats); wear of valve bushings, stud pin threads and threaded holes, the loss of cylinder jacket tightness; crack appearance and burning of combustion chamber walls.

Before repair it is tested the tightness of the walls and sealings of the cylinder head under the water pressure of 0,4-0,5 MPa. 5 minutes leaks and weepings of cylinder head walls are not allowed.

The technology of cylinder head restoration with cracks and breaches in walls is analogous to the elimination technology of the mentioned defects in body parts and was considered in the lecture № 10.

In case the lower plane of the block head is warped is more than 0,15 mm, it is ground or milled with the minimum metal removal.

The most common cylinder head defect is wear of working facets of valve pockets. It is eliminated by milling. For this it is used a set of four special milling cutters (Fig. 3). At first the valve pocket of the head is processed with a roughing mill to complete elimination of wear traces. Then the facet is given the needed width while it is consecutively processed with mills with different angles of the cutting border. Then the facet is finally processed with a finishing mill. The facet has to be 1,5-4,5 mm wide for different heads of a cylinder block after milling. The surface roughness after milling does not exceed R_a 2,5 μm, radial runout of the facet relatively to the opening of valve bushing – 0,05 mm. Valve pockets are ground with an abrasive tip after milling to get smooth surfaces of facets. The extremal diameter of the valve pocket is set by the recess size of new valve (nominal size) plates. The nominal recess size of the valve is determined by the technical requirements for complete overhaul of the corresponding engine brand.

Worn valve pockets are restored by surfacing or cross-feeding. Pockets are bored out to the special depth with high accuracy (permissible pocket ovality is 0,05 mm and tapering – 0,2 mm) and rings made of special (pearlitic) cast iron are pressed into them with the negative allowance of 0,14-0,15 when valve pockets are being repaired by ring press-fitting. The block head is heated to 380-420°C and rings are cooled in dry ice or the head is heated to 90°C and the rings are cooled in liquid nitrogen in order to ease their installation and increase the strength of the seating fit.

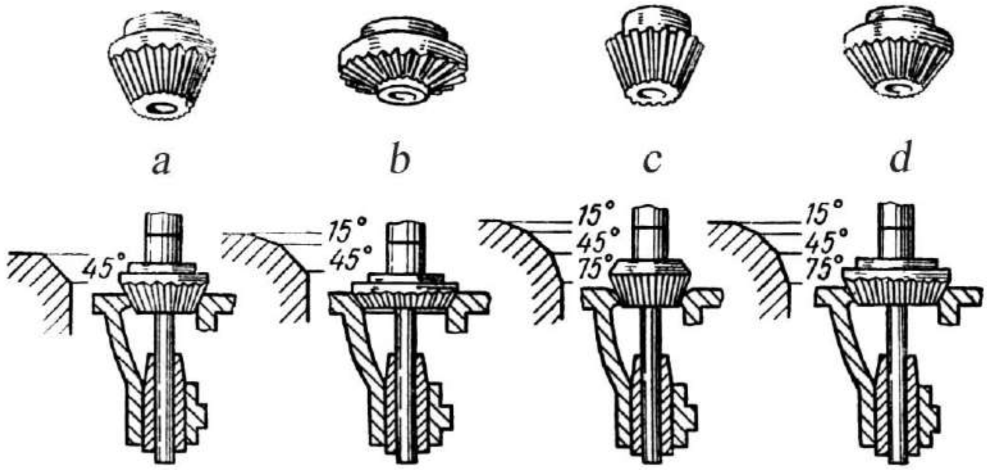


Fig. 3 – Valve pocket processing by milling cutters. Milling at the angle: *a* – 45º; *b* – 15º; *c* – 75º; *d* – finishing at 45º

Guide bushings of valves need to be replaced when their seats are weakened or there is significant wear of their inner surfaces. It is provided a negative allowance of 0,002-0,01 mm and the inner diameter is reamed to the size of a valve stem while press-fitting of guide bushings is carried out. To avoid replacement of guide bushings with worn openings, but with a normal seat in the outer diameter it is cut a thread by a tap in bushing holes, its surface is degreased with acetone, the hole is filled with epoxy glue; its filling compound is graphite. After heat processing busing openings are bored out along the conductor then reamed to the size of the valve stem.

The worn outer surface of a guide bushing is restored by tooth roller surfacing or by the thermal method, heating it slowly in the furnace at the speed of 250-300°C/hour up to 700°C with the equalizing of 10-40 min (depending on the desired increase in the diameter) and subsequent slow cooling. In this case the diameter grows 5-18 μm.

Wear or tearing of thread holes is eliminated using spiral inserts, threading of the increased size or setting additional inserts where the thread of the nominal size is produced. Stud pins are replaced in case of this defect.

Valves can have wear and burning of working plate facets, wear of the stem surface and its end. Working valve facets and stem ends are ground after checking valve stem straightness. The allowable deviation is 0,05 mm. A valve is fitted into the collet holder of the plant at 45° and a facet is ground after checking beating of the stem. After grinding any scratches and scorings should not be left on the plate surface; a cylindrical belt has to be 1,1-1,3 mm high. The facet roughness after processing does not exceed Ra = 0,63 μm, and beating relatively to the axle of the stem surface is no more than 0,03 mm.

Extremely worn valve plates (the belt height is less than 0,5 mm) are restored by plasma spraying, SHF surfacing of a furnace charge with heat-resistant materials (ВК3, ЭП616 I and sormite) and electric-contact spraying with metal powders.

Worn valve stems are ground to the reduced size, built-up by dry topping or chromium coating. Ovality and tapering of the valve stem after its grinding should not exceed 0,02 mm and roughness – Ra = 0,32 μm.

Valve springs. Their defects are the loss of elasticity and shrinkage from permanent alternating loads. Elasticity control of valve springs is checked on the device and it is determined the strength of their compression, comparing to the technical conditions. The springs having elasticity is less than admissible are restored by rolling or by heat fixing method on the plant where they are streched with clamps to the desired length, and the electric current passes through heating them to 400-450°C and then they are cooled in the air.

Assembly of cylinder heads and lapping of valves. Cylinder heads are assembled on a special stand. At first guide bushings are pressed in and valves are selected before their lapping into pockets. Bushings with a bead are pressed in firmly, and bushings without a bead – to the height permissible by technical requirements. The gap between the stem of the intake valve and the bushing – 0,03-0,07 mm and the exhaust valve and the bushing – 0,07-0,011 mm.

Valves are lapped on special plants or on stands for better abutment to the pocket.

The necessary tightness of the valve pair is achieved by this. It is applied lapping paste (boron carbide M40 – 10% microcorundum M20 – 90%: granular fused corundum M 14 – 87%, paraffin – 13%) on valve facets and the cylinder head pocket. The paste is diluted in diesel oil to the creamy state. It is recommended to add surfactant species to the paste, for example – oleic or stearic fatty acids in order to increase the quality and productivity of the process of valve lapping. In this case the productivity increases 50-60%. It is recommended to use the mixture of 40% of grinding powder of gray fused corundum with the gritness of M 14 or M 20 55-58% of diesel oil and 2-5% of oleic or stearic acid for lapping of valves with gray cast-iron pockets. After lapping the surface roughness is R_a = 0,63-0,32 μm, the width of the mat continuous belt is no less than 1,5 mm (Fig. 4).

The allowable difference of width does not exceed 0,5 mm. The repair technology without lapping is used in some overhaul plants. The method is founded on assembling couplings a valve – valve seat (pocket) made with different angles. The valve facet is ground to the angle of 44 ° in a special device and the facet angle of the seat is left without any changes. The angle appearing provides the necessary tightness of the valve pair without lapping, promotes fast running-in of jointing surfaces. Abutment tightness of each lapped valve to the seat of the block head is checked with a pneumatic device (Fig. 5). Air under the pressure of 0,04-0,07 MPa is determined by pressure gauge connected to a cartridge cavity. It is pumped with a pear into the cartridge cavity set above the valve. Pressure drop for 30 seconds indicates the leakage of the coupling and poor valve lapping. In this case lapping is repeated.

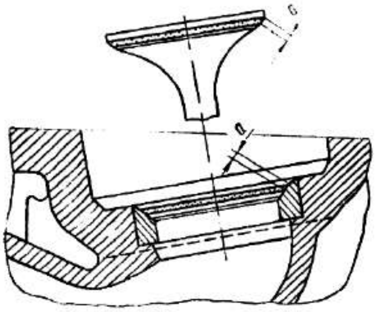


Fig. 4 – Allocation of mat bands on lapped surfaces of working facets of seat and valve

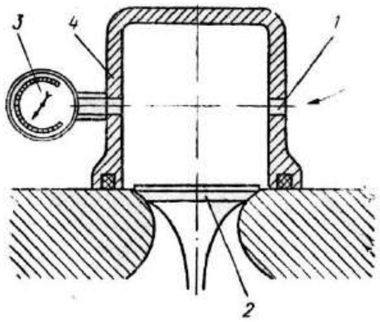


Fig. 5 – Checking valve tightness with pneumatic device: 1 – opening for compressed air supply; 2 – valve; 3 – pressure gauge; 4 – device cartridge

After lapping the valves and pockets must be carefully washed, but the pair can not be disassembled. While assembling, the valves are placed into pockets according to the marking, springs with dentils are pressed with the device. The latter have to abut tightly to the groove in the valve stem and to the valve spring seat.

Springs are tested for elasticity with the device. They are selected so that they were of the same height and elasticity. The roller of the rocker (axle) with wear of the outer surface is restored by chromium coating or dry topping. The bent roller is ground without heating. A permissible ovality of sites for rockers is to 0,02mm and nonstraightlinearity along entire length dies not exceed 0,02 mm after the final processing.

Valve rockers with bushings can have wear of firing-pins and the bushing inner surfaces and threads for an adjusting screw.

If wear of firing-pin surfaces is within admissible limits (no more than 2 mm) it is ground at radius to eliminate wear traces and it is polished to the roughness of at least 0,63-0,32 μm. If the firing-pin is worn more than its admissible value, it is surfaced with powder ПГ-СР4 by gas-powder surfacing. The worn bushing is replaced.

Meanwhile, facets are processed 1,0+0,25×45º on both sides, bushings are pressed in, then they are reamed bushing openings to the normal or repair size as well as the inner surface is strengthened by broaching.

Pushers. Rod surfaces and plates are worn in pushers. Rods are restored by dry topping or chromium coating. Plates of pushers are ground if they have a worn working surface to 0,3 mm. Significant wears are eliminated by gas-powder surfacing with ПГ-СР4 powder and processed to the normal size.

Lubrication system repair

Oil pumps. Their general condition (pressure and productivity) is checked on the stands of КИ-27526 type. The allowable productivity decrease is 10-12% of nominal values.

The main reason of the productivity decrease is the increase of butt-end and radial clearances in the joints of pinion gears with the frame and between bearing surfaces of pinion gear rollers and bushing openings. It should not exceed 0,2-0,3 mm (it is determined by indicating devices).

The main defect of the parts of oil pumps can be wears of pump frames in the joints of pinion gear butt-ends, lid (space plate) planes and butt-end surfaces of pinion gears, roller surfaces, axles and bushings, loss of tightness of valves, thread-stripping and roller spline wear.

There are several methods to restore side jacks of pump bodies. The first consists in shifting of rotation axes of pinion gears into the intaking side. In this case, an opening for a pump roller and the axle of the follower gear (for spacing steel bushes set into them) and jacks for pinion gears are eccentrically bored out. We obtain necessary tightness of pinion gear teeth with side surfaces of jack by 0,7-0,8 mm axle shifting.

The second method involves boring out the side worn surfaces of jacks and setting repair bushings with their subsequent boring out to the nominal or repair size.

Worn frame jacks for the nominal size are repaired by the third method using the epoxy compound A. It is injected into the clearance between the pump frame and the template gage; its outer size corresponds to the nominal diameter of the jacks of force-feed pinion gears.

Lid wear of over 0,05 mm in depth in the places of contact with pinion gears is eliminated by grinding, turning or milling. The allowable nonflatness does not exceed 0,03 mm of 100 mm in length. Worn bushings in lids and frames are replaced with new ones and then they are reamed for the repair size.

Pinion gears of oil pumps with teeth wear in height and length with scratches and scorings are reground for the repair size.

Shaft necks of drive pinions of an oil pump are restored by chromium coating or dry topping.

Worn valve openings of the plunger type are reamed to correct their geometrical shape, new valves are made according to the opening then they are lapped together.

Ball valve tightness is restored by chamfering of the jack until wear traces are eliminated followed by ball deposition on the site.

<u>Oil filters.</u> Filter elements of oil filters are contaminated and lose their flow capacity, and in case of damage they let contaminated oil. The main filter defects can be cracks and frame chips, wears of bushings and axles, thread-stripping, valve tightness failure.

Threaded openings, cracks and faulty sealing are restored by the methods mentioned above. Rotor axle necks worn to 0,1 mm and more are ground on a circular grinding machine to remove traces of wear (of the repair size) or they are restored by electrolytic building-up. Axle bushings are reamed according to the size of axle necks to the normal or repair size providing the clearance of 0,02-0,05 mm in a coupling.

Cooling system repair

<u>Water pump.</u> Defects of water pump parts can be the following: frame cracks, thread-stripping in openings, wear of sites for bearings and bearing sleeves, as well as for a thumb nut on a roller for bushings, gaskets and fan pulleys; wear, cracks and corrosion of blade surfaces of

thumb nuts; wear of the inner bushing surface.

Cracks in frames are eliminated by the methods described in the lecture № 10.

It is applied a layer of the metal on the worn sites for bearings by dry topping or the mixture based on epoxy resin. Then they are bored out to the normal size. Damaged surfaces for bushings are reamed until wear traces is eliminated, then repair bushings are pressed-in with the negative allowance of 0,015-0,045 mm. Bushings are reamed after press-fitting. Unevenness of butt-end surfaces of frames are eliminated by grinding. Face runout should not exceed 0,1 mm.

Worn roller sites of a water pump for bearings and gaskets, as well as damaged threaded surface are surfaced in the carbon dioxide medium, key grooves with the clearance of more than 0,05 mm are milled to get the increased size.

Fan. Fan defects are wear of sites for bearings in pulleys and the conical surface of a gutter for a pass; weakening of rivets, bend of blades and crossbars.

Worn pulley sites are bored out and there is fitted a bushing using the epoxy mixture; then it is bored out to the normal size. Sites can be restored by dry topping with the following boring out. Sheave grooves worn more than at 1 mm are turned until wear traces are eliminated. Weakened rivets are tightened and if openings for rivets are oval in shape they are drilled and rivets of a larger diameter are set. In case blades are replaced, the difference in mass should not exceed 3-5g.

Before assembly unprocessed surfaces of cast iron parts of water pumps are coated with primers (ГФ-0119, ГФ-021), and bushing butt ends – with a thin layer of oil colloidal graphite lubricant (60% of diesel oil and 40% of graphite), the bearing cavity of the frame of the water pump is filled with lubricant (Літол-24 and І-13 40-50 g).

While assembling, a bearing spring, a sleeve gasket ring, a sleeve gasket and a gasket becket, a sealing washer and a closing ring are set in a thumb nut. The ball bearing is pressed-in on a roller using the press and it is set a spline. The water pump frame is fixed in the device, a bearing sleeve of the sleeve gasket as well as an assembled roller are pressed-in, and closing rings are installed. The pulley, the thumb nut and the pump lid are press fitted, the angle bar and the final nipple are driven in.

The fastening nut of the pulley hub is tightened at least by 120 N·m. The clearance between thumb nut blades and the water pump butt-end has to be 1,2 mm (Д-240 does not exceed 1 mm). Projectings to 0,4 mm are allowed.

The fan pulley is statically balanced. The permissible imbalance for the engine of YAMZ type is respectively 0,05 and 0,02 N·m. Testing and running-in of the water pump are carried out on КИ-16378 stand. Leakage is not allowed. Tightness test is carried out for 1 min at the pressure of 0,1-0,2 MPa with and without pump shaft rotation.

Fans are statically balanced. The residual imbalance of fans for different engines ranges within 0,025-0,050 N·m. Balancing is carried out by metal plate welding on the unworking side of the blade.

Feed system repair

Technical and economic characteristics of diesel engines is mainly determined by the state of fuel equipment. Disfunction of its regulation can lead to the capacity decrease and 25-35% falling of diesel efficiency. Symptoms of the feed system disfunction are a difficult start of a diesel engine, decrease of the rated capacity and maximum torque, unstable work, increased exhaust opacity, worsening of efficiency, etc.

In case a disfunction of the feed system is detected, they controll operating conditions of its component parts – high pressure pumps, booster pumps, injectors, filters, delivery pipes.

Design features of the fuel equipment installed on modern diesel engines can be considered on the samle engines – YAMZ, Deutz.

<u>The difference of the feed system of YAMZ engines</u> – an inline high pressure fuel pump also combined into one assembly with an all-speed governor, a fuel feed pump and an injection timing device.

There is an annular groove on the bushing inner surface of a plunger, and there is a radial opening to run off fuel in the wall, it leaks through the clearance in the Pump element. The sealing between the plunger bushing and the pump frame is made by a rubber ring.

Regulators of rotation frequency is all-speed mechanical, which changes the feed of fuel depending on load, maintaining the given by a driver rotational speed of the crankshaft. The regulator is set on the after end of the high pressure fuel pump.

<u>On DEUTZ engines</u> (Fig. 6.) in the cylinder block it is fitted 6 individual fuel pumps, plungers of which are driven through pushers from the camshaft, and fuel feed control is carried out with a common rail connected with an all-speed governor located on the engine butt-end. This design allows increasing the maximum fuel pressure up to 120 MPa

(1,200 kg/cm^2).

Individual fuel pumps are produced by BOSCH (Germany) and they are regulated by the manufacturer. Adjusting fuel feed uniformity with cylinders and the angle of lead of fuel supply are carried out when the pump is set on the engine.

Recently a significant number of foreign diesel engines are assembled by fuel systems of an accumulator type with electronic control – Common Rail.

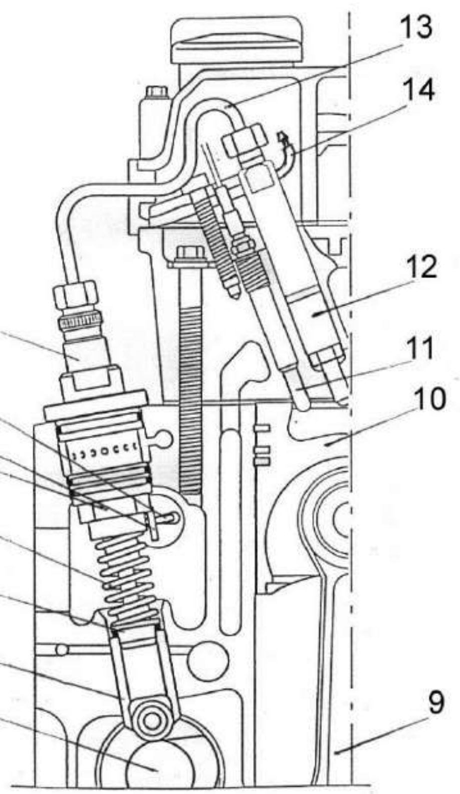


Fig. 6 – Fuel feed system:

1 – high pressure connecting branch;
2 – rack;
3 – plunger lever;
4 – individual fuel pump;
5 – plunger spring;
6 – axial bearing;
7 – pusher;
8 – cam;
9 – connecting rod;
10 – piston;
11 – glow plug;
12 – injector;
13 – high pressure delivery pipe;
14 – connecting branch of fuel runoff from injector

In these systems the high pressure fuel pump supplies fuel under high pressure to the hydraulic accumulator and simultaneously to all injectors of electrohydraulic type. Fuel injection takes place only when the electronic module feeds an electrical impulse to the correspondent injector.

In all these systems high- precision pairs create high pressure, commutate fuel flows by valves and fuel is injected into the combustion chamber by sprayers.

Let us consider the basic defects and restoration methods of these parts.

<u>Pump elements</u> may have the following defects: hydraulic density

loss due to the side surface wear of a plunger and an opening in a bushing as well as a plunger mobility in a bushing due to corrosion, dints, hollows; weakening of a driver site. Hydraulic density of worn pairs is controlled on devices. Plungers and bushings with big dints, scorings and deep corrosion destructions as well as bent and with damaged bearing board are discarded.

Pump elements to be restored are disassembled. Approximately 15-20% of them can be restored by rekitting. In this case, lapping eliminates wear traces and provides pump elements with a regular geometric shape. Then it is selected a plunger for a bushing so that after their simultaneous lapping a clearance is created which will provide the necessary hydraulic tightness. Pump elements which can not be repaired in this way are restored by chromium coating, manifactoring a repair part, plastic deformation, diffusion metallization etc. After building-up pump elements are ground on centerless grinding machines and refined by abrasive pastes on lapping devices (stocks) or lapping and polishing machines. Ovality and tapering should not exceed 0,002 mm. Then plungers are sorted by size groups over 0,001 mm, and finally refined by compound 1-3 μm and re-sorted. Bushings of plungers and dispensers are processed on machines or lapping stocks using a split-design lap 14- and 7-micron compound and the rotational frequency of 200-500 min^{-1} and 40-160 of double run of a spindel per minute are used for lapping.

Ovality, lobing and barrellikeness of bushing openings should not exceed 0,001 mm and tapering – 0,002 mm. Bushings and dispensers are sorted into size groups in 0,001 mm.

While completing, it is selected to the plunger a bushing with the diameter 0,001 mm larger than the diameter of the plunger so that it is forced 2/3 of its length into the bushing. Pump elements are lapped at the same time on stocks with 1-3-micron compound at the frequency of 250-1000 min^{-1} and the number of 20-50 double strokes per minute.

After lapping, the washed and oiled by diesel fuel plunger has to move smoothly along the whole length of bushings under its own weight.

<u>Pressure valves</u> (Fig. 7) may have surface wear of a discharge belt, a shut-off cone, the guide part of the valve, an opening in the valve seat and a plunger bushing. Cracked, chipped valves with deep corrosion damage on surfaces are discarded. Pressure valves are restored by the same technology as their pump elements. 50-60% of valves can also be restored by rekitting. Valves which can not be completed with seats due to the insufficient diameter of the cylindrical belt are restored by the

same technology as plungers. Worn openings in valve seats are refined by cast-iron lapping on vertical finishing machines. Sealed butt-ends are processed on lapping and polishing machines. Pressure valves are sorted into dimension groups in 0,002 mm. Ovality of the guide part should not exceed 0,002 mm, tapering – 0,003 mm, ovality and tapering of a valve seat opening – 0,001 mm. Valves and seats of the correspondent group are lapped together and after washing they are tested for hydraulic tightness for stut-off and unloading belts.

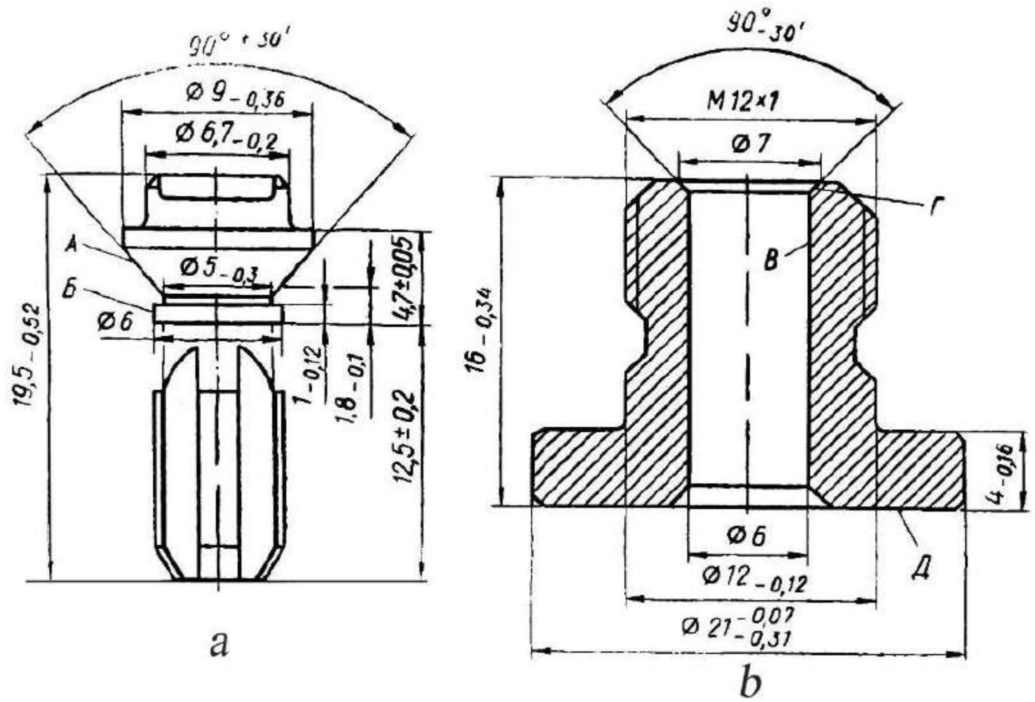


Fig. 7 – Pressure valve of pumps of 4TH–8,5×1type: *a* – valve *b* – seat; *А* – shut-off valve cone; *Б* – unloading belt; *В* – guide valve seat surface to which unloading belt abuts; *Г* – facet to which shut-off cone abuts; *Д* – butt-end to which plunger bushing abuts

Injector nozzles (Fig. 8) may have the following defects: wear of a shut-off cone, carbon formation, jet hole gumming.

In case the coupling needle–nozzle frame is worn, the needle and the frame are disassembled.

The technology of processing and building-up of injector nozzle heads is the same as for plungers. Restored needles and frames are sorted by the diameter of joint cylindrical surfaces, assembled and lapped, so as to provide a 1μm gap. Then the movement of a preliminary washed in diesel fuel needle put out 1/3 of the length from the shell of the injector nozzle at the angle of 45° must take place under its own weight. A needle cone angle must be 40'-1°greater than a injector nozzle cone angle to ensure injector nozzle tightness at a shut-off cone. Cones have to be connected with a ring belt with the width of no more than 0,2 mm. The needle is ground on a prism. Its rotation is transmitted by a rubberized roller. After grinding the needle is lapped, a guide part is lubricated with oil and a cone – with M 10 paste.

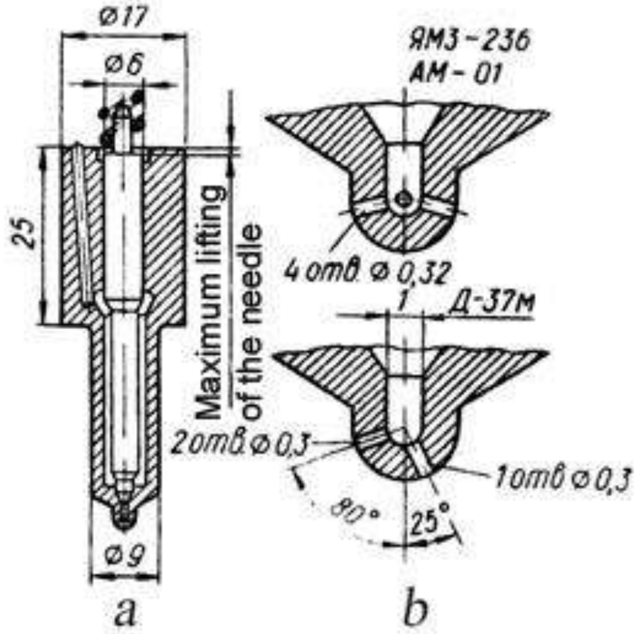


Fig. 8 – Nozzle with many holes:

a – general view;
b – allocation of holes
maximum lifting of needle

The shut-off cone of the injector nozzle is processed by lapping. Carbon deposit is removed from injector nozzles with brass brushes and scrapers. Openings are cleaned out with a steel wire clamped into collet holders.

Restored sprayers are tested for tightness, leakage and the quality of fuel spraying on stands.

Injectors can have wear of a frame butt-end connected to the injector nozzle; wear or thread-stripping on the frame and governing screw, loss of spring resistance.

Injector frames, spring hooks and injector nozzles are discarded if there are more than 2 thread turn of cracks, fractures, disruptions. Wear of injector nozzle butt-end frame is eliminated by lapping on cast-iron plate. While assemblying, injectors are completed with injector nozzles which correspond to the engine brand.

Frames of fuel pumps and regulators may have the following defects: wear of openings for pushers and guide grooves for pusher axles, openings for racks and regulator lever rollers; outer cracks; breaches and threaded wear in openings.

Frames with holes and cracks in internally wired leads, chips of guide groove are discarded. The repair technology of outer cracks in body parts is considered in the lecture № 10.

The worn hole for a rack is predrilled and a manufactured bushing with a line with the negative allowance of 0,1-0,03 mm is pressed into it. Worn openings for a regulator lever roller are bored out and bushings with the negative allowance of 0,075-0,15 mm are pressed into them. Worn surfaces of guide grooves for pusher axles are broached for the increased size. Tapering of an opening does not exceed 0,02 mm, the deviation from the surface perpendicularity for the head is up to 0,1 mm at the length of 100 mm.

Eccentric and crank shafts may have the following defects: wear of matching sites for bearings and joint surfaces with gaskets, a profile of cams and eccentrics, key grooves or grooving walls of the coupling of camshaft-drive gear, the retaining cone and thread.

Shafts with cracks and chips are discarded, camshafts with bending over 0,05 mm are ground on prisms under pressure.

Worn matching sites for bearings and joint surfaces with gaskets are surfaced or built-up by dry topping and then ground for the nominal size. The allowable ovality, tapering and neck beating are no more than 0.02 mm. The profile worn in depth less than 0.5 mm is reground to get an equidistant one on a copy grinding machine until wear traces are eliminated.

Testing, running-in and adjustment of fuel pumps

While a pump is prepared to test beforehand, we carry out the following adjustments. The fork bolt is put so that it is projected 13 mm. The control lever is fitted in the position which corresponds to the maximum feed. Theclamp of the first injection unit is fixed at the distance of 50 mm from the outer joint face, and the other clamps – on the rack so that the distance between the axles is 40 mm. The normal camshaft rotation is checked by making 2-3 turns by hand, the stand is turned on and leakage and other malfunctions are eliminated with the spindle rotational frequency of 400-500 min^{-1}.

There are two phases of pump running-in: initially 15 minutes at 500 min^{-1} of turned off feed without injectors, then 30 min at 600-

700 min^{-1} with injectors at the position of the control lever, which corresponds to the maximum feed. The detected during the test run defects are eliminated.

The desired range of the injection rate from blackout to feeding which corresponds to the maximum capacity is provided by the adjustment of the rack travel.

The normal rack travel of fuel pumps has to be 10,5-11 mm. The rack travel is measured by a caliper from the joint face of the pump to any rack clamp in two extreme positions. The rack travel is regulated by the fork screw of the regulator and fixed by a lock-nut.

Regulator adjustment begins with unscrewing 3-4 turns of the stop bolt for. The control lever is fitted into the position corresponding to full supply. Then the stand is turned on and the nominal rotational frequency is defined. Gently increasing it, we controll the rotational frequency when the fork screw starts moving away from the prism – the start of regulator`s work (the start of fuel supply). The rotational frequency in the beginning of regulator`s work has to exceed the nominal rotational frequency in 10-20 rotations. If adjustment requires, the number of gaskets under the bolt of the limiter of the maximum rotational frequency is replaced. After adjustment 4-12 gaskets must be left under the limiter bolt. If the gaskets can not adjust the regulator, then their number is changed according to the outer or inner regulator spring.

Adjustment of the stop bolt is carried out at the nominal rotational frequency of the pump shaft. Twisting it slowly, the fork screw is observed. When the fork screw begins to move away from the prism the bolt is unscrewed for 1 turn and fixed. In case the rotational frequency of the pump shaft increases in 80-100 min^{-1}, the pump rack has to move away to the extreme position which corresponds to the turned off feed.

Productivity and evenness of fuel supply are regulated by turning the plunger in the bush sleeve at the nominal rotational frequency. The control lever is in the state «Full supply». Productivity is regulated by moving clamps on the rack.

Unevenness of fuel supply by pump sections is determined by the following formula:

$$H = \frac{K_{\max} + K_{\min}}{K_{cep}} 100, \qquad (1)$$

where H – unevenness of fuel supply, K_{max} i K_{min} – the biggest and the smallest amount of fuel supplied by the pump section;

$K_{cep} = \dfrac{K_{\max} + K_{\min}}{2}$ – an average amount of fuel supplied by pump sections.

Unevenness of fuel supply at the nominal mode should not exceed 3%.

The time of initial fuel injection is checked and regulated at the nominal rotational frequency at the position of the lever which corresponds to the full supply. The angle of initial injection is determined by the device provided for the design of this stand (a stroboscopic device, a digital measuring device, etc.).

The difference between the angles of initial fuel injection of separate sections of the fuel pump should not exceed ± 0,5°. The angle of initial injection is regulated by the pusher bolt and fixed by nuts.

The final regulation of productivity and evenness of fuel supply are carried out so as the preliminary one. Re-adjustment is needed because the productivity of the pump section changes when we adjust the angle of initial injection. The evenness of fuel supply must meet the requirements of the manufacturer.

Fuel supply during starting condition must be 2-2,5 times higher than the nominal one. While testing the starting fuel delivery, we adjust the rotational frequency of the pump shaft as 80-100 min^{-1}, a dresser is removed and the fuel pump productivity is determined according to the control lever position which corresponds to full supply. The cycle feed of fuel pumps of TH type must be at least 140 mm^3/cycle.

A dresser roller should return into its initial position when the rotational frequency increases to 650 min^{-1} (the control lever of fuel supply at the mid position).

Testing, running-in and adjustment of distribution pumps

Running-in of distribution pumps is carried in the following way. While adjusting the angle of initial fuel supply, the inlet connecting branch of the pump is jointed with a stand pump by a high pressure hose. And it is fitted a technological cap on the outlet connecting branch. High pressure connecting branches are jointed with the drain holes of the stand by transparent tubes.

The regulator control lever is set into the position «Maximum supply». The stand pump is turned on, its pressure is risen to 3 Pa. Slowly turning over the pump shaft by a tap wrench, the overlap moment of the inlet port is fixed by the plunger butt-end determined by the fuel supply termination into the transparent tube of the correspondent section. For all pump brands of НД-21 the initial supply angle of the first section must be 57±1°. It is adjusted by the pump body turning relatively to the mounting flange. Supply alternation by the other sections relatively to the first one should be with the accuracy of ±0,5°.

Fuel supply at the starting rotational frequency of 100 min^{-1} should be 160-180 mm^3/cycle. While measuring, the regulator control lever must be in the position of the maximum rotational frequency.

If cyclic feed does not meet technical requirements, then the rod length of the regulator is changed or the eccentric finger is turned (depending on the manufacturing date of a fuel pump).

The beginning of the regulator operation is adjusted when the control lever stops into the screw limiting the maximum rotational frequency. When you turn the corrector so that its rod does not touch the regulator lever, the rotational frequency is set (corresponding to the beginning of the regulator operation) and the fuel pump productivity is determined (must meet the nominal productivity).

Productivity is adjusted by the limiter screw of the maximum rotational frequency. If screws do not succeed, then the number of working regulator spring coils is changed by turning spring lugs. Then the rotational frequency of the cam roller is increased to cutout of fuel supply. Adjustment of the «Stop» Screw is carried out when the rotational frequency of cutout does not meet technical specifications. The nominal fuel supply is adjusted at the rated speed when the control lever stops into the limiter screw of the maximum rotational frequency. The supply decreases when the corrector body is screwed, and increases, when it is unscrewed.

Unevenness of fuel supply by connecting branches should not exceed 4%. If it exceeds this parameter, the assembled pressure valves are replaced.

Cycle fuel supply at the mode of the maximum torque must 12-20% increase comparing to the nominal one. The increase of the feed is regulated by the corrector screw. After regulation the nominal fuel supply is re-regulated.

Turbocompressor repair

When a turbocompressor is in service, the following defects appear: wear of bearing openings for a rotor shaft, shaft necks for bearings and bushings in grooves for sealing rings; cracks in turbocompressor frames; rotor imbalance; bending of blades of working turbine blades etc.

Bearings with worn inner openings are restored with figured rollers by local pressure.

Restoration in assembly involves preliminary operations of grinding and lapping of the center hole from the wheel side.

Worn shaft necks are restored by dry topping with the following grinding or the worn area is cut on a turning machine and a work material is welded on a friction machine. Then we carry out tempering, grinding in centers, SHF hardening and finishing processing of the shaft.

Worn grooves for sealing rings are restored by setting a repair bushing with the further mechanical processing to get the nominal size.

Turbocompressor assembly

Before assembling a rotor is balanced on the stand ДБ-10. It is installed on supports which oscillate only in one plane passing through the axle of the rotor rotation. This allows to determine the vibration amplitude of each support with the help of sensors. The rotor rotates from the electric motor through the pass. Sensor signals are sent through the measuring planes and the amplifier the device; its scale is graduated in terms of imbalance. The angular placement of imbalance is determined by the stroboscopic method. The inertialess lamp lights at the maximum deviation of supports and illuminates the points of the technological bushing fitted on the rotor shaft. Balancing can be carried out with the accuracy of $0{,}05 \cdot 10^{-4}$ Nm, rotational frequency of the rotor shaft is 15,000-25,000 min^{-1} on a balancing machine.

Balancing is carried out in two stages: at first, separately the rotor shaft in assembly in the turbine wheel plane, and then, after fitting and fixing with a special compressor wheel nut – the rotor assembled in the compressor wheel plane. Imbalance must not exceed $0{,}2 \cdot 10^{-4}$ Nm in both planes. The metal from disks and blades is removed in places provided by the drawing.

Disassembling of rotor parts in assembly after dynamic balancing is strictly prohibited. It is put a mark with a broach file on the outer surface of the rotor screw against the label at the rotor shaft butt-end.

After balancing the rotor is disassembled and fitted into the bearing of the middle frame. Meanwhile, the marks on the rotor shaft have to match the marks on the supporting bushing, oil baffles, compressor wheels and nuts to prevent rotor imbalance. The rotor has to rotate in bearings easily, the axial play has to be 0,17-0,3 mm. The middle frame of the turbocompressor is connected with frames of the compressor and turbine using gaskets to seal joints. After assembling the turbocompressor is subjected to running-in and testing on special stands placed in boxes.

The turbocompressor is fitted on the stand frame using pneumatic clams. In this case, the inlet opening of turbocompressor`s scroll (Fig. 9) is connected to the combustion chamber.

Fuel injected by the nozzle is burned there. Air necessary for fuel combustion is partly fed from the turbocompressor and partly – from the compressed air pipeline. Gases generated during the process of fuel combustion are sent into the turbocompressor turbine. We regulate fuel consumption and the amount of air supplied from the external compressor to set the desired mode of testing.

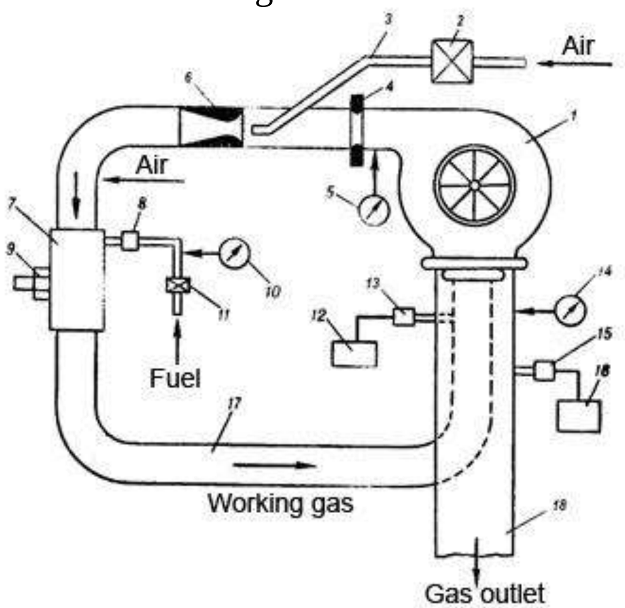


Fig. 9 – Scheme of stand to test a turbocompressor: 1 – turbocompressor; 2 – faucet; 3– tube to supply compressed air; 4 – throttling orifice; 5, 10, 14 – distance pressure gauges; 6 – diffuser; 7 – combustion chamber; 8 – injector; 9 – spark plug; 11 – faucet to regule fuel consumption; 12, 16 – galvanometers; 13, 15 – thermocouples; 17 – pipe to supply gases to turbines; 18 – exhaust pipe

Turbocompressor bearings are lubricated with diesel oil under the pressure at least 0,3 MPa and the temperature 85-95°C of the stand lubrication system.

Every repaired turbocompressor is subjected to running-in and control and delivery trials on the modes recommended by the specifications for complete overhaul of the turbocompressor. Selective quality check of part run-in is carried out by partial or complete disassembling of every twenty turbocompressor. After revision the turbocompressor is subjected to iterative running-in.

Assembling, running-in and engine testing

Block-crankcase assembling begins with fitting bush sleeves. Mounting faces and the upper plane of the block-crankcase are cleaned from carbon deposit before cylinder sleeve press-fitting. Sleeves are set into the block without sealing rings and it is checked scrolling in mounting faces (should be free). After installing a new sealing ring into the groove of the lower face for a bush sleeve, we check if a bush sleeve ledge butt-end overhangs above the block surface when we press the bush sleeve with the force of 9 kN.

The ledge butt-end of cylinder sleeves is checked by the indicating device (Fig. 10), fitted with the base on the sleeve. Moving upward, the pin turns over the lever which moves indicator`s leg through the rod. All sizes of bush sleeves and pistons must be of one size group.

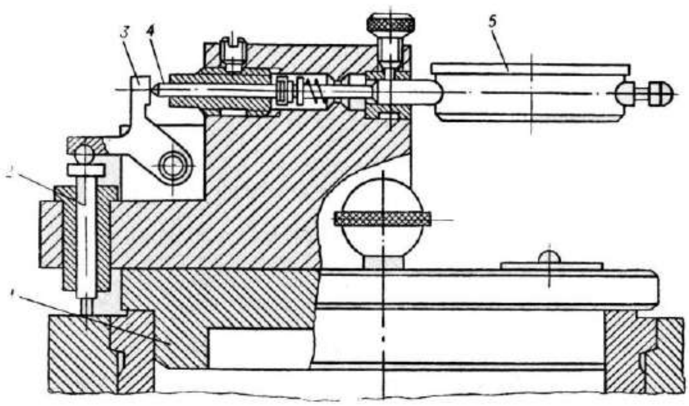


Fig. 14 – Device to control bush sleeve ledge butt-end above cylinder plane: 1 – base; 2 – pin; 3 – lever; 4 – rod; 5 – indicator

Crankshaft fitting. At first, we check the accuracy of crankshaft kitting-up with bushes which are selected according to the repair size of crankshaft necks. There have to be completeness marks on lids and fastener means. It is provided an opening for lubrication in bushes fitted into the bearing bed. It has to match with the oil channel in the block. Swinging bushes in pockets or their hanging on fixing projections are not allowed. Lids with bushes are fitted and the nuts of main bearings are tightened evenly in 2-3 steps.

Inner dimensions of bushes are measured with an indicator hole gage. If clearances are within admissible limits, marks are put on the butt-ends of screw nuts and stud pins. Bushes are accurately wiped and greased with motor oil after main lids are removed. The crankshaft is put into the bearing bed, thrust half-washers of length travel of the shaft are set, the lid is fixed where the thrust half-washer is located and length travel of the shaft is checked. The rest of main bearings is fitted and fixed until marks coincide in 2-3 steps in the following order: 3, 1, 5, 2, 4. Nuts or studs of main bearings are cottared by locking washers or wires.

Instalation of connecting rod and piston group. The cylinder sleeve reflector, the piston outer surface and the lower head of the connecting rod with fitted bushes are wiped with clean cloth and greased with motor oil before fitting pistons assembled with rings and connecting rods into the block-crankcase. They check the correspondence of size groups of pistons and cylinder sleeves. Locks of piston rings placed close to each other have to be at the angle of 180° relatively to each other. The piston is fitted into the bushe sleeve using a special device or a taper mandrel and technological sleeves.

For engines SMD-60 and SMD-62 pistons assembled with connecting rods are fitted into the cylinders of the block-crankcase so that arrows on piston bottoms are directed to the water pump, and in engine YAMZ replacement of combustion chambers in pistons is directed to the diesel axle. The piston bottom in the top dead point must protrude (deepen) above the block plane.

Protrusion (deepening) of a piston for diesel engines SMD-60 and SMD-62 must not exceed 0,5 mm. It is measured by an indicating device. The connecting rod is jointed with the crankshaft neck, and connecting rod bolts are tightened using a torque-control wrench ORG-8928.

The torque of crankshaft after tightening of all connecting rod bolts should not exceed 50 Nm.

Installation of oil pump and tray of block-crankcase bottom lid. Before oil pump is set, they check easy rotation of its pinion gears. Dints on pinion gear teeth are not allowed. Guide pins of oil pump must enter fitment bores tightly. The separation plane of the block-crankcase is lubricated with sealant. When the oil pump is fitted, spring washers are placed on a pin. Fastening nuts are hard and fixed. Free ends of radial tubes and tubes to oil pumps are protected from contaminations. Tubes are finally fastened to the oil pump frame when free ends on block-crankcase are fixed. Spring washers are placed under fastening bolts of tubes. Bolts are hard and fixed. While assembling, the clearance between gear drive teeth of the pump has to be within 0,15-0,7 mm.

<u>Installation of distributing shaft, gear carrier and front lid.</u> Non-flatness of abutment of the gear carrier to the block-crankcase and pinion gear lids to the block-crankcase must be no more than 0,15 mm at the length of 200 mm (checked in compressed state). The processed surfaces of the gear carrier should not have dints, dents and other damages. The gasket of the gear carrier is lubricated with sealant on both sides. Fastening bolts of the gear carrier to the block-crankcase are uniformly fastened hard and fixed, turning down the edges of locking washers on the edge of bolts.

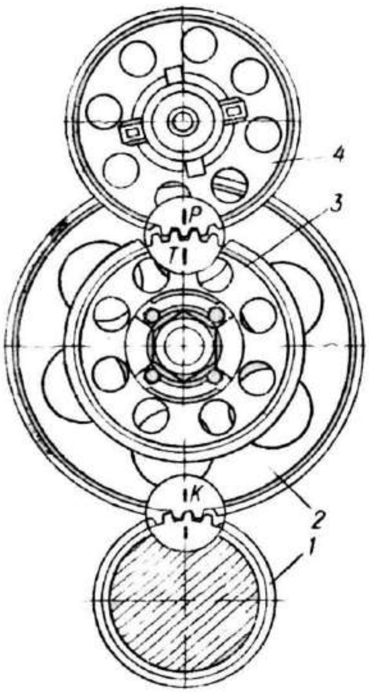


Fig. 11 – Installation scheme of timing gears of diesels of YAMZ type:

1 – crankshaft gear;
2 – camshaft gear;
3 – intermediate gear;
4 – fuel pump gear

Before the distributing shaft is fitted, pushers, bearings of the distributing shaft and hole surfaces for pushers in the block-crankcase are blown out with compressed air. Bearings of distributing shaft necks and pushers are lubricated with motor oil. Pushers must move freely without jamming in the openings of block-crankcase, the distributing shaft must turn over freely without jamming in bearings from hand efforts.

Axial movement of the distributing shaft has to be for YAMZ-240B – 0,121-0,265 mm.

Pinion gears on distributing shafts are fitted on splines. The nuts winded on the threaded shaft end keep them from axial movement. On YAMZ engines pinion gears of distributing shafts enter into interlocks with crankshaft gears (Fig. 11), on D-240 – through the intermediate gear (Fig. 12). Pinion gears of gas distribution are fitted by marks left on teeth and near cavities. The side clearance between pinion gear teeth is within 0,1-0,6 mm.

Lid surfaces of the gear carrier should not have dints, dents and other damages. Gaskets of pinion gear lids are lubricated with sealing paste before fitting and put on gear carrier using a guide pin and then they are fixed. The front support is fitted on block-crankcase pins and fastened with bolts with locking washers, bolts are fixed by bending the locking washers on the edge of bolt heads.

The rubber sleeve gasket is pressed-in against stop, a spline is fitted into the groove of the crankshaft and the crankshaft pulley is press fitted. The fitted ratchet is tightened, and then the flywheel housing and flywheel are fitted.

Installation of cylinder head and valve mechanism. Mating faces of block-crankcase and cylinder heads are wiped, the gasket is fitted on the block-crankcase surface with wide side of the fringe having lubricated its both sides with sealant or graphite paste СК-2/6-13. 30 g of motor oil are poured in each cylinder before installation of the cylinder head. Cylinder fastening nuts are tightened in a special sequence in several steps. At one time nuts are tightened no more than at two panes. Finally, they are tightened with a torque-control wrench.

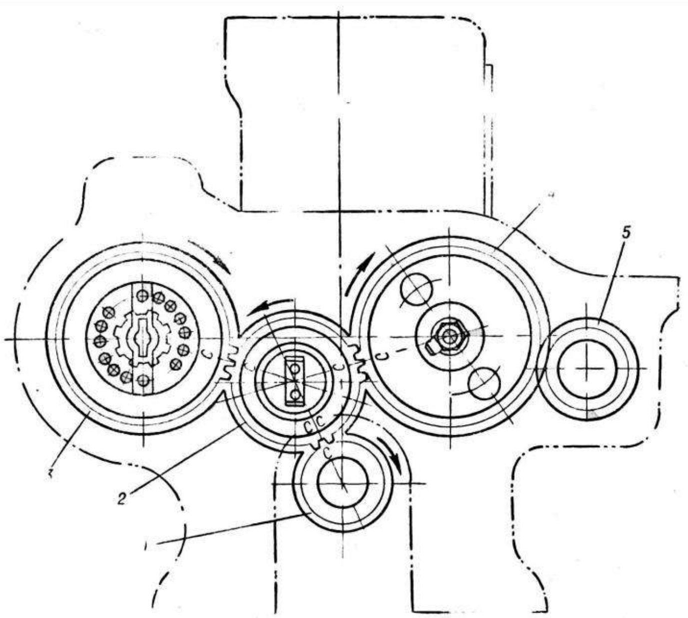


Fig. 12 – Installation scheme of timing gears of Д-240 і Д-144 diesels: 1 – crankshaft gear; 2 – intermediate gear; 3 – fuel pump gear; 4 – camshaft gear; 5 – pump drive gear of hydraulic system

Pusher bars are fitted as well as the valve mechanism in assembly and it is fixed. Rockers have to turn over freely on the axle and do not have transverse vibrations and rocker panes have to abut to the butt-ends of valve pivots without warpings.

There has to be a clearance between the valve and the rocker, behind the piston in the top dead point; it provides a valve fit on the seats, compensation of thermal expansion of parts of the valve operating system and their reliable operation.

The decompression mechanism is included to control the valves of in-line engines. Watching the valve rocker of the first cylinder, the crankshaft is slowly rotated. Meanwhile, both valves (the exhaust one and then the intake one) open and close. The top dead point is determined when the intake valve is closed.

Piston location in D-240 diesels close to the top dead point is determined with the set bolt (probe). When the intake valve is closed, the bolt is screwed out of the threaded opening of the back sheet and fitted into the same opening with the plane end. When the bolt gets into the opening on the flywheel, it corresponds to the piston position of the diesel engine to the top dead point, D-240 – 26°. When the intake valve of the first cylinder is closed in diesel D-144, the crankshaft is turned over until it coincides with the neck of the top dead point on the crankshaft pulley with a mark on the index. When the the top dead point is detrmined, the decompression mechanism is fitted into the state «Off».

The clearance between the valve rod and the rocker panes is checked and if necessary, both valves of the first cylinder are regulated. For this a governing screw lock-nut is loosened, the probe of necessary thickness is fitted between the rocker drop point and the valve rod head. Turning over the governing screw with a screwdriver, the probe is moved to the point where it is slightly pressed by the rocker (Fig. 13). Keeping the screw in this position, the lock-nut is tightened.

Then the clearance is checked again. The probe does not have to protrude freely. After adjusting both valves of the first cylinder, the valves in other cylinders are adjusted in the same sequence. The operation order of four-cylinder in-line engines is the following: 1-3-4-2.

Gaps in the valves of V-shaped eight-cylinder engine YAMZ-238NB are regulated in the following way. The crankshaft is turned over until the marks on the crankshaft pulley coincides with «0» mark on the lid of the case of timing gears. In this case, the piston of the first cylinder is located in the top dead point. Gaps in valves of the second cylinder are adjusted. Then gaps in the fifth cylinder are adjusted turning over the shaft by 90°. To adjust the gaps of the other cylinders crankshaft is turned over each time by 90° and valves are adjusted according to the operation order. Having checked the correct placement of gaskets, the cylinder head lid is fitted after valves are adjusted.

Installation of the fuel pump and injectors is carried out according to specifications after adjustment on the stand. Openings in the fuel pump and injectors are closed with protective caps. The lead angle of fuel supply has to correspond to the diesel brand while the fuel pump is fitted. Setting error of the lead angle of fuel supply must not exceed 1,5° on the turning angle of the crankshaft (the angle of fuel supply start is determined with a momentoskop). The lead angle of fuel supply for engines is 16-18°.

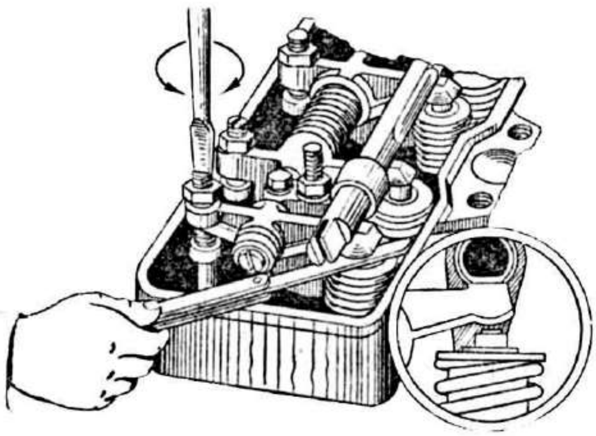


Fig. 13 – Adjustment of clearances in valve mechanism

The mating face of the flange of the fuel pump has to be clean, without dints and dents, the gasket – without tears and layerings. The pump is fastened to an attachment and fuel tubes are joined.

An injector set must have one group by the flow capacity. A sprayer with four nozzle holes with the diameter of 0,34 mm is used on YAMZ; a three nozzle sprayer with holes of 0,3 mm is used on D-144 and D-21; a sprayer with four holes with the diameter of 0,29mm is used on D-240.

Running-in and testing of engines during in-line repair. After assembling the engine is checked for completeness. The area of testing and adjusting engine has to be equipped with a running-in and braking stand which allows to carry out running-in and testing of diesel without its removing from the tractor (through power shaft). During running-in and testing, there are the following conditions when selecting a stand for diesel of the corresponding brand: torque and maximum rotational frequency of diesel crankshaft must not exceed admissible limits of stand technical characteristics.

They carry out hot and cold running-in of an engine while it operates without load and under load as well as engine testing for capacity and fuel consumption on the stand. The engine is subjected to running-in and testing after in-line repair or complete overhaul, replacement of piston rings and other parts of the cylinder-piston group of the crank mechanism.

To carry out cold running-in, the stand electric motor is turned on and the rotational frequency of the diesel crankshaft is adjusted within 500-700 min^{-1}. Running-in duration is 3-5 min. During cold running-in of the diesel its lubrication and cooling systems must meet the following requirements: oil pressure in the main diesel oil pipeline must be at least 0,08 MPa at the minimum rotational frequency of the crankshaft; the lubricant temperature in the diesel pan (or in front of the oil radiator) must not exceed 75°C, and the coolant temperature at the outlet of the cooling system is 80°C.

After cold running-in coarse and fine filters are accurately cleaned and washed in diesel fuel.

Diesel is subjected to running-in at idling speed (no load) for 10 minutes, with smooth increasing the rotational frequency of the crankshaft from minimum stable to maximum at idling speed.

Diesel running-in under load is carried out for 20 minutes (5 min on the diesel torque, which is 25, 50, 70, 90 ± 5% of the nominal one). The lever position of the rotational frequency controller must correspond to full fuel supply.

After hot running-in if it necessary, nuts of stud pins (bolts), fasteners of cylinder head (heads) are checked and tightened. Fuel and lubricant leakages are not allowed.

The value of the diesel rating moment is determined by the following formula:

$$M_H = \frac{9550 Pe_H}{n_H}, \qquad (2)$$

where Pe_H and n_H – a nominal value of effective capacity, kWt, and a rotational frequency of crankshaft, $min.^{-1}$ according to the passport data.

Two types of accelerated running-in of engines are used on trade shops: using diesel fuel with АЛП-4Д additive and electrical direct current feed to friction couples.

Acceptance testing is carried out for 30 min to control repair quality (assembly and adjustment) of diesels in production. Testing includes checking the maximum and minimum stable rotational frequency at idle speed; lubricant pressure in the main oil pipeline at the nominal rotational frequency under load and minimum rotational frequency at idle speed; coolant temperature in the outlet of the diesel engine; oil temperature in the pan or main oil pipeline; capacity at rated speed and location of control bodies of the rotational frequency controller which corresponds to full fuel supply; fuel consumption at rated capacity and location of control bodies of the rotational frequency controller which corresponds to full fuel supply. During acceptance testing diesel characteristics are basically the same as those during hot running-in under load.

Lecture № 12
Repair peculiarities of transmission and running gear

Repair of transmission assemblies and units

Friction clutch. The clutch housing of tractors and motor vehicles may have chips and cracks; wear of the center hole, holes for a starter and in supporting legs, for bushings, clutch fork etc.

Cracks of the clutch housing are eliminated by arc or gas welding. Worn holes are surfaced or reamed and bushings are pressed into them.

Worn at height supporting legs are surfaced, or covers are welded to them and then they are milled. Loosen shaft bushings of clutch forks are pressed-out and the opening is reamed with the following fitting a bushing of the repair size and its opening is finally reamed.

Driven clutch plates may have wear of friction facings, holes for rivets, hub splines; disk warping; weakening of hub fastening rivets; face runout of hub flange.

Loosen rivets which connect driven disks with hubs are eliminated. Worn holes for rivets in disks, hubs and oil baffles are reamed to get a repair size with the following setting repair rivets and their riveting in the hot condition.

Hub splines worn over admissible sizes are restored by plastic deformation.

Friction facings worn over admissible thickness are replaced with new ones, and warping of driven disks is eliminated by dressing on a plate. Friction facings are fixed with hollow brass, copper and aluminum rivets or adhered with glues BC-10T and BC-350. Minimum recesses of rivet heads in new facings is 0,6-2 mm, admissible spot clearances between the disk and the facing is 0,1-0,4 mm and face runout of facing surfaces relatively to the axle of the splined hub is 0,5-1,2 mm, unevenness of the friction facing surface is 0,3-0,8 mm. The difference in the thickness of driven disks with facings must not exceed 0,2-0,3 mm. Assembled driven disks are statically balanced after repair.

The main defects of pressure plates, driving and intermediate disks can be wears, scorings and warping of working surfaces, cracks and fractures. In case working surfaces have wears and scorings, disks are turned and ground to eliminate wear traces. Disk thickness must not be lower than the minimum value (e.g, for engines of SMD-60 type – 24 mm).

Clutch shafts may have wears of matching sites for rolling bearings, sealing in the master clutch; wears and damages of splines, key grooves and threads.

Matching sites for bearings and slots are restored by the technology given in the lecture №10.

Worn at height cams of release levers are surfaced with a flux cored wire of high hardness, then they are ground to get the nominal size according to the template gage. Worn holes in levers for a pin or a quill axial bearing are reamed for the pin of the increased size. The difference in weight of release levers of one coupling must not exceed 10 g, and in the engine of SMD-60 type –15 g.

Springs installed on one coupling are selected at the length and elasticity.

When a friction clutch is assembled, they carry out adjustment to fit cam surfaces of release levers in one plane and on a particular distance from the friction surface of the pressure plate according to specifications. Reciprocal deviation of cam thrust faces to 0,4 mm is allowed. In two-disk couplings the gap between the spacing disk and thrust screws is adjusted. The friction clutch is assembled with a special device (Fig. 1).

The complex coupling is balanced on the stand. The imbalance of the pressure plate with a clutch cover, for example, in engine ZMZ-53 does not exceed 0,0036 N·m. The plate is balanced by drilling openings in bosses with a diameter of 11 mm to the depth less than 25 mm.

After complete assembly of machines, it is adjusted the clearance between release levers and an outtake bearing and the free motion of the clutch pedal.

The gearbox may have the following defects: increased noise; heating of frames, shafts and box levers; oil leakage; complicated turning on and off of gears; torque decrease in the boxes where frictions are hydraulically operated.

These defects result from wear of fitment bores for bearings and their jacks; cracks in jumpers between holes in side and bottom walls; damage of adjusting pins and threads in holes what results in irregularity of the center-to-center distance and shaft parallelism, alignment and parallelism of opening axles and the center-to-center spacing; wear of gear teeth at thickness as well as at length; gap irregularity in couplings of bearing fits in the gearbox frame and shafts with bearings; wear of synchronize parts, drives and gear actuation coupling links, hydrosystems and friction clutches of the gearbox.

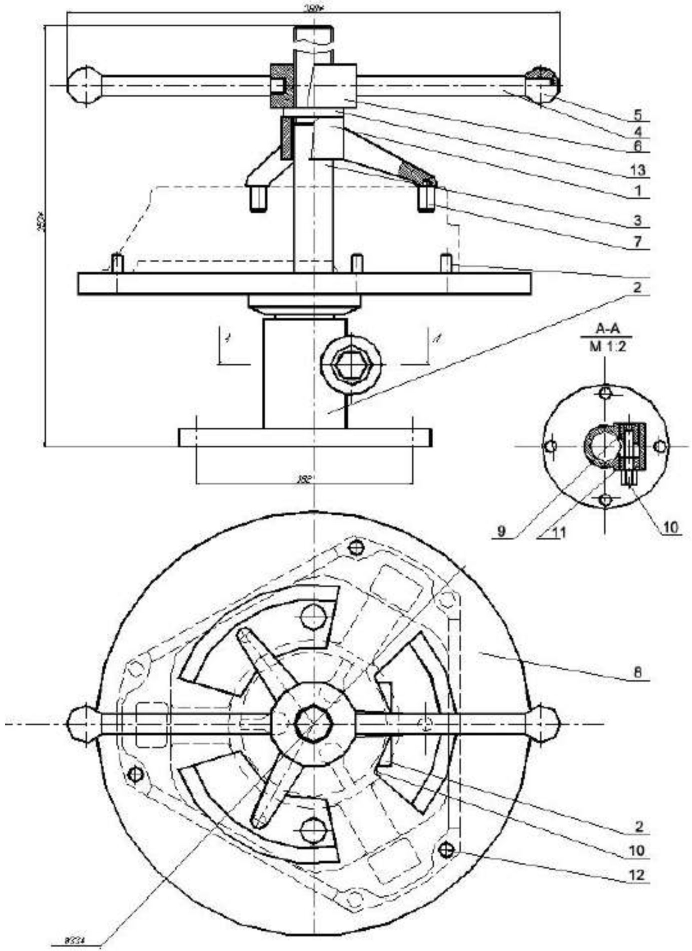


Fig. 1 – Device to assemble and disassemble friction clutch:

1 – tee piece;
2 – stake;
3 – shaft;
4 – handle;
5 – handle ending;
6 – nut;
7 – guide;
8 – bearing plate;
9 – catch nut;
10 – catch bolt;
11 – catch bushing;
12 – pin;
13 – washer

The complex coupling is balanced on the stand. The imbalance of the

Gearboxes are disassembled on special stands using kickoff mechanisms and devices. It is not recommended to disassemble main suitable parts.

Gearbox frames may have chips and cracks, wear of matching sites for rolling bearings, holes and butt-end surfaces of bosses for the block of reverse gears.

Wear of butt-end surfaces of bosses for the block of reverse gears is eliminated by milling.

The repair technology of frame parts, shafts and axles is described in the lecture № 10.

Side surfaces of jaws of gear shift forks which are bent over 0,3-0,5 mm are ground on a plate. Misalignment of surfaces coupled with a gear groove relatively to the axle of the opening must not exceed 0,1 mm at extreme points. Worn jaw side surfaces are surfaced.

Bent rollers, rods and levers are ground in the cold state.

Roller beat can be up to 0,1 mm. Worn surfaces are surfaced. After bearings having been pressed in, the clearance between the jack bead and the outer ring butt-end of a bearing must not exceed 0,1 mm, and between shaft bead and the inner ring butt-end is 0,05 mm on the arc of 90°.

Moving gears must move freely along shaft splines. Clearances in spline joints of gears and shafts are 0,025-0,4 mm. Mismatching of teeth butt-ends of new gears on the manual-on position must not exceed 0,5-1,0 mm and gears that were in operation must not exceed 2 mm.

While secondary shafts and gearbox clutches of tractors of T-150 type are being assembled, they watch that one arrow on the back clutch and two arrows on the front clutch are directed along tractor movement and placed on the top, and the line at the front shaft butt-end must be turned up (Fig. 2). Clutch operation is check with the air under pressure of 0,2 MPa fed in turns to drillings on the front shank end of the secondary shaft. In this case, the plates of the corresponding clutch must be pressed with the piston, and after pressure drop – to return into the initial position.

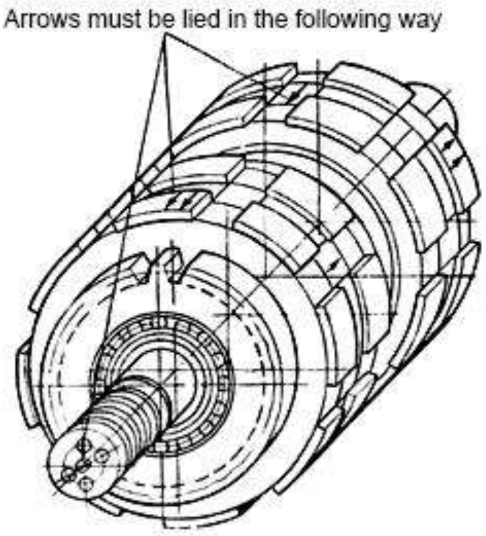


Fig. 2 – Assembling diagram of secondary shaft and hydropressure clutches of tractor of T-150 type

The four-disk (as for the number of driving disks) hidropressure clutch is fitted from the side of two arrows and the five-disk one from the side of one arrow. In the assembled clutch the total clearance between disks on the four-disk side are as follows: maximum – 5,51 mm, minimum – 1,38 mm; on the five-disk side: maximum – 6,36 mm, minimum – 1,53 mm.

Disk leaf springs have to be shifted at the angle of 45° relatively to each other.

The side clearance between teeth of cylindrical gears of any gear have to be 0,2-0,5 mm.

The milled groove of the lower cartridge 150.37.122 is shifted with the line put on the box frame.

While a distributor on the gearbox of T-150 tractor is being set, it is provided a uniform clearance (0,15 mm) between the generating line of the shank end of the secondary shaft and the distributor bushing controlled with the probe.

While a pump drive of the hydraulic system is being set, the side clearance between teeth of the conical gear couple must be 0,2-0,4 mm. It is adjusted by selection of gaskets A of the conbical gear and gaskets Б of the gasket frame (Fig. 3).

After assembling, the gearbox is subjected to running-in without and under load and tested on special stands.

A gearbox is subjected to running-in for 2-3 min on all drives of front and back moves. They are loaded with a special torque while testing. We check operability of fixing and locking devices, ease of gear changing, operation of valves and oil pumps, absence of oil leakages, knocks, gear noises and part overheating. Part heating to 65°C in winter and 85°C in summer is not allowed.

The cardan drive may have beating (vibration) of the cardan shaft; weakening of fork fastening; side and butt-end play of the crossbar in bearings, wears in spline joints; wears and damages of sealings and bearing gaskets and spline joints; seal failure of lubricators and crossbar safety valves. These cardan drive failures result due to part defects.

The cardan tube can have a shaft bend, wear of splines and fork openings, thread damage in holes.

The bent cardan shaft is ground on the stand. In case outer splines are worn, shafts are repaired by surfacing and following mechanical processing or a spline end is replaced with a new one.

Worn fork holes for cartridges quill axial bearings are repaired by surfacing or dry topping with the following mechanical processing.

Thread damages in fork holes is repaired by surfacing and the following threading of the nominal size. The cardan shaft fork with a worn spline shank end is surfaced and processed to the nominal size.

Worn holes for quill axial bearings and threads in holes for fastening bolts of lids are repaired as well as in cardan shaft forks.

Crossbars of cardan joints are cemented to the depth of 1,1-1,9 mm, hardened and released to 58-65 HRC. Worn crosspins are restored by surfacing with the following mechanical processing to the nominal size or by plastic deformation or chromium coating. The hardness of surfaced crosspins must be at least HRC 45.

Before disassembling cardan shafts, a mark is applied to fix their reciprocal placement in order to keep factory balancing and shorten the process of part grinding after assembling. Parts with high processing accuracy, for example, quill axial bearings of shafts are removed especially carefully.

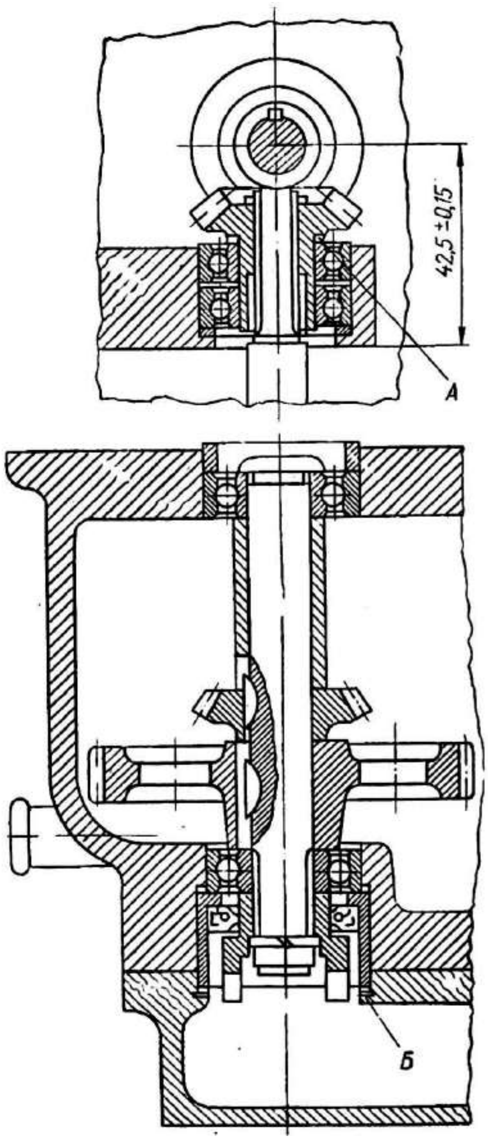


Fig. 3 – Installation diagram of pump drive of hydraulic system of gearbox of T-150K tractor:
A – filler block of conical gear;
B – filler block of gasket frame

Cardan shaft beat of a tractor or motor vehicle should not exceed 0,4 mm near forks, at the length of the tube – 0,8 mm, and intermediate shaft beat near the shut-off butt-end of the neck – 0,1 mm. The allowable axial play on crossbars is no more than 0,24 mm.

While assembling, a slide fork is set into the spline bushing of the intermediate shaft so that opening axles for bearings are in one plane.

Cardan shafts are assembled and disassembled using special equipment.

<u>Driving axles</u> of tractors and motor vehicles can have problems which cause typical sounds and smells of burnt lubricant, increased temperature of frame parts, worsening of plant controllability, jerks while moving from the place, oil leaks in sealing areas of parts and joints of assembly frames, increased vibration and loss of speed of tractors or motor vehicles.

While disassembling, housings of reduction units must not be disassembled with lids of differential bearings as they are finished at the same time.

While disassembling of the differential, right and left cups should not be disassembled. Cups with chips and cracks are discarded. Dents, scorings and butt-end wears for the washer of the axle drive gear are eliminated by processing of the butt-end surface to get a correspondent repair size.

Wear of holes for coupling bolts in the cup are eliminated by drilling of new holes in the spaces between the old ones. The spherical surface for satellite washers with dents, scorings or wears are reamed with form-milling cutters to get the repair size. Instead of worn holes for crosspins, new holes are drilled; they are placed at the angle of 45° to the worn ones.

Accurate conical gear meshing of the main gear and in the most of modern tractors is determined only while assembling after repair or after changing parts of back axles. Fitting a drive gear is checked with template gages and devices.

Peculiarities of assembly of rear axles is the need to regulate of conical gear meshing of the main gear which involves accurate placing of gears relatively to each other and getting the normal side clearance between their teeth as well as the clearance in conical roller bearings.

Gears are fitted correctly if the tops of their initial cones coincide at the point *O* (Fig. 4) and the generating lines of initial cones – with line *OC*. Therefore, while the gearbox is assembled, the gear of the secondary shaft is fixed at the distance *A* from the gear butt-end to the finished plane of the frame back wall. It provides placing of initial cone top of the gear of the secondary shaft on the axle of the follower gear of the main gear.

We use special devices to install the initial cone tops of the secondary shaft gear or the drive pinion of the main gear on the rear axle. For example, in tractors of T-150K type the clearance in follower gear bearings and in bevel pinion gearings it is adjusted while pinion gears are changed. While adjusting, the cardan shaft end is disconnected from the flange 3 (Fig. 5) and having removed the bolt and cartridge fastening 8 with two long bolts 4, the cartridge is pressed off. The nut 2 is hard and the thickness of adjusting gaskets 7 is checked turning over the pinion gear behind the flange without cartridge disassembling. If the pinion gear turns over with a big gap, the thickness of gaskets is reduced and if it is too tight, a gasket is added. In bearings we create a negative allowance using gaskets 7. The moment of resistance of the driving pinion turning over without gaskets must be 0,6-1 N·m.

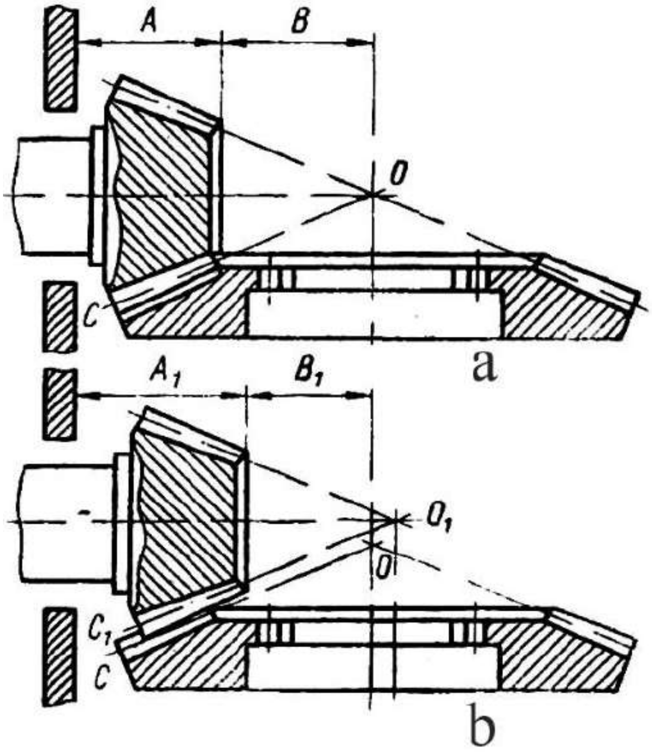


Fig. 4 – Regulating circuit of coupling of conical gears of main gear:

a – correctly adjusted gearing;
b – incorrectly adjusted gearing: *A* and A_1 – distance from butt- end of driving gear to mating face of gear casing; *B* and B_1 – distance from butt-end to axle of follower gear

Correctness of drive pinion installation is determined by the size of A = 189 ± 1 mm, which is adjusted with gaskets located under the flange of the bearing cartridge.

The gap in follower gear bearings is adjusted in the following order. The fastening nuts of bearing lids are cottared out and loosen. Turning over the follower gear 10 with the adjusting nut 11, from the butt-end side of the pinion gear the bearing is pressed till the pinion gear is fully clamped and then the nut is 6-8 projectings loosen. The bearing is clamped to the adjusting nut 11 by tapping from the teeth side. The pinion gear has to turn over freely by hand. The second adjusting nut is clamped and 2-3 projectings loosen in the same way. The gap is checked, the nuts of bearing lids are hard tightened and cottared.

Gear meshing of the main gear is estimated by a contact spot, a gap and a noise level. Selection and control of pinion gears by the contact spot is carried out on the special stand. The correct location of the contact spot is achieved by the reciprocal relative movement of pinion gears along the axis of rotation.

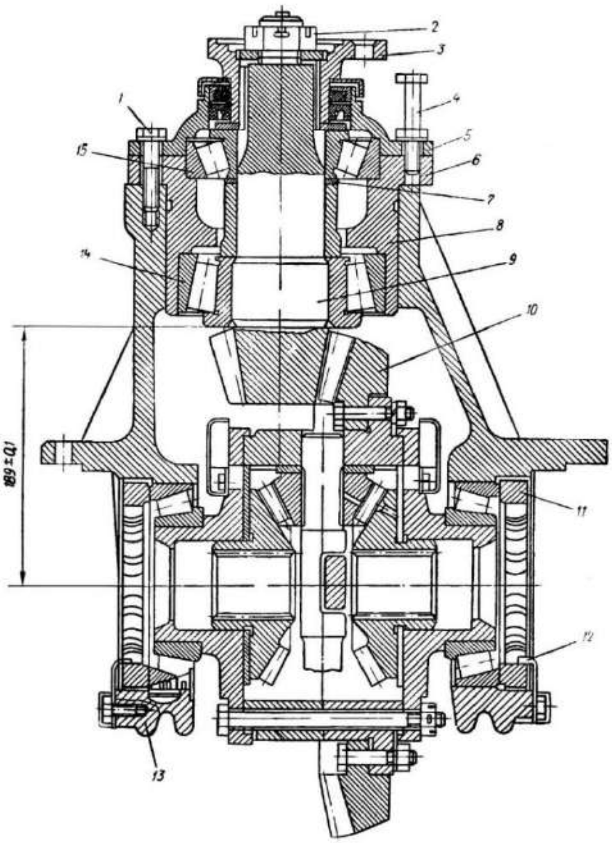


Fig. 5 – Main gear of tractor T-150K:

1, 4 – bolts;
2– nut;
3 – flange;
5 – frame lid;
6 – cartridge;
7 – adjusting gaskets;
8 – bearing cage;
9 – driving gear;
10 – follower gear;
11 – adjusting nut;
12 – lock washer;
13 –bearing cap of differential;
14, 15 – bearings

Clearances in gearing are checked using a detecting head and gearing correctness – using the contact spot (Fig. 6). For this, it is applied a thin layer of oil paint on the working surface of several teeth of the follower bevel gear. Slowing down the follower gear by hand, the driving gear is turned over in both directions. The appeared contact spots indicate the nature of gear meshing (Fig. 7). The side clearance and contact spot can be measured by moving the follower and drive gears.

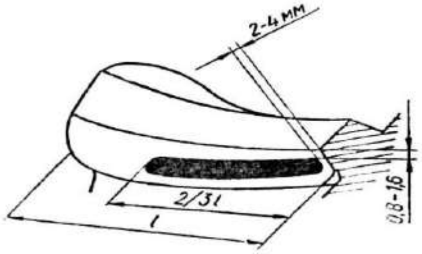


Fig. 6 – Correct placement of contact spot on tooth of pinion gear

The drive pinion is moved increasing or decreasing the thickness of gaskets between the flange of bearing housing, the shaft of the drive gear and the gear housing. The follower gear is moved by gasket shifting from the one lid of the reduction unit to another one. The total thickness of gaskets must be constant, regulating the bearings of the intermediate shaft is violated. The clearance between the butt-end of axle shaft gears and the inner surface of differential is adjusted by installing the back-up plates of different thickness.

The satellite axial clearance on crossbar necks is adjusted using washers of different thickness and the axial clearance in differential bearings – using nuts and they are checked a detecting head.

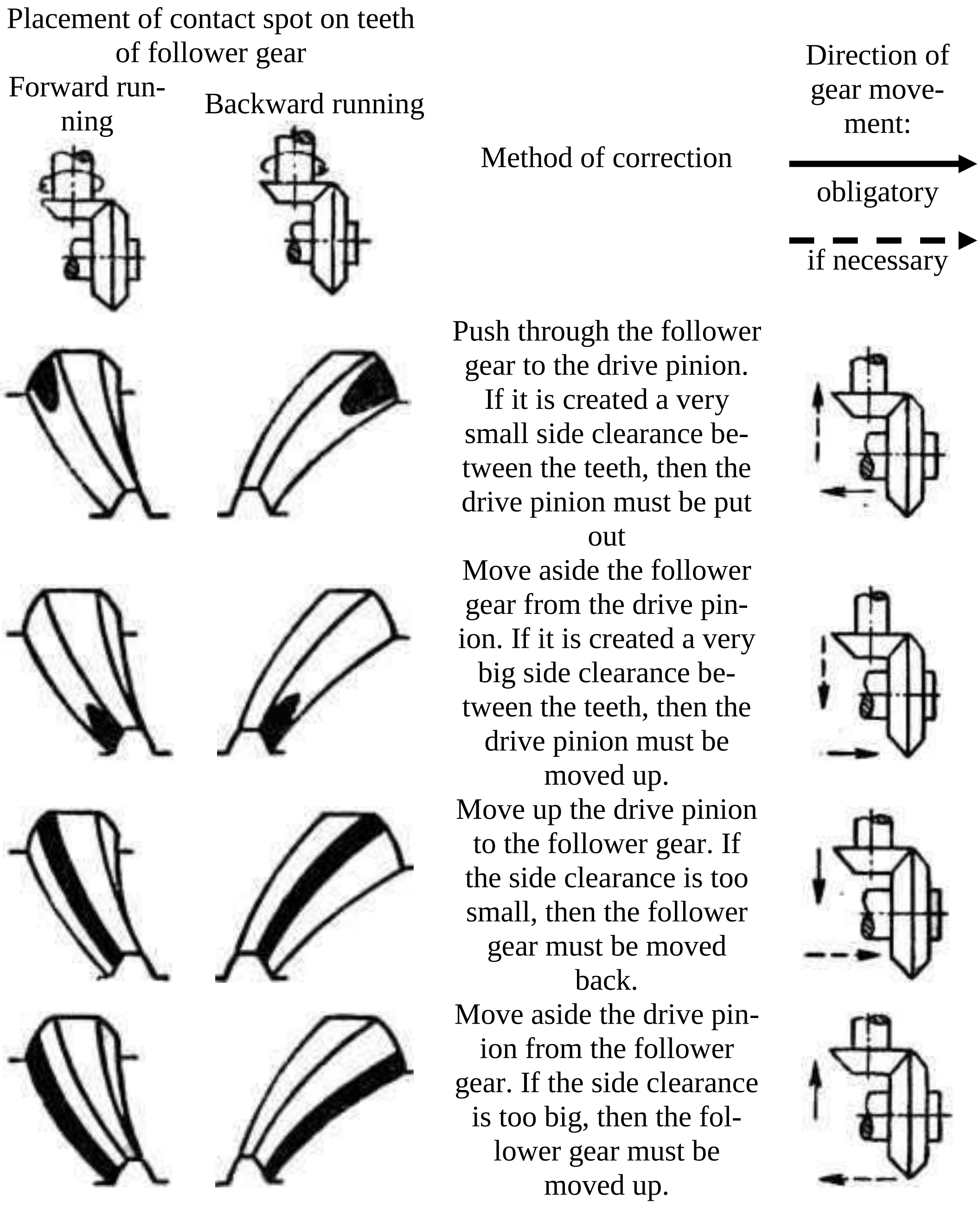


Fig. 7 Control modes of meshing of bevel pinions of main gear by contact spot

Meshing of bevel pinions and the clearance in bearings of the main gear and the differential are adjusted in front driving axles of tractors and motor vehicles.

Having been assembled, the driving axles of tractors and motor vehicles are subjected to running-in and testing on stands with and without loads. Initially, driving axles are tested without loads at variable rotational speed of the driving bevel pinion from 750 to 3,000 min^{-1}, then under load at the same rotational speed and braking torque on each half-axle – 130 N·m.

Operation of the main gear and the differential are checked while testing. In the meanwhile, there must not be any noise, tap, jerks. Bearing heating above 60-80°C is not allowed. Hub rotation must be smooth and quiet. If these requirements are not met, it is checked correctness of adjustment, and malfunctions are eliminated.

Repair of basic units of running gear of crawlers

Running gear parts operate in the abrasive medium at dry friction and receive significant dynamic loads. As a result, they wear intensively (over 10 mm). Therefore, when repair is carried out, we choose the methods which allow applying the coating of considerable thickness and high resistance to wear.

Driving wheels with one-sided wear of teeth are replaced from one to another tractor sides. Significant wear of teeth leads to disruption of normal meshing of the driving wheel with the crawler. Teeth are restored by manual arc surfacing at the template gage by casting of liquid metal (Fig. 8) or by welding of new wheel sectors (Fig. 9).

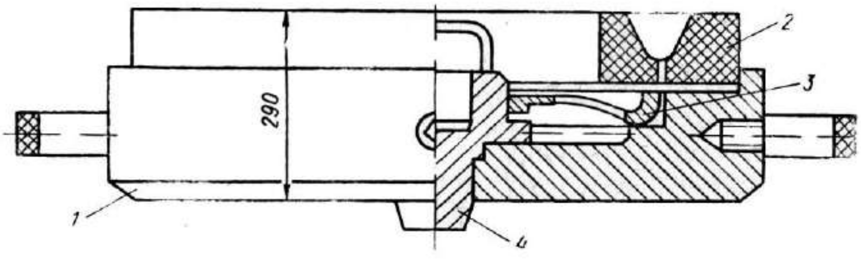


Fig. 8 – Scheme of die-casting tool to restore a follower wheel by casting of liquid metal: 1 – die-casting tool; 2 – pouring basin; 3 – wheel; 4 – central axle

While pouring with liquid metal, the wheel is fitted into the die-casting tool 1, poured with metal through the pouring basin 2 and centered into the die-casting tool using the central axle 4. The wheel and the die-casting tool are heated beforehand to increase adhesion of the pouring metal with the part surface.

When welding of the sectors is carried out, the wheel teeth are cut by a guide block on the special machine for oxygen cutting. The wheel with the cut teeth is put into the template gage and by a guide block instead of the cut teeth the sectors 2 are welded automatically under the layer of AH-348A flux.

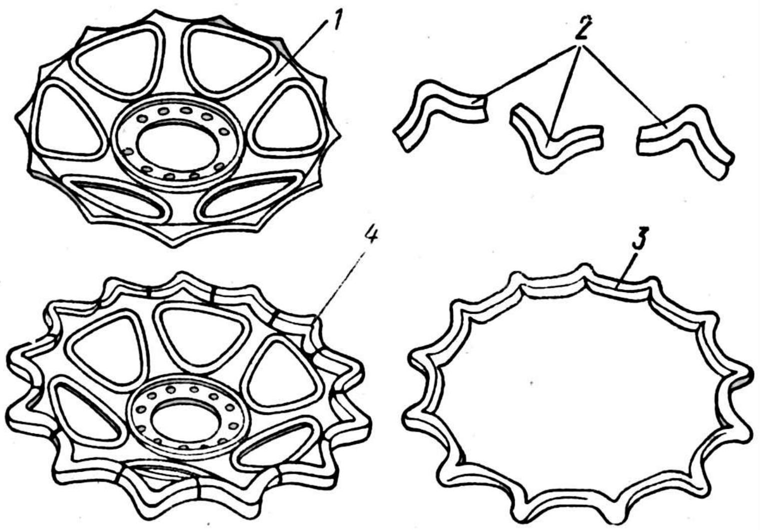


Fig. 9 – Restoration scheme of drive wheel by welding of sectors:
1 – drive wheel; 2 – sectors; 3 – sprocket; 4 – remanufactured part

New sectors which match the shape of the driving wheel teeth are produced by stamping or casting.

Track links are made of high-manganese steel Г13Л, which has high wear resistance in the abrasive medium.

The main defects of track links is wear of eye holes, link rails and grousers as well as cracks.

Up to 80% of track lines are discarded because of wear of openings and cracks of links. Wear of eye holes of links can be up to 3,5 mm on the wall thickness. They are restored by casting with liquid metal or plastic deformation.

Before casting with liquid metal the butt-ends of eyes are cleaned out on the peeling grinding machine. Technological holes of 10-12 mm are burned with the carbon electrode in walls at the side of the most wear. The link is fitted with the eye up, and the technological finger with the diameter of 0,2-0,4 mm larger than the nominal diameter of the hole is placed inside. The butt-ends are strengthened with metal washers. Molten steel 45Л, 50Л або 55Л is poured into the eye through the burned technological hole. The metal is poured into the cold link, thus its fusion with the eye does not take place. After the molten metal is cooled, it is created a bush which copies the worn part of the hole and it is kept there by the intake as by the rivet.

Restoration of link eyes by plastic deformation is carried out on special punches. For this it is suitable links with the thickness of the front wall on the arc of 120° of at least 8 mm, the thickness of the link pin and the link rail of at least 7 mm are. Initially, links are heated to 350-400°C in the saline electrode bath, and then kept in the barium chloride melt at 1000-1050°C for 5 min. It prevents losses and burnout of alloying elements and improves metal ductility.

The heated link (Fig. 10) is placed into the matrix 2, and the technological finger 5 is placed into the eye hole. Moving in the vertical plane, the block of basic punches is pressing the top and bottom parts of the eye to the finger and forces out the metal to the front wall due to plastic deformation. The additional punches 3 are pressing the front wall to the finger and finally form eyes. The duration of link deformation in the punch is 5-6 s. Then links are hardened in cold water. Link rails are restored by surfacing under the layer of flux.

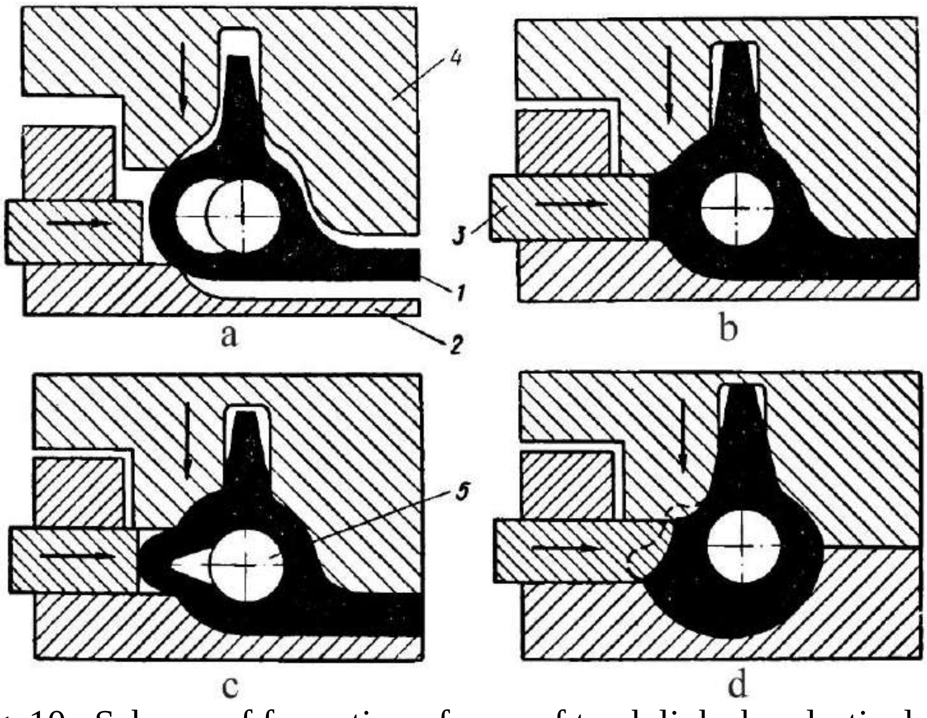


Fig. 10 –Scheme of formation of eyes of track links by plastic deformation: a, b, c, d – deformation sequence in hot condition; 1 – track link; 2, 4 – matrix frame; 3 – press; 4 – frame

Worn grousers are surfaced to the normal height or darts with the diameter of 5-7 mm are welded to their tops.

After restoration parts are assembled and the units of the crawler running gear are created.

The guide wheel after assembly must turn freely by hand. The axial speeding-up of wheels on the axle must not exceed 0,5 mm (T-150). Having been pressed into the cap, the sealing ring must move back freely under the spring action. The friction surfaces of rings are lapped to full abutment to the plate (checked for the paint).

If the axial divergence in the guide wheel bearings exceeds allowable, we carry out the following adjustment: the adjusting nut is tightened to the tight rotation of the wheel by hand at the rim and it is unscrewed at 1/6 turn. We check free rotation of the wheel by hand and the lock-nut is tightened with the subsequent fixation by the locking washer.

The length of the springs of the amortization device compressed to the working condition must be 507 mm for the inner and 525±3 mm for the outer one (T-150).

The carrier is assembled on special stands. Carriers are subjected to running-in for 15 min at the rotation frequency of rollers – 151 min^{-1}.

Tracks of the running gear of tractors T-150 and DT-75M must be assembled of restored links which meet the following requirements: the hole diameter in the link eye must not exceed $22^{+2,0}_{+0,5}$ mm, the size of the chain link pin with the sprocket in the linking place – at least 42 mm; the thickness of the link rail for bogie wheels – at least 7 mm; the height of the bushing rivet poured through the technological hole at the outer side of the eye – no more than 3 mm.

The pitch of crawler webs should not exceed 1730 mm. It is checked at the length of 10 links at least on three sites of the tracks at the stretching force of 10 kH.

All fingers of the assembled track links must be carefully splint-pinned.

Repair of running gear and control mechanism of wheeled tractors and motor vehicles

The main defects of the front axles include: bending and twisting, wear of holes for pins (steering pins), for steering pin stoppers as well as supporting butt-end surfaces of bosses and fastening sites for carriage springs.

Front axles with cracks are discarded. Bending and twisting of the front axles are checked on stands and special devices. Beams are ground in the cold condition without breaking thermal processing.

Worn holes for steering pins are reamed to get the repair size or bushings are pressed into them. Jig plates or special devices are used while reaming to maintain the normal angles of obliquity.

Worn holes in the steering pin stopper are reamed to get the repair size and the increased stopper is fitted into it.

Worn supporting butt-end surfaces of bosses are surfaced to get the nominal size by electroarc welding.

Worn supporting surfaces of fastening sites of carriage springs are surfaced and then ground with abrasive circles.

Frame girders may have bending and twisting, damaged brackets, loosen rivet joints, cracks.

Bent and twisted frame girders are molten in the cold state using screw and hydraulic portable devices or on stands with a hydraulic press. Damaged brackets are replaced with new ones.

Loosen rivets are replaced with new ones. Worn holes for rivets are reamed to get their increased diameter or welded on a copper gasket and processed to get the nominal size.

Riveting is carried out with or without previous heating of rivets. Rivets are heated to 830-900°C. While cold riveting, we use hydraulic riveting plants which allow compressing the rivets with the diameter of up to 13 mm.

Cracks in frame girders or crossbeams are developed under the angle of 70-90°C, and their ends are predrilled with a borer of the diameter of 4 mm. Cracks are welded at the direct current of reverse polarity with electrodes of УОНИ 13/55 or 03С-6 types with the diameter of 4-6 mm. For strengthening the weld and its surrounding surfaces are riveted at the distance of 3-4 mm using a pneumatic hammer with a spherical firing-pin with the diameter of 4,5 mm.

Cracks of the great length are welded and we set a rectangular or diamond-shaped cover on the damaged area. The first is welded only by longitudinal seams. If the crack crosses the entire cross section of the longitudinal beams, it is welded and we fit a cover of the box section on the damaged area of rivets.

Steering knuckles may have wear of matching sites for bearings and holes for bushings of steering pin and key grooves, thread-stripping, chips and cracks.

Worn matching sites for the bearings of front wheels are restored by chromium coating or dry topping.

Damaged threads for nuts are overcut to get threads of the repair size or they surface a layer of metal and cut threads of the normal size. Parts with chips and cracks, with worn conical holes for levers are discarded. Eye wear for the boss of the beam of the front axle are eliminated by milling. While assembling, we set a washer to provide the nominal clearance between the beam boss and the eye of steering knuckle.

Worn bushings for steering pins are replaced with the new.

Steering knuckles are discarded if they have chips and cracks on the pivot bolt, significant wear of conical holes for pivoted levers, eyes, the beam of the front axle and key grooves. Steering pins may have worn outer surfaces coupled with bushings. They are restored by chromium coating or reground to the repair size. In this case, the axle hole is rebored and a bushing is pressed into it and bushings of the steering knuckle is replaced with the new ones – with a reduced hole.

Bent steering links are ground under the press and having been heated, pivoted levers are ground by the template gage. In case the inner thread is damaged, the nozzles of steering links are discarded.

Worn ball studs of steering links and bushings of the pivot pin are not repaired but discarded.

Steering screws and rollers with abscesses and cracks, chips, stepped wear and detached metal on working surfaces are discarded.

Rollers with worn butt-end surfaces are ground and while assembling, we use thrust washers with increased thickness.

Hubs of guide wheels are made of gray cast iron. Parts with cracks and chips are replaced with new ones. Worn threaded holes are reamed and thread of the increased size is cut in them. Matching sites and holes for bearings and holes for the fixture of the gasket are restored by bushing fitting.

Cracks in disks of tractor wheels are welded. Welds are smoothed out. Bent disks are dressed. Loosen rivets are cut down, holes are reamed and rivets of the increased size are fitted.

Car suspension defects are loosen fixation of parts and units, access boards, carriage springs, worsening of shock absorber working capacity, fluid leakages from shock absorbers and wear and corrosion of carriage spring sheets.

While disassembling, a shock absorber is fixed with its lower lid in clamps. The tank nut is unscrewed with the special key with the shock absorber rod stretched to the edge. The gasket becket with the rod gasket is lifted on 30-40 mm using a screwdriver and the gasket of tank nut is taken out of the jack of the guide rod using metal dart with the pointed end. The compression valve is pressed out of the cylinder using a wooden mandrel.

Before assembling the shock absorber`s frame is leak-tested in the water bath with compressed air under the pressure of 0,3 MPa. While assembling, all parts of shock absorber are greased with lubricant АУ.

Depending on the defect, carriage spring sheets are restored or replaced with the new.

Main defects of carriage springs are as follows: reduction of the bending deflection due to loss of elasticity; cracks and failures of sheets; wear of holes for bushings, eye butt-ends and sheets at the thickness.

The sheets which lost their normal shape and elasticity are annealed and bent according to the template gage. After this they are hardened and released to get the required hardness.

In case holes for bushings are worn, eyes are bent. Tiny irregularity of the sheet shape is eliminated by riveting in the cold state with hammer strokes from the side of the incurved sheet surface. Sheets with cracks are replaced with the new.

Before assembling, sheets are smoothed out, washed and greased with graphite lubricant.

Assembled carriage spring are tested on the stand to check the bending deflection or distances to which it extends due to deflection.

Due to a certain load the bending deflection must be equal to zero and after relieving loads, it must have the initial value in the free state.

The link rails of balls, splines and other surfaces are worn in hinge cams of front driving axles.

Link rails are restored in the following way. The cam head is heated in the furnace to 550-600°C and surfaced with sormite wire №2 with the diameter of 2-3 mm using a gas burner. The thickness of the surfaced layer is 2,5-3 mm. After surfacing the head is heated to 800-820°C and hardened in the lubricant over the length of 60 mm. Then the hinge heated to 400-500°C (HRC 58-65) is tempered and ground.

An assembled hinge has to turn at the angle of 10-15°C from the straight position after applying the force of 150 H on the shoulder of 450 mm.

Brake drums may have a worn inner surface, so it is turned to the repair size with a special device on the turning machine (Fig. 11).

Drums are rebored if the surface wear is more than 0.6 mm and they are discarded if the diameter 4-6 mm increases. Drums with cracks and chips are discarded.

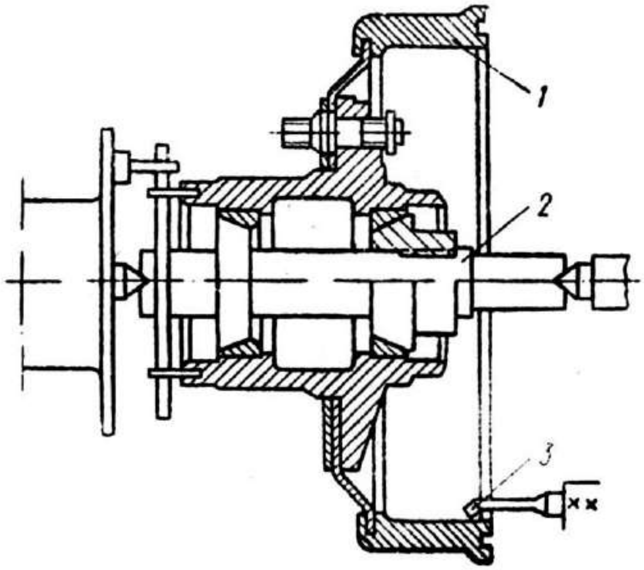


Fig. 11 – Reboring brake drum on turning machine:

1 – drum;
2 – mandrel of device;
3 – cutter

Hubs of front and rear wheels may have wear of matching sites and threaded holes for stud pins of the rear wheel.

Jacks for bearings are restored by surfacing or pressing of bushings (negative allowance 0,05-0,15 mm) followed by mechanical processing for the nominal size.

Worn threads in holes for stud pins of the flange fastening of the half-axle of the rear wheel are overcut to get the thread of the repair size or they fit those which can be driven in.

Conical holes are worn in disks of wheels. They are countersinked and conical washers (bushings) are welded.

Dents and bends of disks are eliminated by melting in the cold state or after heating of damaged areas with the flame of the gas burner.

Bends of half-axles are eliminated by melting and worn slots are restored by surfacing with longitudinal seams. Then slots are milled with the following microwave hardening at 1123-1173°C and cooling in oil. Tempering is carried out at 848-873°C with the following cooling in the air.

After repair we check toe-in using a special device, which is equal 0-3 mm – for ГАЗ-53А, 2-5 mm – for ЗИЛ-130, 1-3 mm – for КамАЗ.

After fitting and adjusting the steering is considered to be operable if the total clearance in trucks does not exceed 25°.

The total clearance in the steering is checked with a dynamometer.

Efforts on the handle of dynamometer for trucks are within 7,5-12,5 H. In motor vehicles with the hydraulic booster of steering the total clearance is checked while engine is in service. In case the clearance is increased, we determine which unit causes it, consistently checking the hinges of the steering links and the steering mechanism. In adjustable hinges of longitudinal draws for adjustment the stopper is fixed and then tempered to the first possible position for splinting but no more than 1/4 of a turn and it is splinted.

Lecture № 13
Repair of agricultural machinery, combines and tools

Typical defects of parts of operating elements of tillage and sowing machines and repair

Combines, agricultural machinery and tools, especially their operating elements, work in conditions of direct contact with the working medium and at high dustiness. Surfaces of machinery operating elements wear under the influence of various physical and chemical factors. Electrochemical wear is more intensive. It is especially typical for fertilizer distributors. Parts of agricultural machinery are often deformed by heavy loads; solid objects sometimes get into operating elements, leading to breakdowns. These factors cause great wears; therefore, it requires extensive use of welding and surfacing.

Repair of plows. Plowshares of domestic plows are made of medium- and high-carbon steels; their quench hardness is HRC 55-62 (steels 40Г, 45, 65М, 70М, Л53, Л65, 65Г).

Plowshare wear intensity (Fig. 1) depends on the density of the soil, the amount and type of abrasive parts in the soil, mechanical properties, plants to be cut, blade material, operating time. While operating, spline sides, tips and blades wear in plowshares, and other defects appear as well (Table. 1).

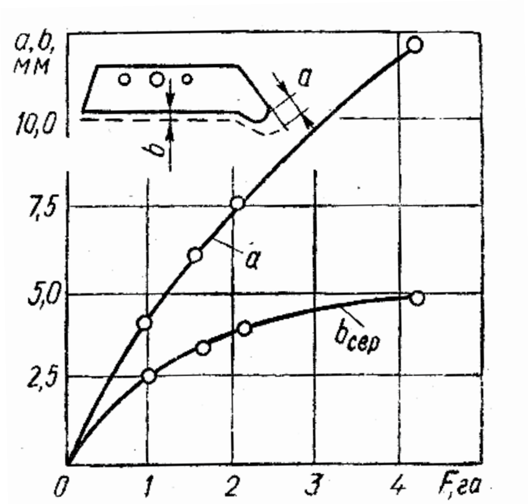


Fig. 1 – Graph of plowshares wear rate on heavy soils:

a – tip wear;
b – wear of straight (middle) part of blade;
F – operating time, ha

A dull blade is sharped at the operating side to get the thickness of 1-1.5 mm with the facet width of 5.7 mm and the sharpening angle of 25-40 °.

Main directions to increase operating life and durability of plowshares are the following:

- ➢ thermal processing of plowshares by hot forge-rolling;
- ➢ blade strengthening by the method of solid material surfacing;
- ➢ application of bimetallic materials.

Table 1 – Plowshare defects

Defect name	Repeatability factor
Cracks	0,02
Dull blades	0,03
Chips, bends, twisting	0,05
Wear at width	0,06
Through rubbing in the adjacent area to the landward edge	0,12
Wear at thickness of no more than 6 mm	0,15
Tip wear	0,30
Back facet formation	0,50
Beamlike wear	0,84

Main methods of plowshares restoration and schemes of their restoration technologies are given respectively in Fig. 2 and 3.

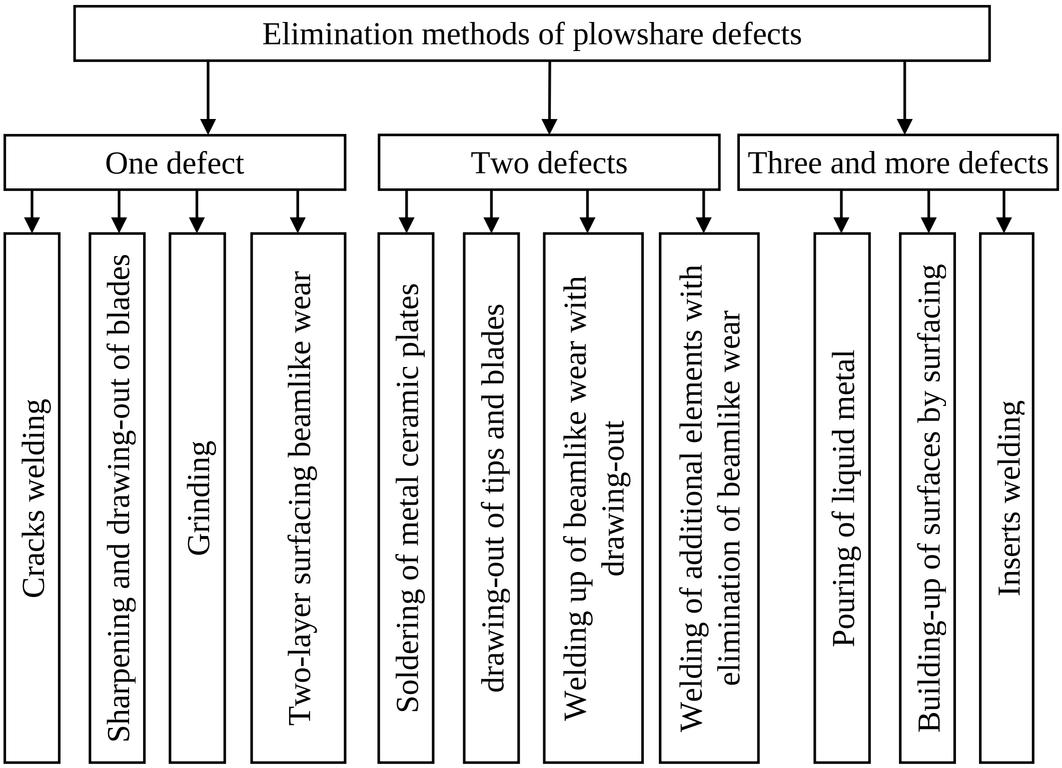
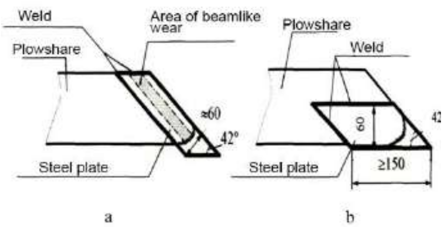


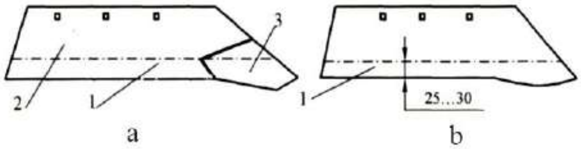
Fig. 2 – Elimination methods of plowshare defects

Having been worn to the width of less than 108 mm (checked with a template gage), plowshares are restored by drawing-out to the normal cross-section with deviation in width of no more than 5 mm, and in length – no more than 10 mm, due to the metal of the back side (tray). Drawing-out can be carried out no more than four times. For this, the plowshare is heated in furnaces or on the forge chimney to 900-1200°C over the entire length and drawn-out on the pneumatic hammer. The surface of the drawn-out plowshare has to be smooth, without cracks. The permissible deviation of its back from flatness is no more than 2 mm, the convexity of the blade operating surface is up to 4 mm.

Scheme of welding of additional elements

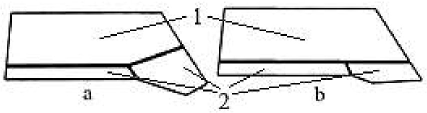


Restoration technology of plowshare by surface build-up

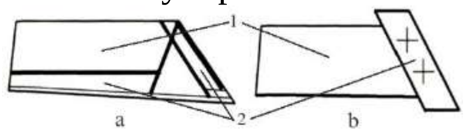


a) welding of patch piece with further strengthening by surfacing; b) drawing-out with further strengthening by surfacing: 1 – built-up layer; 2 – plowshare; 3 – patch piece of plowshare tip

Restoration options of plowshares by repair inserts



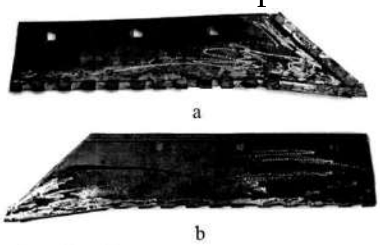
a) by GOSNITI (from Russian ГОСНИТИ) technology;
b) by TchIMECKh (from Russian ЧИМЭСХ) technology



a) by TcOKTB GOSNITI (from Russian ЦОКТБ ГОСНИТИ) technology;
b) by technology of MSAU named after V. P. Goryachkin

1 – plowshare; 2 – insert

Restored plowshare and strengthening and tipping of metal ceramic plates



a) plowshare front side; b) back side

Plowshare after welding up beamlike wear followed by reinforcement

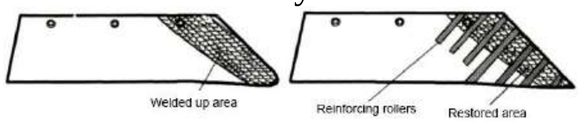


Fig. 3 – Restoration technologies of plowshare

After drawing-out the plowshare is sharpened at the front side, then heated to 700-820°C and hardened along the entire length at the width of 20-45 mm in salt water for 6 sec. at 40°C from the blade side to the hardness of 444-650 HB. Then it is tempered, being heated to 350°C with cooling in the air. Isothermal hardening is more effective when the plowshare is heated to 880-920°C and the blade is cooled to 350°C for 3,0-3,5 sec. in 10% salt water heated to 40°C. Then, it is cooled in the air.

Plowshare blades are made to be self-sharpening in order to increase wear resistance (Fig. 4), its back side being surfaced with hard alloy. It should be noted that hard surfacing on the plowshare blade allows saving of cutting properties and creating conditions for self-sharpening. This phenomenon for certain operating conditions of the given blade cross-section of plowshares is possible only at the special layer hardness. In plowshares this ratio is in the range of HB1/HB2=2,6-2,9. If the ratio of hardness is less than the optimal value, then it takes place blade dulling. If the ratio of hardness exceeds the optimal value, then it takes place blade over-sharpening, as the result, the sharpening angle reduces, what causes breaking off of the blade tip. The hardness of surfaced hard alloys is usually within HRC50-66, and the resource of the surfaced plowshare is 1,3-3,0 times more than that which were made without reinforcing surfacing.

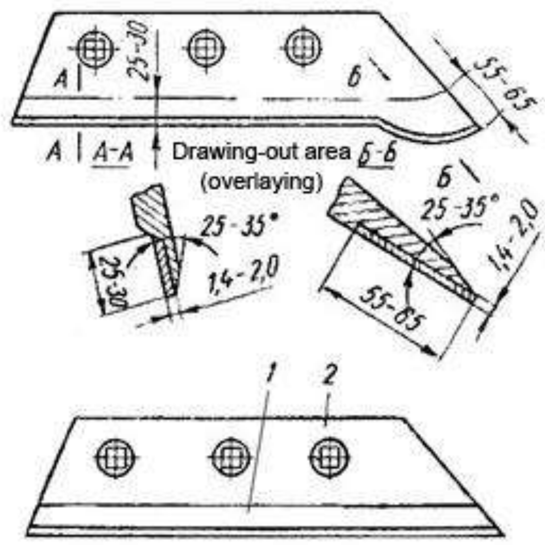


Fig. 4 – Self-sharpening plowshare: 1 – strip; 2 – back

Before surfacing they draw out a strip of 25-30 mm wide from the side of the blade of the plowshare and a section of 55-65 mm wide near the tip of the wedge-shaped share. The thickness of the built-up layer must be 1,4-2,0 mm.

Methods of hard surfacing became the most widespread:

- oxyacetylene surfacing with cast rods ПР-С1 (the type of welding metal – У30Х28Н4С3), ПР-С2 (У20Х12Н2), ПР-С27

(У45Х28Н2ВМ) and alloys of "Sormite" type;

- arc surfacing with electrodes НЦ-29, Т-590, Т-620, ЕН-ИТС-01;
- surfacing with flux cored wire ПП-АН-105, ПП-АН-123, ПП-АН-125, ПП-АН-135, ПП-АН-192, ПП-АН-198 and powder belt ЛС-У10Х7ГР;
- plug weld with flux cored wire ПП-Нп-80Х20Р35-Н-С-3,2;
- surfacing with ФБХ-6-2 alloy by freezing out;
- inductive welding of alloys of "Sormite" type, ПГ-С-ВУС-25, ФБХ-6-2;
- plasma-jet hard-facing of ФБХ-6-2 alloy.

The thickness of the surfaced layer is checked with a template gage. Blades are smoothed out on grinding machines and sharpened from the front side at the angle of 25-35°.

In case wear is less than 92 mm wide, a plowshare is restored by strip welding. For this, strips of correspondent sizes of discarded plowshares are prepared in advance. They can be welded by the forge method, gas or electric arc welding. When forge welding is applied, plowshares and strips are jointed with the overlapping of 30-40 mm. Plowshares and strips must have convex surfaces on the overlap area. Having been heated to 1100-1200°C, clean river sand is placed on the plowshare and strip; it is used as flux, and then it is welded by the forge method. The slag formed is easily squeezed out of the overlap areas due to convexity of surfaces of jointing parts. The strip is welded from its middle part to the plowshare.

The strip is welded by gas or electric arc welding in the usual way, after facet being removed on jointing parts at the angle of 45°.

In recent years in our country and abroad ceramics is used to increase durability of plowshares. However, application of ceramics as wear-resistant material was usually restrained due to the cost of plates and drawbacks of the methods of their fastening to plowshare surfaces. Today the attitude to ceramics has changed due to development of new wear-resistant materials with high physical and mechanical properties and low cost characteristics. It has led to the widespread use of structural ceramic materials: carbides and nitrides of boron, tungsten carbides, carbides and nitrides of silicon, zirconium dioxide and aluminum oxide.

Methods of fastening of ceramic plates to plowshare surfaces has developed in two directions – adhesive joints and soldering.

Plowshares strengthening is carried out according to the adhesion technology in the system of aluminum oxide – steel with high-strength adhesives. Thereupon, alumina ceramics based on LTC material (low-temperature ceramics, which charge is made of industrial argil of ГН-1 brand and highly dispersed additives of titanium manganese) adhered. Dimensions of adhered ceramic plates are 35x25x2,5 mm. Tests of plowshares with adhered plates were carried out on loamy, loamy-sandy and chernozem soils compared with serial plowshares made according to the traditional technology. As the result, it was determined that wear resistance of testing plowshares with adhered ceramic plates is 3-5 times higher than in serial ones at the same parameters of the quality of the technological process and the energy datum. In addition, we conducted experiments to increase the wear resistance of plow operating elements by applying adhesive compositions based on ВК-36 adhesive and fused corundum powder.

Soldering of metal ceramic plates for plowshares allows significantly increasing the strength of the "metal ceramic-plowshare" joint comparing to adhesive joints. Plowshare testing with soldered metal ceramic plates of ВК-8 alloy has shown that their wear-resistance on middle loamy soils is 4,6-5,0 times higher than in serial ones.

Regardless of the above-mentioned ways of plowshare strengthening, nowadays we carry out works to change configuration and geometrical sizes of plowshares.

Most plows of leading western companies have composite plowshares which consist of a changeable point (so-called "straight bit") and a plowshare itself. A straight bit can cover plowshares (a covering straight bit) or it is fitted next to the plowshare, in the same plane. The thickness of such straight bit and its strength are higher than in the plowshare tip. According to foreign research, on average they used 2-3 changeable straight bits till the plowshare is completely worn. Experience shows that a straight bit is necessary on stone soils.

Landward edges most intensively wear in mouldboards. The shape of the worn working surface of mouldboards is checked by the template gage. The permissible deviation of the template gage is no more than 6 mm.

The worn field edge of mouldboards is welded by consecutive application of rollers with electrodes Т-590 or sormite alloy № 1 and sharpened under the angle of 45-50° to the working surface.

If a tip is significantly worn, the worn part is removed and the work material of the corresponding shape is welded instead of it and fit at the joint. The work material is made from old mouldboards according to the template gage. If a tip breaks off, the process is carried out in a similar way. Before welding, the work material is thermally processed to the hardness of HRC 50-62. For heat rejection while welding the areas near the seam are coated with the solution of clay and asbestos, a sub plate of red copper with the thickness of 5 mm is placed under the seam and a rag moistened with water is placed under the sub plate. The seam is smoothed out after welding.

Landsides are usually worn at the side turned to the wall of furrows. Worn landsides are used for further work, turning them at 180°. At this, in the heated parts new square holes are punched out with a square puncher after preliminary sketching, drilling and chamfering. Then landsides are subjected to heat treatment. Landsides with little wear are overlaid with the sormite № 1 and sharpened.

Plowshare blades, edges of landsides, heels of the back landside, furrow and rear wheels have to lie in one plane in the operating position of the correctly assembled plow. Deviations from parallelism of field edges of mouldboards and plowshares can be only on the side of furrows but no more than for 10 mm. Tips and heels of frames must lie on the same straight line with the deviation of no more than ± 5 mm. The permissible distance between the inner border of the furrow wheel and the plowshare heel of the first frame is 50±5 mm. The disk plane of the back wheel must be inclined to 6-10° from the vertical to the plowed field. The permissible gap between the plowshare heel or the back edge of the landside and the plane of the control plate is to 10 mm. The placement of the plowshare tip above the heel or landside is not allowed. Mouldboards and plowshares must tightly abut to each other and the plowshare must project over the mouldboard surface at the joint no more than 1 mm. Shifting of the back wheel from the straight passing through the field border of the last frame of the plowshare cannot be more than 5 mm.

Repair of harrows. Worn and bent teeth of harrows are pulled off and ground with heating by the forge method with the difference in length of no more than 10 mm. The working part of the tooth is hardened by heating to 820-840°C and cooled in warm water at 30-35°C. While assembling, harrows teeth are set with edgeways along the run and the teeth of steel strip – with a narrow edge along the run.

Main defects of harrow disks are cracks near square holes, wear of the latter and blade dulling. Dull harrow disks are sharpened on the plant for sharpening of circular knives, on the device of the abrasive machine or they are turned with a cutter on the turning machine. Disks are turned from the cambered side with the plate cutter of hard alloy T15K6, creating a sharpening angle of 37° with the disk blade thickness of 0,3-0,5 mm (Fig. 5).

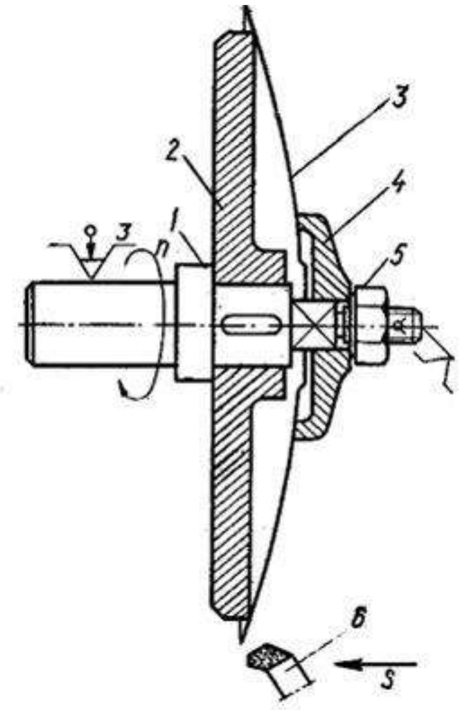


Fig. 5 – Scheme of turning of disk dull blade: 1 – mandrel; 2 – facing head; 3 – disk; 4 – washer; 5 – nut; 6 – cutter

Moreover, the blade of the disk cutting edge having been sharpened, it can be strengthened by the impact centrifugal surfacing with a rotary head (Fig. 6).

Cracks near the square hole are welded by electric welding with further processing.

In case square holes are worn, a patch piece with a square hole is welded to the disk; it is made from the discarded disk by the forge method. When welding is carried out, wet asbestos or clay solution is placed on the disk not to disturb heat treatment.

The compensating elastic washer is placed on each battery of the disk harrow to reduce hole wear and shaft edge creasing.

In the assembled bearing set of batteries the bushing must be turned over by the lever of the length of 330 mm and efforts of no more than 40 N. The allowable axial clearance in bearings must not exceed 0.5 mm. The permissible gap between disks and their axial runout at the diameter can be no more than 4 mm in the assembled disk tools while checking on the monitoring plate. Scrapers are installed at the distance of 2-4 mm from disks.

Repair of cultivators. Main possible defects of cultivators are blade dulling of operating elements (center hoes, coverers etc.); wear of bushings, wheel axles, gaskets, threads on parts, parts of raising mechanisms of operating elements and wheels operation, connecting hinges; warping and twisting of frame parts, beams.

Most of operating elements of cultivators (except of cultivator points) are self-sharpening, welded on the back side with hard alloys. They cannot be restored. Cultivator points are sharpened above to the thickness of cutting edges of no more than 1 mm. Center hoes are restored by detachable blades fitting on secret rivets or by welding a patch piece on the tip (Fig. 7, a). Detachable blade having been set, the hoe is heated to 820°C and hardened in water. Hoes of steel of 70Г are hardened in oil. The patch piece (Fig. 7, b) is made of the discarded segments of reapers and mowers or of colter disks of seeding machines. After welding a 0,7-1 mm thick layer of sormite №1 is welded to the protruding part of the patch piece from the back side by gas welding, then beads are smoothed out and the blade is sharpened.

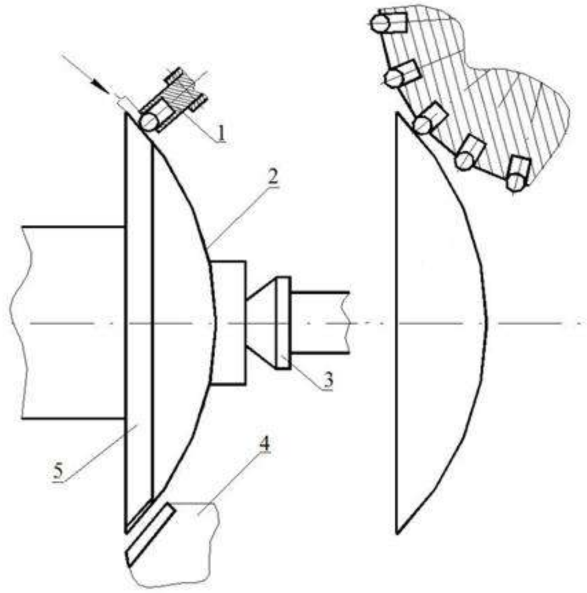


Fig. 6 – Cut-map of disk cutting edge:
1 – rotary head; 2 – harrow disk;
3 – wringing center; 4 – cutter;
5 – mandrel

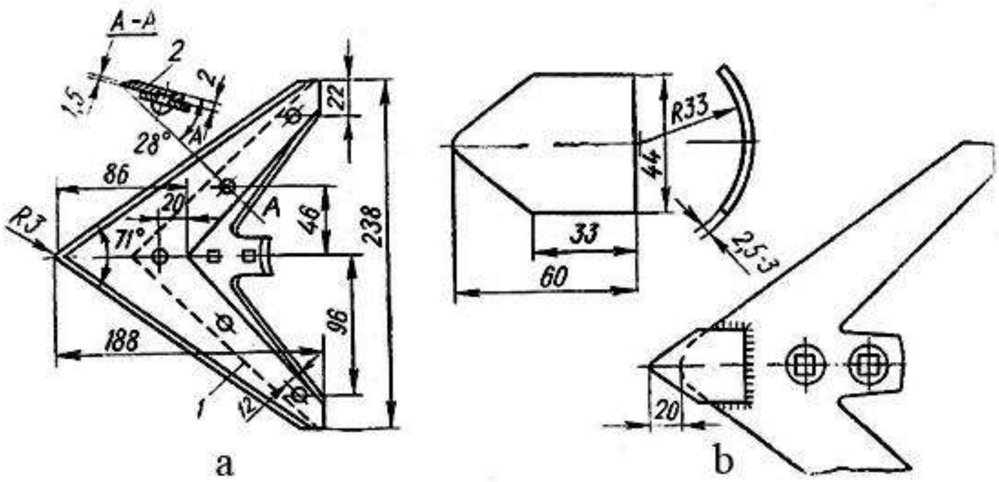


Fig. 7 – Recovery of hoes: a – by fitting detachable blades;
1 – smoothed out blade; 2 – blade-piece; b – by welding a patch piece on the tip;

Hoe poles are ground in the heated state if they have deviations from flatness. Countersunk heads of hoe pole fastenings must be 1 mm deepened. Poles are fixed so that hoe tips have a gap no less than 1 mm and blade edges – 3 mm while testing on the plate. Center hoe tips can be ± 3 mm reduced from the vertical axis of the beam symmetry.

Repair of seeding machines. Main defects of fluted force-feed drills include: wear of patch pieces, connectors and sides, shaft bowing, crushing out reefs (ribs).

The worn surface of the patch piece is overlaid in the medium of carbonic acid to the thickness of 1,2-1,5 mm and calibrated. If wear of the patch piece exceeds the permissible one, then the 1.2 mm thick sheet metal and the 80 mm thick work material is cut out and a new patch piece is made using punches. The rosette and the side of the device are restored in the same way at their thickness of at least 1 mm or they are made of 2-3 mm thick sheet steel by punching. The side is assembled after restoration of worn surfaces. For this purpose, three rivets are fitted into the side hole, the patch piece is put on the rivets with holes and unriveted. Shaft bowing is eliminated by cold straightening on the plate. The coil is replaced with a new one if ribs crush out.

The frame may have wears or thread-stripping, cracks. Threads are calibrated or welded and threads of the nominal size are cut. Cracks are sealed with adhesives based on polymeric materials or welded by the known methods.

Disk plowshares wear at the diameter, get blunted and deformed. Disk fittings also wear: bushes or bearings as well as disks and rubber seals. Disk wear at the diameter and increasing gaps in the bearing unit leads to gaps at the point of disk convergence, which must not exceed 2 mm when the compression force is applied from the opposite side. The exceeding gap leads to shallow seeding.

Being repaired, colters are defected in the assembled state. If warping is over 3 mm and the gap exceeds 2 mm at the point of disk convergence, colters are disassembled.

Disks are straightened in the cold state or by hammer strokes on a plate or a plant pressing them to the rollers or by heat fixing. In the latter case they are put into the package between two parallel plates, loaded and put into the electric furnace where they are heated to 450-480°C and kept for 4-5 hours. Then disks are sharpened with the cutter from the outer side on the turning machine (two disks are clamped) at the angle of 20° to the facet width of 6-8 mm and the blade thickness of 0,1-0,5 mm. Blade creasing is permitted no more than in three places with the depth and length less than 1,5 mm. Repaired disks can be of one or three repair sizes: the first – with the diameter of 342±2 mm, the second – 336±2 mm, the third – 328±2 mm.

The bend of the seed guide is checked with a template gage. If it 5 mm exceeds, it is ground. If the side surface of cleaners are worn more than 5 mm, they are discarded.

Tubular colters may have blade dulling, bending of wings, lug supports and poles. Dull blades are sharpened. Lug supports are pulled off or overlaid with a wear-resistant alloy in the same way as hoes from the outer side. The bend is eliminated by grinding.

Blades are sharpened from the front side to the thickness of 0,4-0,5 mm at the facet width of 7 mm. Lug supports are restored by drawing-out with a hammer to the blade width of 15±5 mm along the whole length. Pole bends are eliminated by grinding on the device through heating of the bending place to 800-1000°C with a gas burner.

After being repaired, tubular coulters have to be without dents on the surface of skeeps. Deviations of the tip end from the symmetry plane of the colter frame must not exceed 4 mm. Front and back colter drivers have to turn over freely in hinges at the angle to 45° from the horizontal.

Grain tubes can have creasing, stretched and broken coils, they are ground with a wooden hammer on the cone steel mandrel. Stretched grain tubes are compressed to the normal length, fixed with wire hooks, heated to 850°C, then in the vertical position they are plunged into the water heated to 50°C for 1-2 seconds and we carry out self-tempering by cooling in the air to 200-300°C and then in the water. While stretching grain tubes with the tensile force to 40 N, there must not appear the residual coil deformation.

Fractures and layering are defects of rubber corrugated grain tubes. In this case they are replaced**.**

Grain tubes are twisted at 360° and folded in two to check their quality. Operable grain tubes have to get back into their initial position without deformation traces when loads are removed.

Nozzles of grain tubes with fractures are discarded, and they produced new ones made of sheet metal 1 mm thick.

Repair of combine harvesters

According to the current technological normative documentation, combine harvesters and their component parts having operated the prerepair resource no less than 1500 motohours (1100 physical hectare) or the overhaul period no less than 1200 motohours (900 physical hectare) and reached the boundary state are subjected to complete overhaul. Component parts of the combine which do not need complete overhaul are diagnosed without their featurelessness. While being repaired, component parts and assembly parts are removed from the combine only when their repair is impossible or complicated without it.

Repair of the cutterbar is carried out if the following basic defects appear: break, bending and twisting of the belt, wear and failures of cutter segments, spheres, clamps, anti-cutting plates, deformation or finger fractures.

If the cutter back breaks off on rivets, it is welded by electric welding using a jig plate followed by cleaning the seam to the same level with the base metal. Segments with the worn cutting edge at the length of more than 5 mm are replaced with the new. At this, rivets are removed, the cutter back is ground and new segments are riveted. Weakened rivets of fastenings of segments are precipitated. At this, there are use special stands are used at enterprises or workshop sections.

Cutter backs are discarded when breaks and wear at the width of more than the allowable size appear repeatedly. The guide head of the cutter is repaired through replacing fillings in case a slot wears at width. Clamps with a worn wiping face at thickness are replaced with the new. Deformed fingers of the cutter are ground in special devices.

Working surfaces of anti-cutting planes and fingers have to be placed in the same plane while assembling a machine. Gaps between segments and clamps must not exceed 0.75 mm. Adjustment is carried out through straightening clamps. At the extreme positions of the cutter, segments have to be placed symmetrically to the anti-cutting plates of fingers and the cutter has to be moved freely in the finger bar by the efforts of hands.

Repair of reaper screw conveyors. While operating, reaper screw conveyors may have the following defects: bends and breaks along the weld seam, tube inflection, axle radial runout, finger bends etc. However, a screw conveyor fails more often due to wear or damage of the central tube where the pin mechanism is placed. It occurs due to its design and operational imperfection of combines, for example, improper adjustment of the overload release clutch of the screw conveyor. In this case the central tube is replaced with a new preliminary manufactured one. At this, initially the pin mechanism is demounted, coupling bolts of the webs of tube hangers of the pin mechanism are screwed out, tubes with bushings are taken out and bearing frames with axles are removed. Then the defective central tube is cut out with the gas flame cutter on the rotator of the screw conveyor and it is carried out operations to eliminate defects of the outer tubes of the screw conveyor and the screw belt (Fig. 8,a). After that outer tubes are pressed into the preliminary manufactured central tube of the screw conveyor on the special stand (Fig. 8,b). We carry out electric welding of joints and the ends of the screw belt are welded.

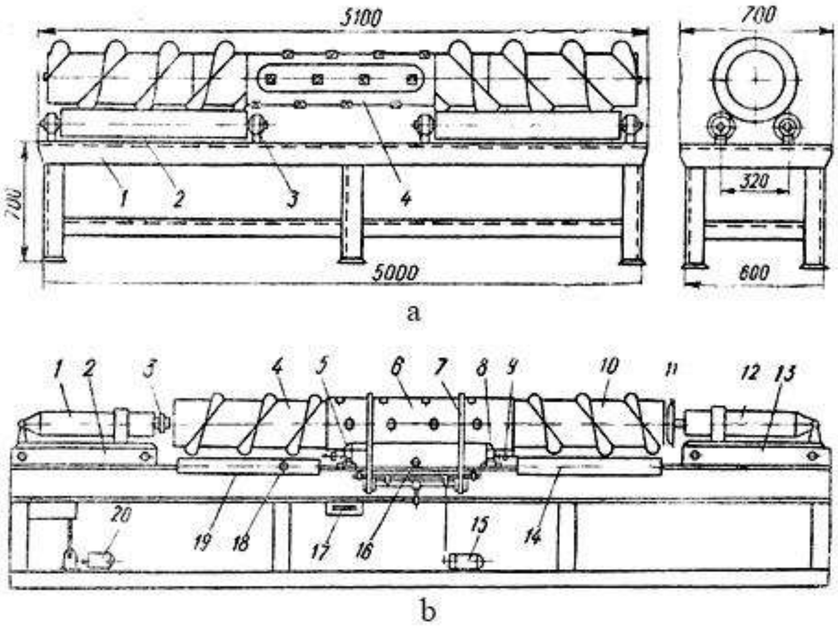


Fig. 8 – Equipment to restore reaper screw conveyors of combine harvesters: a – rotator of reaper screw conveyor: 1 – frame; 2 – rolling mill; 3 – bearing; 4 – reaper screw conveyor; b – stand scheme to press in outer tubes of reaper screw conveyors of combine harvesters: 1, 12 – hydraulic cylinders; 2, 13 – guide; 3 – punch; 4, 10 – outer tubes of screw conveyor; 5, 8 – catches; 6 – central tube of screw conveyor; 7 – pass, 9 – roller; 11 – disk; 14, 19 – rolling mills; 15, 20 – electric motors;16, 18 – fastening places of catches; 17 – control board

Repair of reel. Main defects of reels are cracks of weld seams; deformation and fractures of beams, blades, braces and rakes; wear and fractures of the eccentric mechanism, half bearings of rake tubes, friction linings, and teeth of sprockets and friction hubs of the overload release clutch.

Having flattened and put mating parts in advance, cracks and fractures of metal parts and weld seams are welded by gas or electric welding. Chipped rakes are replaced with new ones, deformed fingers and tubes of rakes are ground. Worn pivot bolts are built up. In case teeth of sprockets wear at thickness, the latter is replaced with a new one. In case friction hubs wear at thickness, they are also replaced with new ones. Friction linings worn less than 2 mm think, or with cracks and crumbs are replaced by the typical technology.

Repair of inclined chamber. Main defects of the inclined chamber are bottom wear, cracks of sidewalls and weld seam, frame warp, breaks, deformation of guides and runner block, wear of shafts and parts of the overload release clutch, weakening of fastening rivets, failures and bends of conveyor racks and extension of the chain.

Wear and cracks of bottoms, sidewalls and weld seams are restored using electric arc and gas welding. Deformed guides and runners blocks are ground, defective lower linings are replaced with the new. Marks and scorings of surfaces for linings of the coupling of the driving disk and the friction hub in a combine "Don" are whetted to eliminate wear traces. Worn surfaces for bearings, sprockets, pulleys, driving disks, ratchets as well as key grooves are overlaid by arc welding in the medium of carbon dioxide, then they are ground; key grooves are milled and ground to the size in the working drawing. Loosened rivets and stretched chains are replaced with the new. Repair of the conveyor in the inclined chamber is carried out on special stands (for example, for combines "Don", on stand OP-6689). An assembled and adjusted inclined chamber is run for 5 min at the rotational frequency of the upper shaft 500 ± 10 min^{-1}.

Repair of thrashing drum. Thrashing drums may have the following defects: wear of beater ledges, shaft bending, disk cracks, imbalance.

Beaters with ledges worn to the height of less than 5 mm are discarded replacing the diametrically opposed ones in pairs. At this, the mass of the new beater must not exceed the mass of the removed one for more than 10 g. The mass of beaters in a pair must be equal.

Cracks in end disks are welded from the outer side, but from the inner side they place strengthening disks of 4-6 mm thick welding them at the outside diameter to the main disk with an uneven seam, to hubs: they weld them from the inside of the drum with a continuous seam. Inner disks with cracks are discarded.

While beaters are being replaced, their radial runout is controlled at three points along the beater. It should not exceed 0,1 mm. Liners with the total thickness of no more than 1 mm are placed under the thinner beater to eliminate runout. The shift of beater ends in a circle (in the end disks) must not exceed 10 mm.

In the axial direction of beater deviation relatively to surfaces of the under beater butt ends must not exceed 2 mm. The allowable bend of the under beater is 2 mm. The drum shaft runout of more than 0,3 mm is eliminated by grinding. Having been repaired, drums are statically or dynamically balanced.

Drum balancing. While static and dynamic balancing, imbalance is eliminated by fitting additional washers and plates for nuts of beater fastenings from the lighter side of the drum. Washers and plates are placed evenly along the beater or symmetrically to the butt ends of the drum.

The drum is considered to be statistically balanced if when it rotates a few turns and while its self-stopping (repetition at least three times), different beaters are occupied the same position every time. At this, the cargo of 30-35 g fastened on the beater has to overbalance the drum.

Dynamic balancing is carried out using device DB-2K. Its operating principle is converting mechanical vibrations by a vibration sensor caused by the imbalance of the thrashing drum of the combine harvester into the proportional-to-them electrical signal that goes to the DB-2K device (Fig. 9).

In the electronic block the signal from the vibration sensor is amplified, filtered, rectified and fed to the needle indicator of vibration velocity. The amplified signal of the sensor is sent to the comparison circuit which determines the time of "easy place" passage on the flywheel of the thrashing drum by the vibration sensor and starts the generator of the pulse current supplied to the stroboscope. The stroboscope illuminates an "easy place" on the flywheel of the thrashing drum, each time it passing through the lowest point of the flywheel. If the vibration velocity exceeds the limit, a balancing plate is fastened under the lash illuminated by the stroboscope in the designated place for it in the measuring plane, and then measurements of the vibration velocity are fulfilled one more time.

Rotations of the threshing drum (750 min^{-1}) are produced with the electric motor fastened on the combine. The left sensor is fastened with a nut to the lower stud pin of the bearing frame fastening of the thrashing drum from the left side of the combine. The right sensor is fastened to the lower stud pin of the frame the bearing frame fastening of the thrashing drum from the right side of the combine.

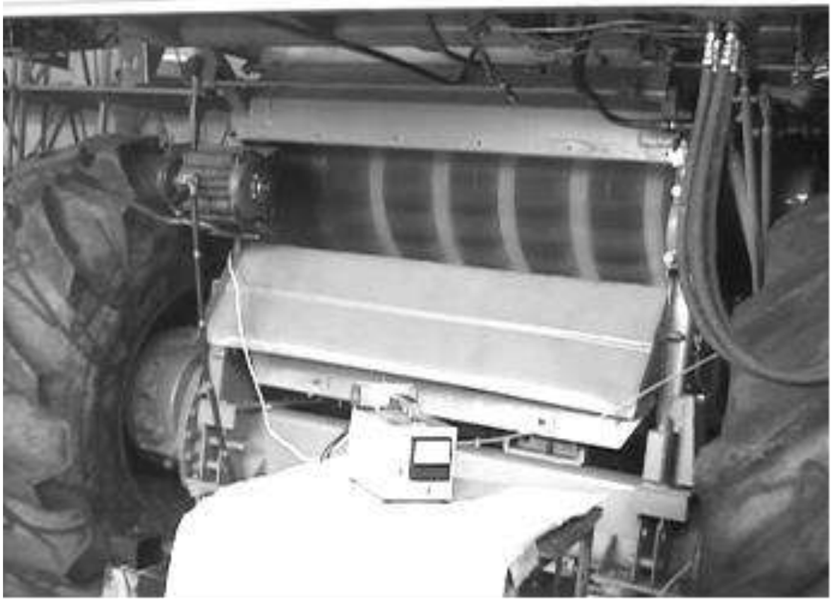


Fig. 9 – Location of DB-2K device and electric motor while balancing

Initially, measurements of the vibration velocity is carried out from the left side of the thrashing drum, and then – from the right. Received data are compared with the normative one. The standard of the vibration velocity for the balanced drum must be 1,0±0,5 mm/s. If the standards exceed, the electric motor is stopped and the balancing plate is placed under the lash illuminated the stroboscope in the plane of imbalance and the operations mentioned above are repeated till imbalance elimination is completed. The 1mm thick plate 1 mm/s reduces the vibration velocity.

Concave repair. While combine is operating, the following defects of the concave are observe: deformation and breaks of surface rods, deviation of the plate flatness in both horizontal and vertical directions, wear of working edges of plates.

If plates are more than 3 mm bent in the horizontal plane and more than 1 mm bent in the vertical plane, they are ground on special semicircular plates, using a special key with two posts, which has openings of the size corresponding to the thickness of plates. Plates with a considerable bending are ground with warming in advance. After smoothing the plates, cracks and broken weld seams are welded by electric welding.

Plates with worn front edges are 180° rearranged so that the worn back borders were placed in the front. Plates with significant wear of working edges are overlaid and processed with special cutter heads in specialized repair workshops.

Repair of straw separators. Main defects of straw separators are bends of shafts, wear of necks of shafts and bearings, cracks of key frames, failures of brackets, bend of rakes and grids.

Bent crankshafts of straw separators are ground on a special device – a template gage, with deformed places having been warmed in advance. Necks of straw separator crankshafts coupled with wooden bearings are turned with the following grinding to get a repair size.

Shafts are discarded in case the surface of the crankshaft for bearing bushings is worn. Deformed frames, keys, racks and rakes are rectified to restore their original shapes. Broken racks are removed and then new racks are welded by gas welding or semi-automatic welding in the carbon dioxide medium. Cracks and gaps are sealed by gas welding, patches are welded on the worn spot of the case. Defective rivets are removed, weakened rivets are settled.

Repair of cleaning unit. Main faults of the cleaning unit of a combine harvester are as follows: wear or breakage of the front and side seal bands of the lower sieve boot; cracks, tears and breaks of racks; deviation from flatness of the sides of the sieve boot; gaps and cracks of shakers, frames of the lower and upper sieve boots and the sifter extender; wear of scraper chains of grain elevators; deformation, breaks, cracks and wear of screw belts and cases of screws, wing nut blades and fan guard; worm shaft deformation.

Through-worn seal bands with fractures and deformation are replaced with new ones. Racks of the lower and upper sieve boots and sifter extender with cracks and gaps are sealed by gas welding followed by cleaning and straightening. Racks, broke away from the axis, are set in the position of full closure, and then each rack is welded by gas welding to the axle at two points of the non-working side.

Sieve boot borders with over 4mm dents are straightened, fractures and cracks of shakers, frames of the lower and upper sieve boot and sifter extender are welded by gas welding from the nonactivated side, having corrected damaged spots beforehand.

Deformed plates of the scrapers stiffness of elevator chains are straightened, layered and worn rubber scrapers are replaced with the new, worn elevator chains are sent to the specialized repair plants where they are repaired according to the standard technology.

Deformed frames, shafts and screw belts of the screw conveyor as well as wing blades and fan housings are ground to the initial form. Cracks, fractures and holes are welded using gas or semiautomatic welding in the carbon dioxide medium. The wing nut of the fan is statically balanced.

Repair of grain tank and unloading device. Main defects of the grain tank and the unloading device are: deformation and cracks of grain tank sidewalls; cracks of weld seams; deformation of screw belts and casings of screw conveyors; wear of screw belts at height, matching sites of shafts for bearings, sprockets and plugs as well as grooves of screw conveyors at width; radial runout of pivot bolts, screw conveyors.

Deformed surfaces are ground; cracks are welded by gas or semiautomatic welding in the carbon dioxide medium. Holes and fractures are repaired by 30 mm welding patch pieces. In case casings of screw conveyors are significantly damaged, the worn part is cut off, a suitable patch piece is made of pickled sheet steel and welded with the 30 mm overlap. Deformation of screw belts and runout of pivot bolts of screw conveyors are eliminated by flattening. Screw conveyors are discarded in case screw belts wears at height. Matching sites of shafts for bearings, sprockets and plugs as well as key grooves are restored according to the standard technologies.

Repair of combine equipment to crop non-grain part of harvest. Combines are assembled with the following types of equipment to crop the non-grain part of the harvest – straw collectors or roller mills. The most widespread are straw collectors. Main defects are as follows: cracks in weld seams; deformation of rake fingers; wear of link fingers and bearings of straw collectors; deformation and fractures of platforms, sidewalls, fingers, frames, hooks, cogs; bracket breaks of finger fastenings. Cracks in weld seams and platform fractures are welded by gas or semiautomatic welding in the carbon dioxide medium, patch pieces of the nonactivated surface are welded if platforms are considerably broken. Deformed rakes, sides, platforms, frameworks are ground using local heating until the original form is restored. Wooden half bearings with cracks and chippings on the working surface are replaced with the new. Worn fingers and links are also replaced with the new. Torn thrust washers of the crankshaft and brackets of finger fastenings are welded by electric welding.

Repair of units and parts of the hydraulic system and the hydraulic drive, engines, the running gear, gearboxes as well as electronic means of combine harvester automation is carried out according to the technologies of the corresponding tractor typical parts and units.

Adjustment and test run of combine harvesters are carried out after assembly. Meanwhile, they check fitting belts and chains according to the schemes on thrasher panels and the negative allowance of belts and chains – according to the standards. Overload release clutches are adjusted to transfer a corresponding torque.

It is checked if adjustment of combine harvester units is correct. All adjustable parameters must meet the specifications and operating conditions, an average value of adjustment range. It is determined if fittings of sealings and their abutment tightness are correct. Then all combine mechanisms are checked and lubricated according to lubrication charts.

Combine harvester test run after repair involves the consecutive test run of an engine, a reaper, a thrasher and a straw collector of the combine harvester on the run at various speeds.

Repair of special combine harvesters

Special combines are corn-, feed-, root-, potato- flax combine harvesters etc.

Various combines used in agriculture have parts and units of the same type similar in the repair and technological criteria, e.g., frames, shafts, axles, wheels, bearings, chain and belt drives, conveyors etc.

Typical parts and assembly parts have significant differences in design but perform similar work. Thus, failures which occur there are of the same nature. Therefore, the technology to eliminate failures can be the same.

Repair of frames. The frame is the basic load element of machines which has the following defects: weakening of rivet and bolt joints, fractures of weld seams, wear of holes and sites, cracks, breaks, deformation of individual elements and frames in general.

Weakened rivets are tightened in the cold state. If at this rigidity of joints cannot be restored (rattle is heard around rivets while knocking), rivets are changed and the shape of holes are restored through reaming to get the increased size of the hole and the rivet. The repair technology of bolt joints is analogous.

Destroyed weld seams, cracks and fractures are eliminated by welding and pretreatment of welding surfaces. If necessary, additional patch pieces are welded in weld spots if they do not prevent fitting of the other parts (Fig. 10).

While units are set (fastened), worn holes and matching sites are repaired (restored) by surfacing or welding of patch pieces followed by processing for the sizes from the working drawings.

Deformation of individual elements of frames is the reason of loosening and warpage of the whole frame what causes displacement of transmission mechanisms and operating elements of the machine.

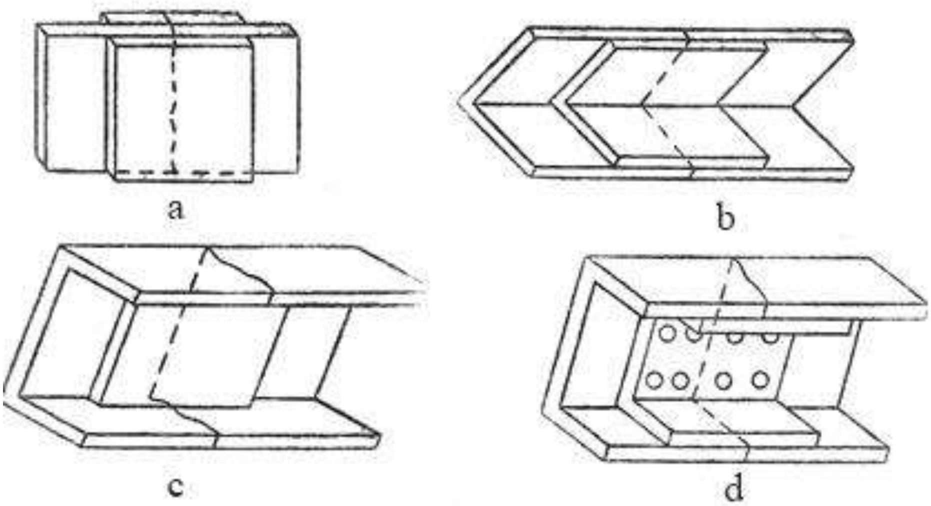


Fig. 10 – Repair of frame parts with strengthening patch pieces:
a, b, c – welding of patch pieces to flat bar, angle bar and channel bar;
d – fastening of patch piece to channel bar with rivets

Minor deformation of individual frame parts are eliminated by dressing in the cold state with a device such as a screw device (Fig. 11). If the frame is significantly deformed, it is disassembled, removed parts (if sizes permit) are ground on the press or with devices, cracks are welded with strengthening them with covers.

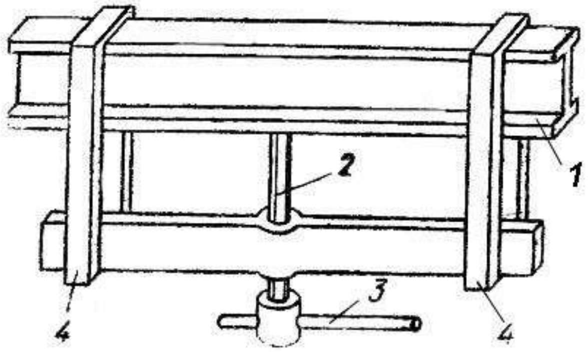


Fig. 11 – Screw device to grind frames:

1 – bar;
2 – screw;
3 – tommy;
4 – cramps

In case weld seams deteriorate, the built-up layer is cut off and this place is welded again; seams are strengthened with riveting along them from the middle to the edges, with each following stroke overlapping the previous one of 1/2-2/3 of its size.

Repair of chains. Chain transmissions of combines are different in design but have one defect – wear of links when the pitch gets bigger and the chain expands; it disrupts the normal gearing with the teeth of sprockets.

Roller chains with the limiting increase of the average pitch of chains to 3% can be operated in chain contours with pitch sizes of 15,875; 19,05; 25,4 and 38 where allowable limiting increase of the average pitch is up to 5%. Calipers are used to determine the average pitch.

In case the pitch is increased over admissible, the chain is repaired on specialized workshop sections. To restore the normal size of plates and rollers it is applied heating followed by compression and processing to get sizes according to the working drawing. Rollers are usually discarded.

Hook-link chains are discarded if the hook thickness is less than 3,5 mm and the width of its opening exceeds 5,5 mm. Being repaired, the chain links belonging to the same group (with the same wear of pivot bolts) can be installed with wear less than it is allowed. Hooks of links are compressed to restore the chain pitch. Chains restored in this way have less strength and used in less loaded machine.

Combined chains are discarded if the working part of pressed links is worn less than 2 mm thick and cast links are worn to the size less than 4mm. The chain is repaired if these surfaces do not reach limiting sizes and extension of the chain is more than admissible. While being assembled, cast links are fitted into the chain turning them by 90° from the initial position making it possible to increase the service life of the chain. While a chain is being assembled, stamped links are compressed in a special device, paying attention to the bending place of the stamped link because in this spot cracks may appear. Links with cracks are discarded. Having been repaired, chains are run in on the special stand.

Repair of conveyors. Conveyors used in special combines move corn, potatoes, feeds etc. They work in different conditions and differ in materials, design and sizes.

Army duck and belt conveyors are used mainly in reapers and have the following defects: weakened fastening, failures and breakaway of plates as well as wear and fractures of the army duck and belts.

Being repaired, weakened rivets of plate fastening are tightened; broken plates are replaced with the new. If there are worn spots or fractures on the army duck, they are eliminated by putting a patch piece of the spare conveyor fabric. Patch pieces must 40-50 mm overlap the defective spot. While a belt is repaired, patch pieces are adhered or put on rivets.

Bushing-stud conveyors operate in severe conditions e.g., on potato or root harvesting machines where a conveyor moves up to 200 kg of soil on 1 m of passage of the machine. The main defect of these conveyors is wear of working surfaces. When the machine is repaired, the conveyor is removed and the chain length is controlled. If its extension is 5% more than the extension of the initial chain pitch, the conveyor is not subjected to the further operation. Repair of conveyors is often reduced to replacement of some defective links. Worn-in-places-of-couplings-with-joint-links rods of the base conveyor (elevator) to the size less than ∅10 mm are replaced with the new or repaired. Meanwhile, worn parts of rods are cut and the defective part is compensated with the additional rod. Rods are coupled in the joint with the bushing. Its butt ends are welded to rods by electric welding. Repaired rods are placed on the conveyor.

Chains are tested by turning over drive shafts after assembling and fitting on the combine. Having ensured that the conveyor moves without scorings it is run in without loading. At this, we pay attention to smoothness of the conveyor operation.

Combines have a number of original units and assembly parts beside typical ones. Defects of basic units of combines and methods of their elimination are considered below.

Repair of corn combines. The cutter of corn combines is of rotary type. Its parts may have wear and chips of working surfaces. The service life of the cutter can be increased by changing the cutting part position or drawing out the cutting edges.

Head separating apparatus is formed from two obliquely placed rolling mills; their wear determines the working capacity of the unit in general. While being repaired, worn rolling mills are overlaid. The height of ledges after surfacing must be 4-6 mm. Rubberized rolling mills are repaired on the specialized workplace where vulcanization of the worn part of rolling mills is carried out.

In crushers of the combine after processing 2500 tons of mass, blades are blunt to the radius of 1 mm and more. To increase the operating life and provide self-sharpening blades are overlaid with the 0,4-0,6 mm thick layer of hard alloy. Before surfacing is carried out, blades are pulled off and after surfacing they are hardened by heating to 830-840°C and cooling in water followed by tempering.

Repair of haulm gatherers and beet harvesters. The cutter of haulm gatherers is equipped with disk smooth and segment (for work on areas with tall weeds) blades. Main defects of cutters are wear, chips and breaks of operating elements. Dull blades are sharpened on the special device or the turning machine. Being repaired, disks are pulled off according to the technology similar to the repair technology of cultivator disks.

Operating elements of root harvesters (diggers) work in the same conditions as operating elements of tillage machines. Thus, worn surfaces of diggers are restored in analogous ways.

Root cleaner is made of screw conveyors which wear because of interaction with soil, they deform because stones and other hard objects get in. Worn parts of screw conveyors are cut by the gas flame method and replaced with the new. The coil pitch is controlled with a special template gage.

Lecture № 14
Repair of motor and tractor electrical equipment of hydraulic system units, cabs and bodies

Repair of storage batteries

Main faults of storage batteries are as follows: oxidation and damage of output terminals of the battery; cracks of frames of battery jars, covers, baffles, mastic and its layering; accelerated self-discharge; sulphatization, short-circuit; fractures of plates.

Accelerated self-discharge of batteries takes place as a result of output terminal locking with the electrolyte found on the surface of battery covers, or dirt if plates of different polarity are locked with the active mass which is falling or due to failures of separators.

Self-discharge is caused by metal additives which are in the grates of plates and form local galvanic couples if the electrolyte is present.

Sulphatization of plates is formation of large sparingly soluble crystals of sulfuric lead ($PbSO_4$) in the form of white spots on the plate surface and on the walls of pores of the active mass. These crystals block the pores of plates of the active mass; it prevents electrolyte penetration into the depth of plates. As the result, not all active mass will be involved into the work; it reduces the battery capacitance. Sulphatization of plates is accelerated when batteries are stored for a long time without charging, high density of the electrolyte, large discharge, interaction of plates with air at low electrolyte level, systematical insufficient charging of battery and strange additives in the electrolyte.

Superficial sulphatization is eliminated with long charging at low current strength which does not exceed 0.05 of the battery capacitance. Meanwhile, the electrolyte is drained, the battery is washed with distilled water, and then distilled water is poured into the battery again. After battery charging when the electrolyte density reaches 1,15 g/sm^3, the operation is repeated, pouring it with distilled water. Charging is continued until the electrolyte density starts increasing. Deep sulphatization of plates is not eliminated.

Short-circuit of plates takes place as the result of the separator destruction, active mass precipitation on the bottom of the tank and the edges of separators.

A short-circuited battery discharges quickly, and its plates are sulphurized.

Destruction of plates takes place due to long overcharging of the battery, freezing of water in the electrolyte, lowering the electrolyte level below the upper limit of the plates, battery short-cutting etc. It is accelerated if density and temperature of the electrolyte increase.

Ways and means of control of the technical state of storage batteries are based on the properties of electrochemical processes which take place in batteries in the following way:

Anode	Cathode	Electrolyte	Process direction	Anode	Cathode	Electrolyte
PbO_2	Pb	H_2SO_4	discharge → charge ←	$PbSO_4$	$PbSO_4$	$2H_2O$

The scheme shows that the electrolyte density falls if discharging decreases and it may be a sign of the storage battery discharge, and thus the estimate (characteristic) of its technical state. However, the electrolyte density is related to the electromotive force (EMF) relating to:

$$E = 0,84 + \gamma B, \quad (1)$$

where 0,84 – a constant number; γ – an electrolyte density, reduced to 15^0 C, which is determined by calculation of the ratio:

$$\gamma_{15} = \gamma_t + (t-15) \cdot 0,0007 \text{ г/см}^3, \quad (2)$$

where γ_t – a measured electrolyte density, g / cm^3, t – an electrolyte temperature, °C.

The electrolyte density is measured with a densitometer. It varies within1,10-1,31, corresponding to EMF fluctuations (according to the given above relation) 1,94-2,15 B.

The recommended density of the electrolyte for charged battery depends on the temperature conditions where the storage battery is operated. In winter conditions the electrolyte density must have high values of the given above range. It is because in this case, the allowable density for the discharged battery will also be higher what will protect the electrolyte from freezing at low temperatures. However, the operation of batteries at high density of the electrolyte reduces its durability. Thus, it is rational to change the density of the electrolyte in summer and winter.

EMF is measured by a voltmeter as the voltage in output terminals of batteries without a turned off consumer of electricity, i.e without loads. When a consumer is switched on, the voltage in output terminals of the storage battery and thus, the entire battery falls due to the inner losses what arises from the dependences for the voltage:

$$U = E - Ir\,, \tag{3}$$

where I – a current while the battery is discharging through the consumer (load current);

r – an inner resistance of the battery.

From the given dependence we can see that the greater inner resistance of the storage battery, for example, caused by sulphatization of plates, the lower voltage at the output terminals of storage batteries. However, EMF can remain unchangeable because its value depends only on the density of the electrolyte. Therefore, the main assessment of the technical state of the storage battery is the battery voltage measured under load. For this we use a device – a battery cell tester which has a voltmeter with additional resistance (0,01 or 0,02 Ohm) enabled parallel to the voltmeter. EMF can be measured with this device (at turned off resistance) or voltage under load for each section of the storage battery.

To assess the state of the storage battery, the following data can be used: 0,01 decrease of the electrolyte density (according to the initial one providing the battery is fully charged) leads to 6,25% discharge, and the voltage under load of 100 A describes the state of the battery with the following data: 1,7-1,8 B – the battery is fully charged, 1,5-1,6 B – 50% discharged, 1,3-1,4 B – is discharged to admissible limits (Fig. 1).

For modern unserved vehicle batteries, the word “repair” can include only repair of the damaged frame; replacement of lead plates in these batteries does not take place and even plant manufacturers nowadays are not engaged in repair, they reprocess the old batteries.

While storage batteries are recieved to repair, they are inspected and cleaned of contaminations. If there are cracks in covers and tanks, swelling and delamination of the mastic of batteries are disassembled and repaired. If there are no of these defects, we measure the degree of battery discharge, the level and density of the electrolyte. If the electrolyte density is less than 1,2 or at least one section of the battery is discharged to the voltage of less than 1,4 B, the battery is disassembled and repaired. If the battery voltage is more than 1,4 B, it is subjected to control charging. When the battery does not easily charge, i.e. voltage decreases rapidly after charging or voltage of one of the battery sections is less than 1,6 B, it indicates sulphatization, short-circuit or losses of the active mass. Such battery is disassembled and repaired.

Storage batteries are disassembled in the following order. The electrolyte is pour from the battery frame into the bath. Outlet clamps and cell connectors with the depth equal to the thickness of cell connection are bored with a tubular cutter Ø16 mm and the mastic is completely removed with the paddle with electric heating (180-200°C). The cover is removed with the help of the device and plate blocks are removed from the monoblock with the extractor.

The block is disassembled into semiblocks spreading them with the tensile force of arms. Separators are defecated. Semiblocks are disassembled into separate plates sawing out suitable plates with a hacksaw or melting their lugs with the flame of burner. Plates with destroyed grating, with the swelled and fell out active mass, as well as with hard and coarse-grained sulphatization are discarded. Suitable semiblocks and separate plates are washed with water.

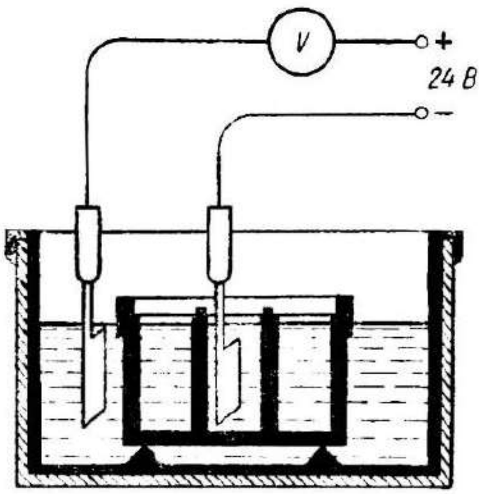


Fig. 1 – Test set-up of tank on electric permeability

Plates are considered to be suitable if their gratings are strong enough and edges are entire, the active mass of positive plates is brown and of negative ones – light gray and it is tightly held in gratings, there are no cracks and delaminations.

We repair plates with fall-out of the active mass of no more than from 7 grating cells in different places.

Suitable, but warping plates (5-7 pcs. in a pile) are pressed on the press for 30 seconds with the tensile force of 50 kN, putting between them metal sub plates with the thickness of at least 7 mm. After washing and drying, plates are placed into a template gage and chipped lugs are overlaid with lead of filler wire with the oxyacetylene flame or with carbon electrode by electric welding.

Monoblocks with swollen or warped walls and inner baffles are discarded.

Monoblocks with through-thickness cracks in walls or baffles which destroy their tightness are restored. Cracks in the tank are detected visually.

The facet is removed from both sides at the angle of 90-120° to the depth of 3-4 mm along the entire length (Fig. 2) on the crack of the tank. Crack ends are predrilled with a boring bit of Ø3-5 mm. The tank surface near cracks is smoothed out with an abrasive cloth and the adhesive based on epoxy resin ЭД-6 is applied at one side with a putty knife and dried till the adhesive is hardened completely. The adhesive composition in weight parts is as follows: epoxy resin ЭД-6 – 100, plasticizer (dibutyl phthalate) – 15-18, hardener (polyethylene polyamine) – 7-9, filling compound (ebonite powder) – the amount necessary to obtain a certain consistency. Then the crack on the opposite side is filled and then dried again, and after that the tank is checked on electroconductivity.

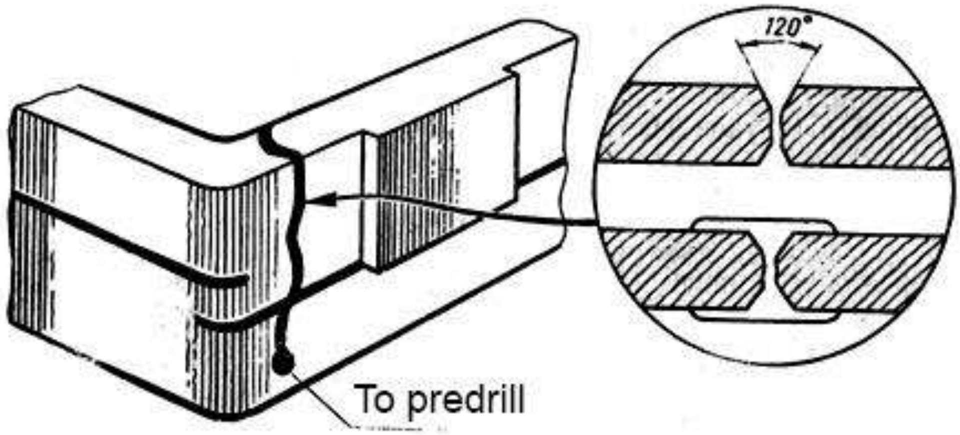


Fig. 2 – Development of cracks of storage battery wall

After repairing, the storage battery is assembled in the sequence reverse to disassembling. Meanwhile, we carry out the following auxiliary operations in the breaks of separate assembly operations: welding of plate lugs according to the template gage, welding in semiblocks in the jig plate, welding of output terminals according to the template gage, pouring of the new mastic (a mixture of 75% petroleum bitumen and 25% of machine oil heated to 170-180°C) in the recesses between covers and walls of monoblocks.

Welding is carried out with gas (lead wire) or electric arc (carbon electrode) welding.

The electrolyte with the density of 1,22-1,25 is poured into the assembled storage battery to the normal level (10-15 mm above the preventive shield), kept for 4-6 hours to fill the plates with the electrolyte and put to charge.

Storage batteries are charged in one of two ways: at the direct current (series connection of storage batteries) or at the direct voltage (parallel connection of storage batteries).

In the first case, the charged current strength is kept constant. As the charging current is:

$$I_3 = \frac{U - E}{r}, \tag{4}$$

and EMF of the battery increases while charging then in order to keep the constant charging current, it is needed to keep the voltage on the clams of the battery while charging. For this a rheostat must be switched in series with the charging battery (Fig. 3). When the voltage at the clams of the battery U reaches 2,4 B on the element (the start of gas emission), then the charging current is 2-3 times lowered in charging is finished at the lowered charging current. The current amount Q obtained by the battery while charging is shown as the shaded plane. Using this method, batteries are turned on in series. The common number of the serial-turned-on elements must not exceed U_M/2,7, where U_M – the network voltage. All batteries must be of equal capacity.

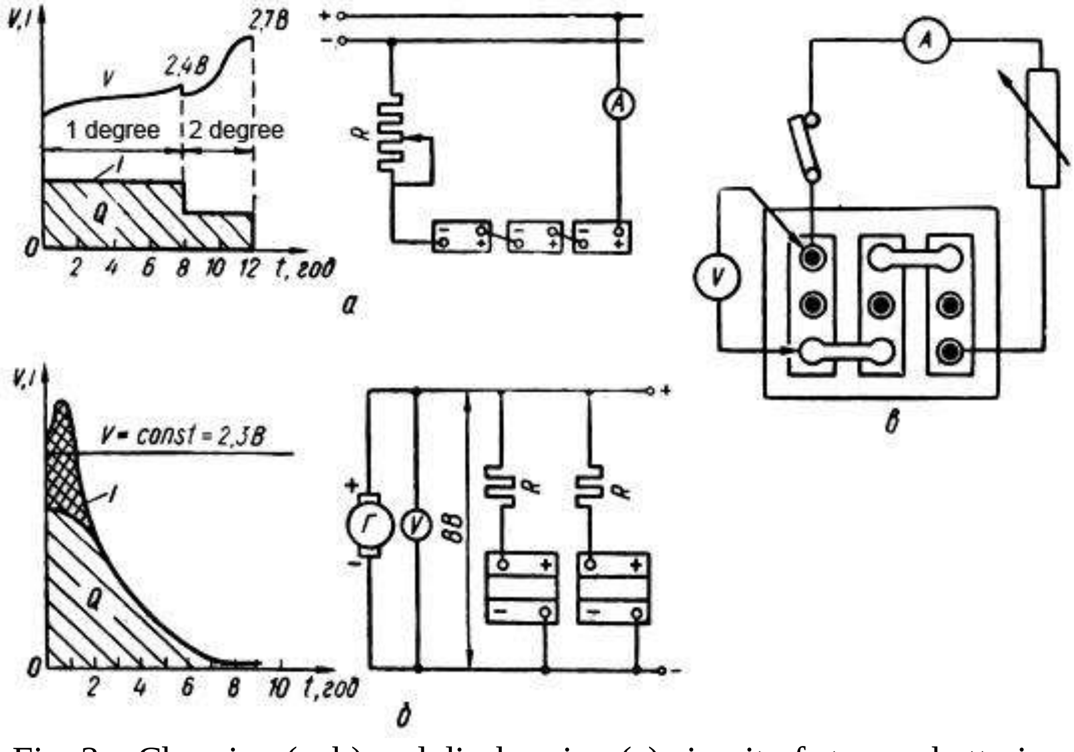


Fig. 3 – Charging (a, b) and discharging (c) circuit of storage batteries

Charging with the constant current strength is a more versatile way. It allows to choose a value of charging current freely and to control it over the time of charging with an amperemeter. A disadvantage of this method is continuous charging and the need of constant monitoring and adjustment of the charging current.

Charging with the direct voltage is carried out when the batteries are simultaneously turned on between wires where the direct voltage of 2,3 V is kept on the element and controlled with a voltmeter.

The charging current I_3 is initially big then sharply falls with the increase of the battery's EMF. Due to the big charging current, at first the charging time will reduce and then for the first three hours the battery will get about 80% of the necessary for it amount of current. If the current is small, charging will end automatically almost without gas emission.

The disadvantage of this method is a big charging current in the beginning of charging what overloads the charger.

The compensating resistance R of the constant value is turned on in series with the charging battery to limit the charging current. In this case, the voltage on wires is kept at about 2,65 V per element. The charging current causes voltage decrease I_3R in the compensating resistance, as the result the voltage at battery clams is:

$$U = U_V - I_3 R, \tag{5}$$

where U_V – a voltage of the generator.

To charging the battery, it is placed with electrolyte which temperature does not exceed 30°C. The charging current must meet specifications for the battery of this brand. As a rule, it is selected to be equal 0,1 of the nominal battery capacity. While charging, the electrolyte temperature must not exceed 45°C.

The end of charging is determined by the strong gas emission (boiling) or voltage stability on the battery terminals for the last 2 hours of charging. After charging, it is checked the electrolyte density and, if necessary, it is balanced to the normal one in all batteries, pouring distilled water if the density is high or the density of the working electrolyte is 1,4 or it is below the standard. Then charging is continued.

We must remember that the rated capacity of the storage battery is set right for the specific mode of control discharge by the plant-manufacturer. Because with the increase of the current battery discharges disproportionately faster and the figure of the measured capacity (the product of force of the discharge current for the time of discharge) will have a lower value, and vice versa, with the decrease of current – a higher value.

The repair technology of storage batteries given above is taken when the structural features of battery allow performing it.

Repair of ignition system devices

Typical defects of the timer-distributor are wear, burning and oxidation of the working part of contacts, wear of plain bearings of the drive axis and the ball bearing of the disk and cams of the timer-distributor, weakening and failure of springs of centrifugal and vacuum ignition timing regulators, damages of vacuum regulator diaphragm, cracks and insulation failures of covers and rotor distributors.

In case of significant wear or burning, the timer-distributor contacts are replaced with new ones, in case of minor wear, we smooth out with a special abrasive plate or a fine-grained glass cloth. While smoothing out, it is necessary to provide parallelism of working surfaces of contacts and their tight abutment in the closed condition.

Worn plain bearings of the drive axis and the ball bearings of the disk of the timer-distributor are replaced with the new and centering plugs of the drive axis are restored by chromium coating followed by grinding for the normal size.

Weakened springs of centrifugal and vacuum regulators, the vacuum regulator with a damaged diaphragm and broken covers and the rotor are replaced with the new.

On modern motor vehicles with spark ignition it is mainly used contactless ignition system which consists of a sensor-distributor, a transistor commutator, an ignition coil, spark plugs, an ignition relay, a switcher and high voltage wires. Sensor-distributors used in this system are of two types: magnetoelectric and with a Hall sensor. Defective items of contactless ignition are replaced with the new.

The electronic ignition system of the injector engine includes the following component parts: a controller, a crankshaft position sensor (CPS); a pulley with ring gear; an ignition module (the ignition module includes two ignition coils and two high-voltage key commutators), high-voltage wires; spark plugs.

If the controller fails, it is impossible to repair it on one’s own without any professional knowledge. The only option is to replace it in a specialized workshop.

The ignition module is not repaired, it must be replaced.

Main defects of induction coils are isolation breaking-down and turn-to-turn short circuit in primary and secondary windings, chips and cracks in the cover, burnout of the additional resistance.

Induction coils under repair are inspected and checked on the spark-formation stand; it is also set the insulation strength of the primary chain. The induction coil is replaced with a new one in case main defects are detected.

Spark plugs may have cracks on the insulator, carbon deposits on the insulator shell and the inner part of the frame, burning of electrodes and increase of the gap between them. Defective spark plugs are replaced with the new.

Modern motor vehicles, tractors, combines have alternating current generators. Main faults of alternating current generators are breaks of rotor and stator windings (Fig. 4). In case of breakage (the lamp is off) the ends of torn wires are smoothed out, twisted, welded with solder ПОС-30 and isolated.

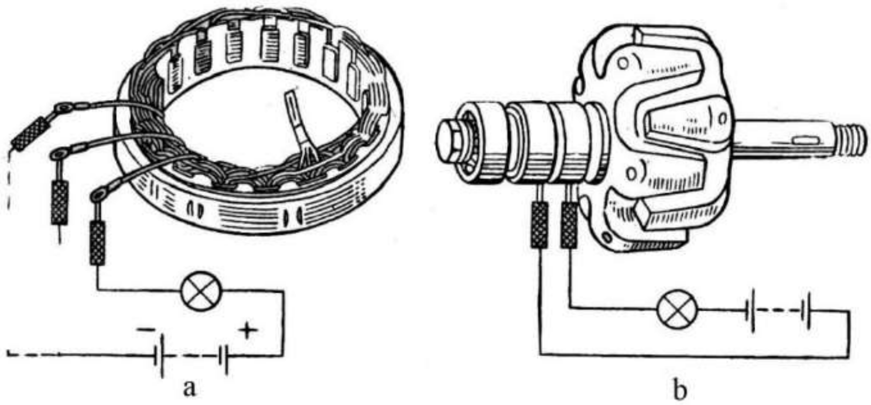


Fig. 4 – Continuity testing of winding of stator (a) and rotor (b)

The ground fault of the winding of the rotor and stator is detected by the circuits shown in Fig. 5, 6. If there is no short circuit, the lamp does not light up. At these defects windings are replaced with the new.

A turn-to-turn fault in the windings is determined by measuring their resistance with an ohmmeter. If it is present, the coil is replaced.

The resistance of stator phase windings (resistance between any two terminals) must be equal.

Oxidation, burning and wear of rotor contact rings are smoothed out with the glass cloth or their surface is turned and ground.

If the rotor looses its magnetic properties, it is magnetized. The value of magnetization is checked with a magnetometer. It has to be at least 220 мкВб.

Wear of matching sites for rotor ball bearings is eliminated by dry topping.

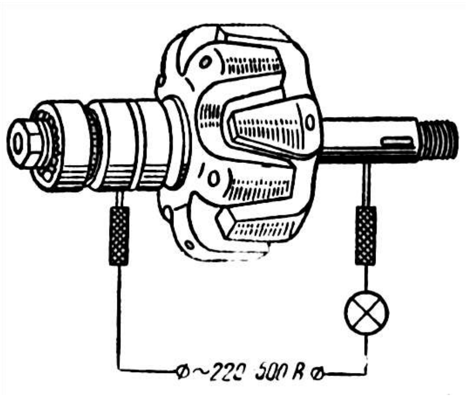


Fig. 5 - Check of drive winding for closing with rotor frame

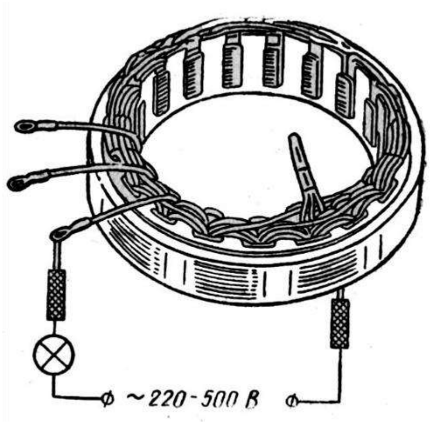


Fig. 6 – Check of stator winding for closing with frame

Damaged outer insulation of pole stator coils is replaced with a new cotton belt followed by lacquer saturation and drying in the furnace.

The wire break between coils and stator coil terminals is eliminated by smoothing out of the ends of broken wires by their twisting and welding with solder ПОС-40 with the following isolation.

In case of short-circuit between turns of stator coils; it is replaced with the new.

If the thread in cover holes is damaged, the new (of the repair size) thread is screwed. If there are cracks and chips in the cover, it is replaced with the new.

Diodes with cracks and chips, breaks and breakdowns are replaced with the new.

Protective covers worn at height over the allowable value are replaced.

Defects of the starter as well as of the generator can be divided for convenience into electrical and mechanical.

Main defects of starter pole coils are damaged outer insulation, turn-to-turn fault, breaks of brush outlet, and damaged jumpers between coils.

Damages of the outer insulation of coils is visually determined and checked under voltage of 220 V. Damaged insulation is replaced with the new.

A turn-to-turn fault is determined by measuring the coil resistance so as generator coils.

Damaged coils are rewound, the jumpers of pole coils and breaks of brush outlets are visually determined or with a control lamp. Defects are eliminated by jumper soldering and the brush output.

A starter anchor may have the following defects: annealing of section ends from collector plates, a short circuit of collector plates between themselves and for the "mass", a short-circuit of sections.

An anchor is discarded in case of the ground fault of collector plates.

Annealing of section ends from collector plates is visually detected and with a control lamp at the voltage of 220 V. Section ends are smoothed out and soldered to collector plates with solder ПОС-40.

A short-circuit of collector plates between themselves is detected with a flaw detector. Meanwhile, the collector surface is ground with glass cloth and cleaned with a swab wetted in gasoline.

The short-circuit of sections is detected on the flaw detector and the closed section is removed. For this, section ends are unsoldered from collector plates. We remove the top layer of wires and groove insulation and then the lower layer of wires. The anchor groove is smoothed out with the glass cloth; the electrical insulating board is placed and compressed along the groove. The wires of lower sections are placed into the groove; there are the electrical insulating board and upper section parts on them. Section ends are soldered to the collector. Anchor sections are fixed in grooves by putting the wire binding under which we set a pressboard filler block as well as chasing anchor grooves.

A starter frame may have creasing, dints and scorings on matching sites for covers, insulation damages of contact bolts, thread damages in holes, cracks.

The working surface of pole pieces may have a local working-off because of touching the anchor, dints and scorings as well as thread wear in holes for bolt fastenings to the frame.

Iron can be damaged in starter anchors, the shaft neck can be worn in couplings with bearings, burning and wear of the collector.

To eliminate wear traces, shaft necks for bearings are ground and carried out dry topping and the collector surface is ground.

In the cover from the collector side we may observe creasing and dints on the cylindrical belt coupled with the frame; wear of jacks for bearings and the inner jack of bearings; loosening of fastenings of the brush holder; insulation damages under insulated brush holders; weakening of brush holder springs and their breakdown.

Wear of jacks for bearings is controlled with an indicator inside-diameter gage. The allowable tension between the jack hole and the outer surface of the plain bearing must be at least 0,1 mm. The jack hole is reamed to get the repair size to provide at least 0,2-0,3 mm of the negative allowance in the coupling with the bearing.

Weakened fastenings of brush holders are eliminated by changing rivets or flattening-out of old ones. Damaged insulation for brushes is replaced with the new.

Springs lost elasticity are changed with the new. New brushes are ground-in the collector and worn brushes at height are replaced. The cover from the drive side may have scorings on the cylindrical surface of the flange coupled with the frame; wear of holes for bearings and of bearings; cracks and chips of the lug of the flange fastening of the starter; thread wear in holes.

The repair technology of the bearing assembly is analogous to the repair technology of the cover from the collector side.

Cracks and chips of the lug are eliminated by arc or gas welding.

Drive parts with the overrunning clutch may have wear of gear teeth, the inner hole of the bushing bearing and the jack for bearing; weakening of the spring resistance. The worn bearing is replaced with a new one.

The spring resistance is controlled on the device, which has to be at least 17,5 kg with its deposition in 16 mm. In case the resistance is lost, the spring is replaced with a new one.

Wear of gear teeth is controlled with a gear tooth caliper. If it grows over a permissible value, gears are discarded.

Dints, scorings and creasing of teeth on the butt-end surface are eliminated by butt-end grinding.

After assembling of stators, we adjust their disconnecting mechanisms.

The overhang of the starter gear with remote electromagnetic switching is regulated by connecting the starter with the storage battery. The gap A between the butt-end of the gear and the support ring (Fig. 7) must be within the limits established by the specifications of this starter brand. If necessary, it is regulated with the screw 5. For this the screw 6 is cottared out and the finger is removed. The screw is driven in to reduce the gap and to increase – it is driven out. Having adjusted the gap, the initial position of the gear is set (distance Б according to technical requirements) using the screw 1.

The gap having been set, we adjust for simultaneity the time of switching of the main and auxiliary contacts of the switcher using indicating lamps included into the electric circuit of the starter.

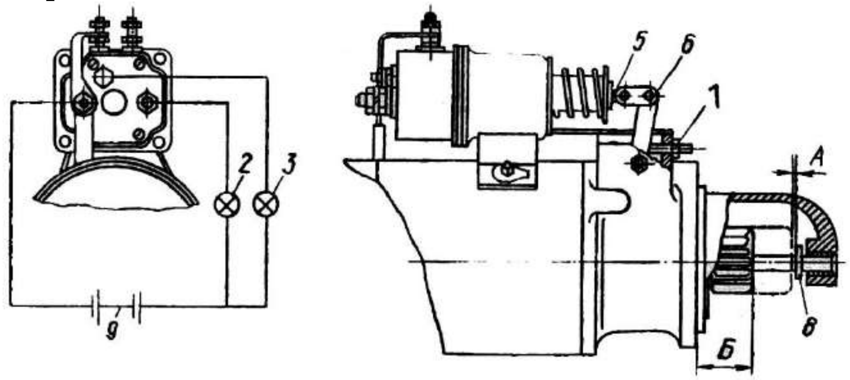


Fig. 7 – Adjustment of starters with electromagnetic switching:
1 – screw to adjust gear initial position; 2, 3 – lamps; 5 – screw to adjust moment of starter switching; 6 – screw; 8 – thrust ring;
9 – storage battery

The time of contact closure is adjusted with an anchor screw of the solenoid starter switch in the starter with remote switching.

After repair of individual parts and units, generators, generator regulators, starters, timer-distributors are assembled and tested on the stands of КИ-968 or 532М types. Before testing, generators are run in on the stand for 5-10 minutes with the rotor rotating frequency of 1500-2000 min^{-1} and loads of 10-14 A.

Alternating current generators are tested at the mode of free running and under load. At the mode of free running we measure the rotor rotating frequency when the generator gives the rated voltage. Under load conditions we measure the rotor rotating frequency when the generator gives the rated voltage under the rated load current.

Starters are tested for operation reliability of the switching mechanism, the anchor rotating frequency, operation quietness and amperage at free running. In addition, they are tested at the mode of full braking, determining the consumed current strength and torque which the starter develops.

Repair of hydraulic systems

Abrasive and hydroabrasive wears are the most common and basic types of part wear of hydraulic units.

Main defects of hydraulic system units include: falling of volumetric efficiency below standards set by specifications, irregularity of adjustments, deterioration of controllability, limit wears of parts. Part wear and aging of rubber sealing of assemblies and units lead to outer and inner leakage of the working fluid, thus the volumetric efficiency of hydraulic systems reduces.

Contamination and other strange particles that get into the hydraulic system cause wear of working surfaces of all parts.

Small particles causing abrasive wear are usually invisible at first sight because their diameter is less than 40 μm. Oil, where such particles are present, may look clean and at the same time contain a sufficient number of abrasive particles which lead to pump failure.

Wear and damages of assembly parts of hydraulic systems also take place due to aeration and cavitational hydraulic processes. Aeration is a process associated with air getting into the hydraulic system and formation of air bubbles in the working fluid. Aeration is the result of mixing air with oil Air enters into hydraulic systems through the couplings of pipelines which are not tight or as a result of oil turbulence in the tank caused by oil flowing into the direction opposite to working, oil runout from the tank and damages of pipes inside the tank.

Cavitation is a process of bursting (explosion) of air bubbles created in the working fluid. Cavitation usually occurs as the result of flow limitation of the working fluid in the absorbing pipeline of the gear pump or at high temperature of the working fluid. Bursting of air bubbles in the working fluid of hydraulic systems eventually causes damages of parts of hydraulic system assemblies, and primarily wears of basic parts of gear pumps.

Aeration and cavitational processes lead to intense wear, erosion and pits on working surfaces of hydraulic system assemblies. Outer features of the negative impact of of aeration and cavitation on operating conditions of hydraulic system assemblies are increased noise while gear pump operation and partial or complete loss of the control over mounted and trailed machine parts.

Defects of hydraulic systems and their assemblies are determined by diagnostics as unreasonable disassembling disturbs the tightness of joints, reciprocal placement and coupling running-in; it eventually reduces durability of hydraulic units. Taking into consideration complexity and high accuracy of manufacturing of parts, units and assemblies of the hydraulic system as well as high demands for tightness, they are repaired in specialized overhaul plants.

Repair of gear pumps of НШ-У type. Operating conditions of pumps are determined before repair by testing on stands of КИ-4200, КИ-4815М types. If, while being tested, the delivery rate is less than 0,65, it is repaired. The delivery rate is calculated according to the following formula:

$$K_{П} = \frac{Q_{Н}}{Q_{Т}}, \qquad (6)$$

where Q_H – a flow rate under nominal pressure and rotating frequency, l/min;

Q_T – a theoretical (rated) flow rate at the rated speed, l/min.

In gear pumps of НШ-У types sidewalls of frame well are worn at the side of the inlet chamber in couplings with bushings and gears, the bearing surface under bushings and the surface under the sealing sleeve gasket. In addition, there are cracks, abscesses on the surface as well as wears or thread-stripping for studs of the cover fastening and connecting clutches to the frame.

Bushings wear for butt-end surfaces which operate in the coupling with a gear. There are also worn inner cylindrical surface, small cylindrical surface of the bushing shank end, a big cylindrical surface and a small butt-end surface in the coupling with the frame and the sealing sleeve gasket. Gear may have worn pivot bolts, butt-end surfaces, heads and tooth form in a circle. Typical defects of pump covers are wear of the butt-end surface at the side of thr pump frame, dints and scorings, tearing off the bead in gasket jacks and cracks.

Pump frames are restored by application if the adhesive composition based on epoxy resins, fitting transition inserts or compression (by the plastic deformation method). According to the data of scientific research, the best way to restore a frame is compression. Thus, under pressure of 14 MPa, a pump casing expands in the area of upper bushings and on the bottom: a new – 115 and 20 μm, a compressed – 55 and 30 μm.

Frames heated to 470-490°C are compressed in a special molding tool on the 100-ton hydraulic press for 10-12 s along the outer contour (Fig. 8, a). After compression, the frame is put into the furnace and kept there for 20 minutes at 520-535°C and then hardened in the water, heated to 50-75°C. The hardened frame is tempered for 4 hours at 170-180°C. The frame hardness after heat treatment must be HB 76-120. Frame wells are bored for the nominal size after compression and heat treatment.

Bushings are restored by precipitation, compression and distribution with the following mechanical processing. Bushings with worn holes, butting and butt-end surfaces are compressed (Fig. 8, b).

Worn outer surfaces of bushings can be restored by the mixture based on epoxy resins or galvanic copper plating of this surface with the following mechanical processing.

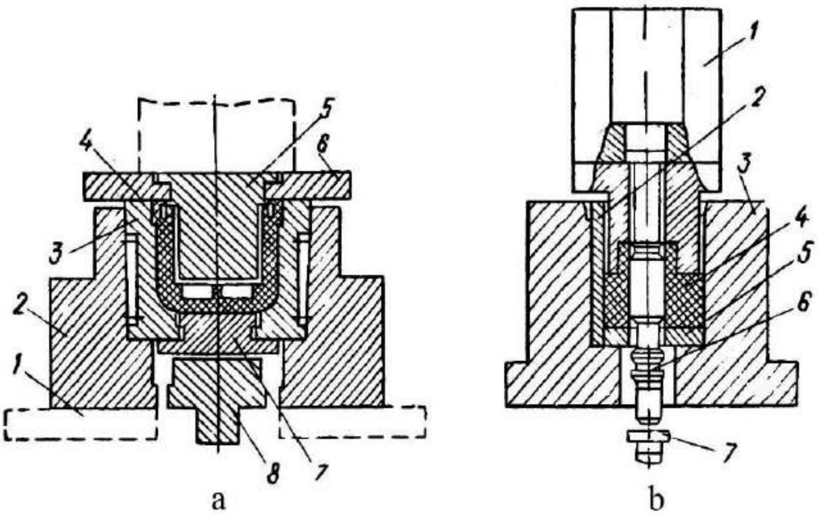


Fig. 8 – Worn-part reclamation of pump of НШ-У type by compressing: a – frame; 1 – press base; 2 – mold; 3 – matrix block; 4 – pump casing; 5 – punch; 6 – plate; 7 – ring, 8 – ejector; b – bushing; 1 – punch; 2 – bush; 3 – matrix; 4 – bushing; 5 – washer; 6 – tool; 7 – ejector

Pinion gears with minor wears within the thickness of the heat treated layers (worn surfaces of pivot bolts, butt-ends, the outer surface of heads of gear teeth) are restored by grinding. Pivot bolts of gears are restored also by galvanic metal building-up (chromium coating or dry topping).

Cover warping, scorings and dints on the mating face are eliminated by grinding. Wear of butt-end surfaces which abut to the pump casing are restored by turning on the screw-cutting lathe with a cutter of plate of ВК3 hard alloy. If the pump casing is restored by compression, then after that, holes in the cover are reamed for studs with a facet.

In case of the bead is torn off in the gasket jack which holds a closing ring, the cover is restored by setting a steel ring.

Repair of valve actuators. As a rule, distributive devices may have worn holes in the frame (for sliding pistons), sliding pistons, valves, levers and covers.

Holes in the frame and sliding pistons of hydraulic control valves while manufactoring are divided into size groups. It allows to restore the gap in the pair "frame-sliding piston" by rekitting with the following adjustment in case of minor wears and a big repair fund. In case of significant wear, the geometric shape of holes for sliding pistons is restored by reaming and lapping as well as by diamond honing on vertical honing machines. Lands of sliding pistons with minor wears are restored by development, grinding until wear disappears, and with significant wears of sliding pistons and frame holes – by building-up of lands by the galvanic method (chromium coating or dry topping) with the following grinding. After restoration of the frame of hydraulic valve actuators, sliding pistons are sorted into size groups.

Wear of the cone sealing surface of the overflow valve is eliminated by processing of the cutter on the turning machine. The conical part of the valve is ground on a special machine or by the grinding wheel (tucked under the angle of 45° at the rotating frequency of 20 s^{-1}) of the circular grinding machine until wear is eliminated.

The piston and the valve shank end worn considerably are coated with chromium or casted with iron followed by grinding. The worn jack of the overflow valve is ground on the surface-grinding machine to form a sharp edge. The jack of the safety valve is restored in the analogous way.

In case the chromium coating is worn, the spherical surface of control levers is coated with chromium followed by polishing.

Cracks in the upper and lower covers are repaired by gas welding or filling with a mixture based on epoxy resins. Restored covers are tested under the pressure of 1MPa. Leaking and misting after restoration are not allowable.

Springs of hydraulic control valves which lost elasticity and worn out are replaced with the new.

Repair of hydraulic cylinders, hydraulic accumulators and hydraulic shock absorbers. While hydraulic cylinders are operating, the following defects often appear: wear of the inner frame surface; wear of holes for the rod in the front cover; wear of holes and lug fracture in the back cover; wear of the inner surface and holes for rod studs; deflection of the rod; piston wear.

The worn frame inner surface is restored by boring on the vertical boring machines with the following honing for the piston repair size which can be restored by dry topping. The worn hole for the rod in the front cover is reamed and the bronze or cast iron bushing is pressed in. Then the bushing is finally processed with reamers to get the rod size.

The gap in this coupling must be 0,02-0,10 mm. Worn lug holes in the back cover are processed with a core drill and then with reamers. Broken lugs of back covers are restored by welding.

Ageometrical shape of the worn inner surface of the rod is restored by grinding on the centerless grinding machine, and then coated with chromium and ground. Worn rod clevis holes are processed with a core drill and then after processing the produced bushings of appropriate sizes are pressed into rod clevis holes. They are welded, and then finally processed with reamers to the normal size. New fingers are produced.

Bent rods are repaired under the press in the cold state. The allowable deflection of the rod must not exceed 0,15 mm.

Sealings are replaced with the new if they are worn out or lost their elasticity.

Repair of high pressure hoses. It is disturbed the tightness of couplings near the ends of hoses with metal braidings or fractures occur.

Parts of the nonseparable clutch are often used for repair. Damaged parts of hoses together with the nonseparable clutch are cut with a circular saw blade or a grinding wheel. A cut off non nonseparable clutch is cut into two halves with a milling cutter. A nipple with a screw nut is inserted into the repaired hose end and clamped with two halves of the cut sleeve using work carriers.

In case the center or several places of the hose are damaged, defective parts are cut off and a piece of the repaired hose of a suitable length is inserted. Hose ends are connected with the reducing nipple.

There is also a demountable way of hose repair. It consists in that the damaged hose end is cut off and the upper layer of rubber is removed to the metal braid on the length of 40-50 mm from the edge. Then a piece of a steel tube is put on the hose with little negative allowance and a nipple with a coupling nut is inserted in the hose center. The hose end is inserted into a special device to compress clutches (of hose nozzles) under the pressure where the tube part is compressed uniformly with split-design dentils (bushes) forming a permanent coupling. Damages in the hose center are repaired in the same way. In this case it is created an extended union nipple. A steel tube which is put over the hose is compressed on both sides of damage. Damaged hose ends are also repaired using demountable nozzles.

Kharkiv Petro Vasylenko National Technical University of Agriculture has developed a method and equipment to couple a hose with a nipple by hose pressing to the nipple with a wire.

Winding a wire is carried out on a screw-cutting lathe. The nipple out of which a clutch and a part of the hose were removed is fixed on a special mandrel with a threaded part with thread corresponding to the nipple nut and simulates a connecting branch of hydraulic units. The wire direction and formation of the tensile force for the winding is carried out with a special device.

The process of fixing a hose on the nipple is carried out in the following order. A threaded mandrel is fixed in the holder of the screw-cutting lathe; a nipple with a hose is fitted on it. A wire end is passed into the radial hole of the threaded mandrel. The wire is clamped between device rollers for wire negative allowance. The first wire turn is made at the distance of 5-7 mm from the hose edge and fixed with wire cross covers in the opposite direction. Winding a wire is carried out in a spiral (Fig. 9).

The wire is wound along the hose surface for the nipple length and the final turn is made with a pitch equal to the wire diameter. To meet safety requirements and prevent possible unwinding, its last turn is fixed by coupling with the previous turn of electric welding (Fig.10).

Reliable fixation of the hose on the nipple is achieved using low-carbon steel wire (wire of type "knitting") with the yield point of wire material of 195 MPa, the diameter of 3-5 mm, the coil pitch of 3-8 mm and wire tensile force of 30-80 kg.

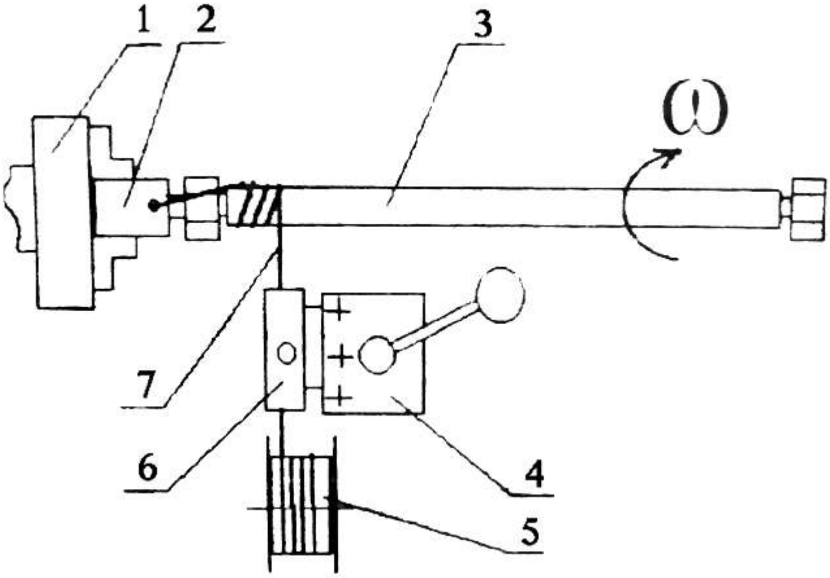


Fig. 9 – Installation diagram to couple hose with nipple of wire:
1 – screw-cutting lathe holder; 2 – mandrel; 3 – hose under repair;
4 – tool holder; 5 – wire coil; 6 – device to span wire; 7 – wire

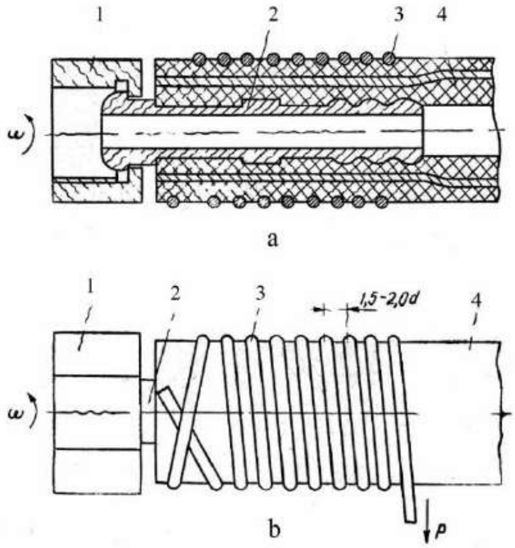


Fig. 10 – Connecting circuit of hose of hydraulic systems with nipple using wire:

a – Connecting circuit;
b – Layout of wire turns on hose;
1 – nipple;
2 – nut;
3 – wire;
4 – hose

Assembly, running-in and testing of hydraulic system assemblies. Gears and bushings of pumps of НШ-У type are assembled according to size groups so that the height of each pair of gears does not differ more than 0,005 mm. The frame must have the repair size corresponding to the repair size of bushings. Bushings fitted into the frame must not project over its upper surface more than 0,15 mm or deepen more than 0,1 mm.

Pumps are run-in and tested, hydraulic control valves together with the pump of the corresponding productivity are adjusted on stands of КИ-4815М or КИ-4200 types according to the modes provided by technical requirements. Having been run-in, the pump is tested on these stands and according to the technical requirements we determine the volume pump output at the nominal pressure.

Before assembling, sliding pistons of hydraulic control valves are assembled with the frame. For this they are selected according to the size group. If the gap is normal, the oiled sliding piston moves smoothly in the frame hole under its own weight. The overflow valve has to move freely in the frame without scorings and with a turn at 180°.

While testing of hydraulic control valves is carried out, we check operation of the device of automatic turning of sliding pistons in the neutral position, pressure of the circulating fluid through pass and safety valves, tightness of frame parts and leaks of working liquid between the frame and the sliding piston.

Requirements for assembling hydraulic cylinders are as follows: the working surface of the rod must be coated with chromium, delamination or clipping of the chromium coating is not allowable; nuts of clamping stud pins (or studs) must be tightened evenly hard; cone plugs must be screwed hard and ensure full tightness; a piston must move smoothly in the cylinder along whole length of run, without scorings.

Hydraulic cylinders are tested on stands of КИ-4815М or КИ-4200 type. They must be equipped with operable pumps and hydraulic control valves of the brands which the hydraulic cylinder operates with on the machine. The cylinder rod is fixed with a finger; the pressure of 12,5 MPa is created and bleeding of lubricant in the cylinder is determined. After repair it must not exceed 0,5 sm^3 for 3 min. The maximum oil pressure required to move the piston of the no-load cylinder should not exceed 0,5 MPa. The rod protrusion of the main cylinder must not take more than 2,5 seconds, returning to the initial position to the automatic stop – 1-2,5 seconds.

The cylinder tightness is tested under the oil pressure of 15 MPa holding the handle of the hydraulic control valve in each working position for 30 seconds. Bleeding of lubricant is not allowable.

High pressure hoses are tested for tightness at the pressure of 20 MPa for 5 minutes.

Repair of bodies and cabs

Parts of bodies and cabs wear on-stream, cracks, holes, deflections and cobbles appears, systems of water supply and tightness etc. When cabs of tractor and automobile facings are repaired, a significant role belongs to sheet metal works with flattening dents, cutting damaged areas, producing and fitting piece patches of simple and complex configurations for welding, manufacturing induvidual parts etc. The most common methods of welding are gas welding, arc welding in the medium CO_2, electrocontact welding.

Surfaces with dents, cracks, fractures or holes are ground and the place of metal fractures is welded and then weld seams are dressed.

While welding of light gage steel parts is carried out, burning and warping may appear. It is recommended to use firstly the track weld of the joint weld in several points and then welding of consecutive workshop sections to reduce a probability of these defects to appear. In case of warping mechanical ginding with compulsory heating of the deformed area is used.

2 mm thick dents are ground using gas flame heating. 2-3 mm thick parts are heated to 650-700° in the area of grinding, and 4,5 mm thick parts are heated to 850-900°C. Duralumin parts are ground heated

to 350-470°C. The width of the heating zone must not exceed the five-fold sheet thickness which is ground. The length of the heating area is determined by the dent sizes. Heating is carried out from the convex side of dents and heating strips are placed on the convex descent at the distance of 80-100 mm from the edge.

While hand-held straightening is applied, we use a flattening hammer and a support selected according to the curvature of the repairing panels. Mechanized straightening is carried out with a pneumatic hammer, having previously greased the part surface.

Straightening is considered to be completed if the roughness is not felt with a palm.

Lecture № 15
Repair of equipment for animal husbandry, technological, electric power and handling equipment

Peculiarities of operating conditions of equipment for animal husbandry

Vegetable mass, manure, fodders and the microclimate of animal husbandry premises belong to strong corrosion active mediums. Thus, operation of some machine parts and animal husbandry equipment are undergone corrosion and mechanical wear while rubbing on solid mineral particles contained in the atmosphere and processed materials, in as well as working with organic acids, moisture, electrolytes and gases. Interrupted operation of machinery and animal husbandry equipment are favorable for processes of formation and destruction of surface films and surface structures of part metal weakened by corrosion; it also increases the process of wear.

As the equipment of animal husbandry farms usually has large overall dimensions and it is difficult to be transported to overhaul plants, it is reasonable to use unit repair.

Repair of fodder production machines and equipment

In fodder production machines operating elements wear the most intensively: crushing hammers, cutting and anti-cutting plates, knives, sieves, decks. Surfaces of these parts wear out unevenly.

The decreased productivity is the main sign that a machine needs repairing. For example, hammer crushers are repaired if their productivity is 30-40% decreased, fodder shredders – 20%.

Structural characteristics and as operating conditions of a cutting pair have a significant impact on power inputs and operation qualities: blade sharpness, fitting a knife and a cutting angle as well as the gap between knife blades and the anti-cutting plate. Blade sharpness is estimated with the thickness of its leading edge, for straw cutters it ranges within δ = 20-40 μm (Fig. 1, a). In case of blade dulling while operating, it is allowed to increase the blade thickness to δ = 100 mm, then the knife is subjected to resharpening.

For straw cutters we use a knife sharpening angle γ = 12-22°. The applied high-carbon steels of У9 and 65Г brands with heat treatment of a 20-30 mm wide working zone to the hardness of 47-56 HRC provide a possibility of continuous operation of straw cutter knives. Sharpening angles are directly related to cutting angles α (Fig. 1, b) and the plant β, the size of which is chosen taking into consideration the adopted cutter sizes and its operation modes. The clean cut is achieved by the gap adjustment between the cutting edge of knives and the anti-cutting plate. Knives are adjusted mainly by lock screws and the middle adjusting screw. If necessary, adjusting filler blocks are fitted between cutting drum disks and the knife. The gap between its blades and the anti-cutting plate must be the same along the entire length of the drum – 0,5-0,8 mm (Fig. 1, c).

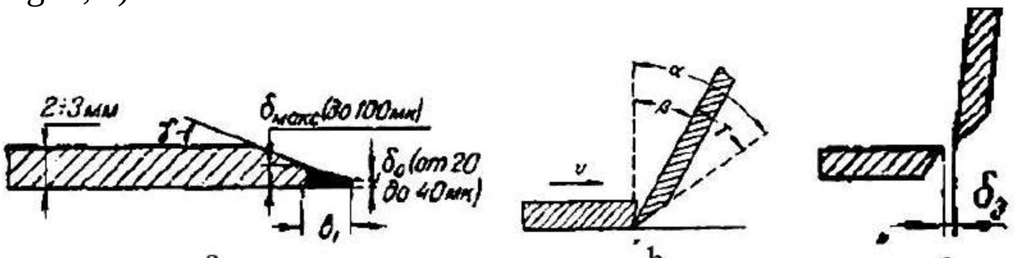


Fig. 1 – To ground blade sharpness (a), knife sharpening angles (b) and gap size of cutting pairs (c)

Knives are sharpened on the emery stone with the following sharpening on the wet stone. Sharpened knife blades must have the thickness less than 0,25 mm along the whole cutting edge. Knife cutting edge must be plain, and its line must correspond to the shape of the knife curve. If the knife cannot be restored mechanically, it is repaired by the forge method. The need of knife sharpening is estimated visually. The knife is replaced after 10-20 times of sharpening and the anti-cutting plate is turned into the other side.

Repair of fodder preparation machines provides restoring cutting bodies by sharpening on the universal sharpening plate of TA-255 type using special devices. Forge drawing-out or surfacing under the layer of flux with Св-08 wire is applied to compensate significant wear. It is also rationally to overlay a hard alloy layer of Sormayt № 1 to create conditions for self-sharpening (Fig. 2).

Hammers (milling cutters), sieves, grate decks, rockers and other elements of the crusher rotor, crushing chamber and the fan wear most intensely in crushers.

Hammers located on the rotor edge where the "coupling" of the product between hammers and the crushing chamber have the most significant wear. The scheme of hammer wear is shown in Fig. 3. Worn hammers are turned to the other side with sharp angles in the direction of impact. If all sides are worn, hammers are replaced with the new.

Hammers are replaced in sets, each hammer and a spacer are put into their place. The difference in the weight of hammer sets fitted on the opposite axles must not exceed 10 g.

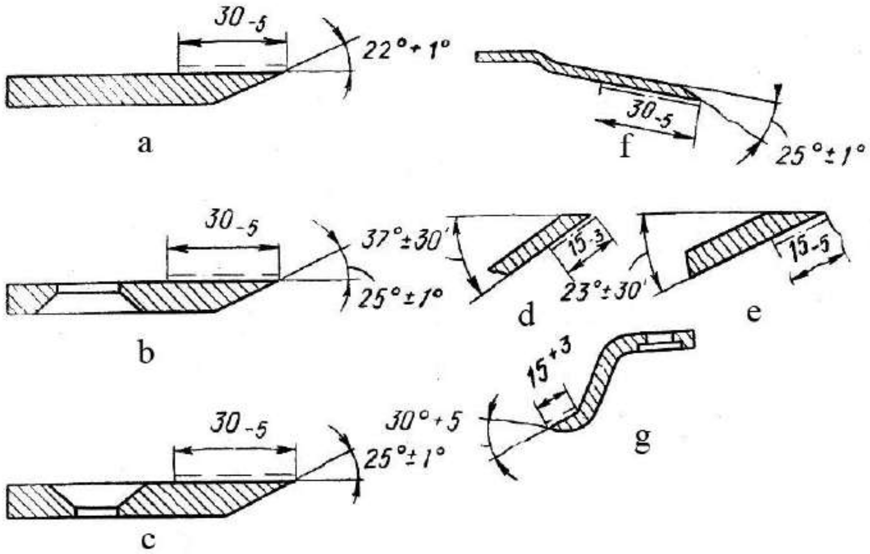


Fig. 2 – Sharpening angles and width of built-up layer of knife in different fodder grinders: a – universal fodder grinder; b, c – straw cutter; f, d – root crop grinder; e – assembly for fodder preparation; g – grinder «Volhar – 5,0»

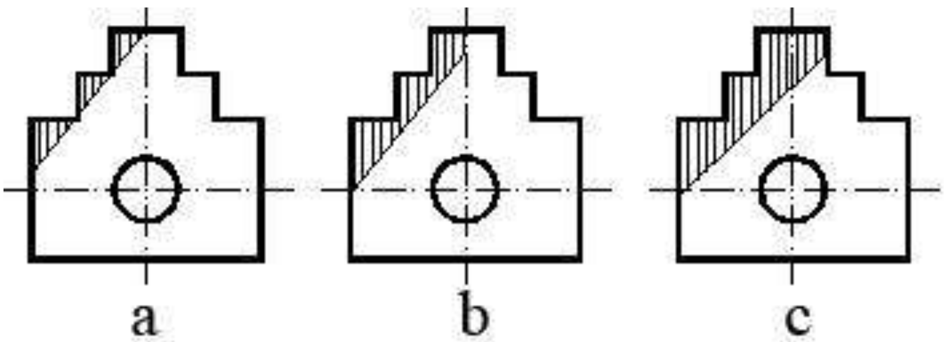


Fig. 3 – Wear diagram of hammer of fodder grinder: a – wear limit has not reached the hammer axle – hammer replacement is premature; b – wear limit has reached the hammer axle –hammer must be replaced; c – wear limit has gone beyond the hammer axle – it is too late to replace.

Imbalance of the crusher rotor reduces durability of machine units, mainly bearings and shafts. Thus, the crusher rotor must be balanced in assembly with all parts but without hammers after each repair. Before fitting hammers, the assembled rotor may have the same imbalance as cutting drums of fodder grinders.

For static balancing of crusher rotors with hinged hammers, sets of hammers with the difference in weight of 5g for new hammers and 10g for utilized hammers and selected for weight in advance are installed on the balanced rotor.

Smooth sieves have advantages relatively to strength. In addition, such a sieve with cylindrical holes, as well as a hammer, can operate in four positions (it is turned around the horizontal axle twice after hole edges have worn and twice – around the vertical axle). After two replacements the sieve is deflected into the opposite side on special machines.

Almost all fodder grinders are equipped with safety elements to stop crusher rotors. Sleeves or pulleys with pins or fingers which are cut off are used as safety elements. Meanwhile, the rotor shaft is coupled rigidly with the drive. If a metal object or a stone gets into the crusher, a finger or a pin is cut off, the crusher rotor stops and the driving pulley starts running free.

Washer tooth surfaces wear out quickly in the toothed overload release clutches. Washers are made of steel 5 and hardened to 27-45 HRC. Toothed washers with teeth worn to the height of less than 5 mm are repaired by upsetting (preheated to 830-900°C) in a special device for pneumatic hammers. After that scorings are smoothed out in the washer, and then it is heated to 810-830°C and quenched in water. Worn washer teeth can be restored also by arc deposition. It is recommended to heat the washer to 600-650°C before surfacing. After surfacing the toothed washer is heated to 800°C, fitted into devices consisting of punches and matrixes, and the original tooth shape is restored by hammer strokes or pressure.

Covers wear in friction overload clutches; they are replaced in repair. New covers are riveted to sheets with hollow copper or brass rivets, or adhered with glue according to the typical technology.

Repair of equipment for machine milking, preprocessing and processing of milk

Before repairing the whole equipment for machine milking is washed and disinfected by cleaning solutions of synthetic powders Л, Б and В, sulfonal, soda ash or preparations "Detergent", "Dezmol" or "Trias 1". Disinfection is carried out with solutions of chlorinated lime, chloramine or calcium hydrochloride.

Basic defects of milking plants occur in vacuum pumps, vacuum pipes, milk pipes and milking devices.

Repair of rotary vacuum pumps. In milking plants vacuum pumps of the following types are used: РВН40/350, УВБ 02.000 and ВЦ40/130. While operation is taking place, pump parts wear out what results in increased gaps as follows: radial (between the rotor cylindrical surface and the frame working surface in places of their most approximation), axial (between butt-ends of the rotor and blades and cover butt-end surfaces) as well as between grooves of rotor and blades. Increase of gaps results in productivity fall of the pump and the vacuum.

Cracks that do not appear on the working surface and breaks of bosses in frames and covers of vacuum pumps are restored by welding or surfacing with wire ПАНЧ-11 ТУ 48-21-593-85. Worn working surfaces of frames are bored out until wear traces are eliminated with the following honing, but less than ∅149 mm – УВБ.02.000, ∅149,2 mm – РВН40/350, ВЦ40/130.

The Rotor cylindrical surface is ground until wear traces and scorings are eliminated but no less than ∅ 122,5 mm – УВБ.02.000, ∅129,4 mm – РВН40/350, ВЦ40/130.

Meanwhile, worn butt-end surfaces of the frame, rotor and blades are processed to the repair size: by grinding – in the frame and the rotor, milling – in blades. Worn working surfaces of the vacuum pump frame are bored with the following honing or they are honed by diamond bars with rigid honing sleeves. The latter method is carried out in two steps. Initially, we perform preliminary honing with coarse-grained bars to remove 0,15-0,35 mm (until wear traces are eliminated), then final honing with fine-grained diamond bars to remove 0,002-0,04 mm.

Worn matching sites of the rotor shaft for bearings, pulleys and places of sealing are restored by surfacing in the carbon dioxide medium with the following mechanical processing.

In future, trying to ensure a normal gap between the rotor with a reduced diameter and the frame with an increased diameter, while assembling, the rotor with covers is replaced relatively to the frame by mill operation of oval holes for studs in frame covers followed by installing pins of repair size or fixing of pins in reamed holes of covers by babbit pouring.

Testing and test running of pumps. After repairs these operations are carried out on the stand in the modes listed in Table 1. After test running it is determined the pump capacity and the ultimate vacuum (maximum vacuum).

In the end of test running the temperature of parts of the vacuum pump must not 60 C exceed the temperature of the ambient air.

Table 1 – Test running characteristics of vacuum pumps

Sequence test running on modes	Rotating frequency of rotor, min^{-1}	Residual pressure kPa (data of vacuum indicator, kPa)	Time of test run, min	Metal-cutting compound
1	720	$\frac{48\pm2}{52\pm2}$	20	Water solution emulsole ET-2
2	1430±10	$\frac{11\pm2}{13\pm2}$	30	Water solution of emulsole ET-2
3	1430±10	$\frac{48\pm2}{52\pm2}$	90	Mineral oil M-$10B_2$, GOST 8581

Repair of vacuum wires and milking pipes is carried out if the tightness is failed which is determined with indicators КИ-4840. At this, the damaged pipe sections are replaced, cracks and damaged weld seam in pipes, frames, frameworks and covers are welded by electric welding. Repaired vacuum pipelines are tightness tested by water pressure testing under the pressure of 0,15 MPa with the following vacuum testing. Milking pipes are tightness tested under the vacuum of 56,5 kPa, which must not be reduced more than 14,6 kPa for 5 minutes.

Repair of milking devices. Basic defects of milking devices are losses of original properties of the teet cup rubber, cracks and holes of milking pails and deformation of the side and butt-end surfaces of the pail mouth.

If elasticity is lost, the teet cup rubber is subjected to rest for a month. At the tensile force of 60 N the rubber length has to be 155 ± 2 mm. If it is longer, the rubber is cut off. The rubber is selected of the same stiffness for one milking device. Cracks and breaches of milking pails and on cans are welded by gas welding using an aluminum filler wire and the flux without lithium or by semiautomatic welding in the argon medium. A failure of the geometrical shape of surfaces of the pail mouth is eliminated by flattening followed by cleaning the surface with an abrasive cloth. The assembled milking device is tested in operation under vacuum and then it is disinfected.

Repair of equipment for preprocessing of milk. Typical defects of refrigerating plants are tightness loss (halocarbon and oil leaking), clogging of inner surfaces of transfer lines and assembly parts, wear of compressor parts, misadjustment and breakdown of automation devices failure. Halocarbon leaking is detected with halide, spirit, propane, petrol lamps or polymer indicators. Lamp operation is based on the dissociation properties of halocarbon at 600-700°C that make chloride and hydrogen fluoride. It colors the flame in green if there is hot copper and if there is much halocarbon, the flame is bright blue.

Joint leakage is eliminated by tightening. If copper tube joints with connecting branches leak and that cannot be eliminated by tightening, they are disconnected, cut off and beaded with devices (Fig. 4).

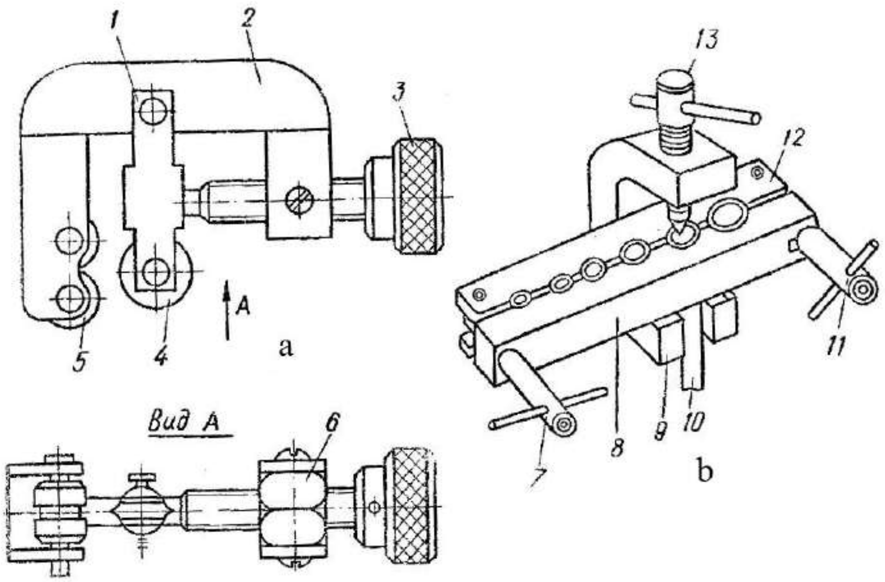


Fig. 4 – tube cutter (a) and ПТ-265 device.10 to bead tubes (b): 1 – carrier; 2 – frame; 3 – screw; 4 – roller; 5 – knife; 6 – nut; 7, 11, 13 – screws; 8, 12 – plates; 9 – clincher; 10 – rolled tube

After leakage have been eliminated, halocarbon is pumped out of the system, the system is tested by gas pressure, vacuumized when a vacuum pump is connected and kept under the pressure of 0,5 MPa for 0,5 hours and filled with halocarbon.

Compressor repair is carried out if the refrigerating capacity 20% falls and more than the nominal one or as to its operating condition. Determination of operating condition and compressor test running is carried out on a special stand.

In case the working surface of the cylinder block is more than 2 mm worn, they are restored by electrolytic welding followed by porous chromium plating and mechanical processing to the size of the working drawing.

In case the cylinder face is more than 2 mm worn and has blisters, cylinders are restored by installing inserts of the spring belt with the following honing to the size of the working drawing.

Crank bearings of crankshafts are ground to one from the standard repair sizes, and main crank bearings are overlaid in the carbon dioxide medium with the following processing to the size of the working drawing.

The lower head of steel connecting rods is restored by its reboring and pouring babbit of Б83 or Б88 brands followed by mechanical processing. Worn planes of valve abutment are eliminated by lapping using the corundum powder.

The assembled compressor is run in for 60 minutes using ХФ12-16 oil in the air without halocarbon at the pressure of less than 0,2 MPa. Every rolled compressor is tested for volumetric productivity and density of the intake and paper valves.

Repair of conveyors

In animal husbandry we use conveyors to carry out various mechanized operations: scraper conveyors, belt conveyors, cable-bucket conveyors, rope-washer conveyors, cable conveyors etc.

For all conveyors the general indicator of their service life is durability of hauling element parts (chains, ropes, belts, etc.).

Repair of equipment to remove droppings. Service life of conveyors to remove droppings is determined by durability of hauling element parts (chains, ropes, belts, sprockets etc.) caused by their operation conditions.

Failures of scraper conveyors are possible; table 2 shows their reasons and methods of their elimination.

If necessary, the hauling chain is shortened by cutting out three links followed by connecting the chain ends using a coupling link which section is cut out at one side. The chain having been connected, the insert (cut out chain section) is put into the coupling link slot and welded by electroarc welding.

While scraper conveyors are repaired, the chain pitch is restored. The most economical and technically profitable method to repair the chain is the one when plates are restored by compression (plastic deformation) in the heated state, and worn coupled axles are replaced with the new.

It is recommended to carry out heating of renewable plates on high-frequency plants. In a special inductor before fitting we can simultaneously heat from two to four plates for 6-7 sec to 850-900°C.

Table. 2 – Possible failures of scraper conveyors, their reasons and methods of their removal

Failure	Reason	Method of elimination
The free-running chain part moves snatching.	Insufficiently strained chain.	To strain the chain.
The chain of the horizontal conveyor broke.	Overloaded conveyor, insufficiently strained chain.	To fasten the chain with a coupling link. To strain the chain afterwards.
The chain of the inclined conveyor slides out of the lower sprocket.	Insufficiently strained chain. The chain with scrapers freezes to the trough (in winter, the temperature below zero).	To strain the chain. To clean the gutter and scrapers of droppings.
Scrapers of the horizontal conveyors turn back and even break.	Scrapers are hooked to gutter walls or its uneven floor, foreign objects, a defective device for scraper lifting	To eliminate defects of the faecal gutter
The electric motor is turned on but the chain does not move.	Insufficient abutment of wedge belts of drive station	To remove the shield and strained belts

Restored plates are strengthened. The most common way of strengthening is heat treatment (quenching in water with the following tempering). Hardened chain plates are subjected to tempering. The tempering temperature is selected 390 ± 10°C taking into consideration necessary mechanical properties of plates that meet their operation conditions.

While clinchers and scrapers of the chain are repaired, parts are ground, worn and new fastening holes are welded and bored respectively, additional parts (covers) are welded to the worn surfaces. Bent and twisted scrapers are ground on the press without heating. Special punches are used for grinding.

Worn surfaces of the thrust journal of the clincher are restored by welding an additional part (cover), produced according to the shape of the clincher surface of plates with the size of 50×55×5 mm. Wear of fastening holes in scrapers and clinchers is welded by electric welding and new holes of the nominal size are bored with conductors.

Joined axles of the chain are not generally restored but replaced with the new made of calibrated rolled metal.

Repair of rope conveyors. The main parameter that determines the rejection moment of belt conveyors is wear or corrosion of more than 60% from the initial diameter of rope wires or breaks of three strands at one spinning step. Parts of rope conveyors are not usually repaired but replaced with the new.

Repair of belt conveyors. In cable-bucket conveyors the main defects are convexities, rupture of rubber, breaks of strings and layering. If there are such defects along the whole length, the pass is discarded, and in some areas it is repaired through replacing defective parts. In this case, there should be no more than three joints along the whole length of the pass.

Repair of lifting screws. Screws are replaced and repaired if we detect bends and breaks of shafts, deformation of coils and spirals, fractures of weld seams in lifting screws.

Repair operations on screws are carried out on specific machines or stands that allow to carry out straightening and welding works.

Having been assembled, the conveyor is manually tested. It is run in for 0,5 hours on free running listening to the operation of all units and for 1 hour – under load, making sure that there are no losses of transported materials.

Repair of shearing machines

Shearing machines may have the following defects: wear of knives and cutter racks, axial bearings and lever grooves, necks of the eccentric and the roller, necks of the transmission shaft and bushings of inner and outer casings, drive gears, stop rods and axial bearings, deformation of levers, and machines with mechanical drive may have damages of the core and the drive shaft shell.

The parts of the disassembled shearing machine are washed in kerosene or in 5% soda solution with the following dry wiping.

Knives and racks with cracks are replaced with the new. Dull racks and knives are sharpened on grinding devices of TA-1 type, having removed beforehand the disk face runout of the grinding device (less than 0,3 mm) and distortion of its geometrical shape. Specified disk defects are eliminated by turning. After sharpening, cutting edges of knives and racks should not have scorings and gaps between the working surface and the line gage – not to exceed 0,05 mm. Sharpened blade ends of the rack are blunt on the emery stone.

Worn lever grooves are reamed to the repair size. Deformed levers are ground according to the template gage. Worn antennae of pressure feet are eliminated with the following fitting and fastening, welding of the new. Distortion of the rack fastening over 0,01 mm is eliminated by grinding. Worn crankpins and rollers are replaced with the new.

Damaged places of the shell of the flexible shaft are cut off by covering the damaged place with a tube and soldering it to the shell. Torn off core ends are soldered to the length of 30-35 mm and then connected with a split-design copper bushing, compressed and soldered to it.

Cutting edges of knife segments in extreme dead points must not come out of rack limits. The allowable longitudinal backlash of the vibrating roller and the eccentric roller is less than 0,4 mm.

Repair of equipment in poultry farms and incubators

The best method to repair equipment in poultry farms and incubators is aggregative when faulty units are replaced with new or renewable ones. If the exchange fund is absent, repair of the equipment is carried out by the individual method.

<u>Repair of nest lines.</u> While nest lines are repaired, they perform the following operations: partial disassembly and assembly of nests to replace defective parts; correcting deformed sections of the network; welding of cracks and breaking of welding joints etc.

Nest lines are disassembled if parts which cannot be restored are replaced.

<u>Water supply system repair.</u> Main faults of the water supply system are as follows: water leaks in joints, holes in bottoms of drinking tanks, operating irregularity stop valves and water regulating tanks.

Micro cup-shaped drinking tanks, connection elements (rings, hoses, sleeves), water-drain pipes, defected sealing are not repaired but replaced with the new.

Operating irregularity of the stop valve usually occurs in case sealing is damaged, or large deposits on sliding pistons or spindles appear or thread-stripping on the spindle. Deposition of salts on stop valve parts is mechanically removed.

Spindles of stop valves are discarded if more than one string of thread tears off.

Main defects of the water-regulating tank are clogging of the valve of the floating-type mechanism, breaks, holes of filter screens, damages of the float.

Clogged frame holes are cleaned with a soft wire and washed. Damaged parts of the water-regulating tank which cannot be repaired are replaced with the new.

Repair of water supply and water drive equipment

Repair of water supply equipment. Water supply equipment is usually repaired if leakage occurs due to fracture of welded seams and joints, cracks and rust through in steel pipes, damages of joints of cast iron, asbestos cement, polyethylene and other pipes, malfunctions of water-stop valves.

Minor damages of steel pipes are eliminated by manual welding, fitting clamps and covers. Defects of considerable sizes are eliminated by changing a pipeline section for a plastic one using special fittings and devices for welding of plastics.

When damaged pipeline sections are replaced with metal pipes, separated parts are connected with flanges or by welding.

Restored pipelines are tested on some separate sections (800-1000 m), creating the pressure which 0,5 MPa exceeds the working one in cast-iron pipes, in steel pipes – 1 MPa more than the working pressure, in asbestos cement and the others – 0,3 MPa more than the working pressure.

After testing the water supply network is disinfected by 0,1-0,2% solution of chlorinated lime and washed with water untill odors are eliminated.

Repair of water-stop valves. The following defects may appear in water-stop valves during operation: cracks and wear of moving parts, thread-stripping, wear and damage of gasket seals and sealing surfaces. Gaskets and gasket seals are usually replaced.

Repair of assemblies and water supply pumps. In animal husbandry centrifugal electric motor hydraulic pump packages and centrifugal cradle-mounted pumps for water are used for water supply. If water supply 25% decreases, the winding of the electric motor fails, or the axial gap exceeds the allowable one, the assembly and pumps are repaired.

Repair features of assemblies and pumps for water supply is the increased amount of cleaning works to remove rust by etching with sulfuric acid solutions with concentration of 200 g/l or pastes. Inhibitors (ethylamine, thioglykol etc.) are added (up to 5 g/l) into the solution to slow down metal reactions with acid.

Main defects of pump parts include wear of gaskets and gasket seals, frame part cracks, wear of mounting surfaces and key grooves, wear and tear of thread, shaft bending.

Gaskets seals and parts made of polymeric materials are not restored but replaced.

Part defects listed above are removed by the typical technology.

The pump is checked for tightness before connecting with the electric motor.

The pump assembled with the electric motor is run and tested for at least 30 minutes at the nominal mode.

Repair of sewage, ventilation and heating systems

Repair of sewage systems. The technological process of repair includes: washing drains, sewer and collector pipes; cleaning siphons, sanitary equipment and vent stacks from dirt and layers; replacing damaged curved parts and threaded connections; removing damaged pipes with their following check for tightness; restoring damaged butt joints. A sewer system is washed with tap water till deposits in pipes and fittings are completely removed under the pressure of 0,03 MPa, and then we visually check the linearity of sewer pipes in the area between inspection chambers.

Disrupted butt joints of flared ends of cast-iron pipes are repaired by cutting out the sealing followed by closing joints. Cracks and knots in cast-iron pipes are welded by electric welding. In addition, cracks in cast-iron pipes and curved parts, siphons and sanitary devices are closed with solutions based on epoxy resins. Damaged ceramic and asbestos cement pipes are replaced with the new.

Repair of ventilation systems. The technological process of repair includes: cleaning the equipment of the air-ventilation chamber and air duct from dust and dirt; checking fastening reliability and operating condition of electric motors, fans and calorifers; eliminating leaks in air duct joints and replacing curved parts as well as ventilation pipe sections damaged by corrosion and badly deformed.

Damaged complex parts of air ducts are replaced with new ones manufactured in specialized workshops. Simple sections of air ducts are made of galvanized iron on their operation place according to the template gage. Then they are precoated and painted with acid-resistant paint.

Repair of fans and calorifers is carried out by the generally accepted technology.

Repair of the heating system is carried out if air and vapour leak into steam pipelines, heating, condensing devices as well as defects of stop valves. Defects are detected by external examination and hydraulic testing under the water pressure of 0,2 MPa.

Leaks in pipe joints, heating devices and stop and control valves are eliminated by replacing seals. Defects of boiler plants, steam pipelines and batteries of smooth pipes (registers) are eliminated by gas or arc welding. Defective heating devices are replaced with the new. The design position of the plant should not be changed when registers are replaced. While a heating system is repaired, we check the condition of compensators and the working capacity of rolling and sliding supports of steam pipelines. Besides, that steam pipelines have to be inclined in the direction of the vapour motion without delinearization. This allows avoiding accumulation of the condensate dirt and hydrodynamic impacts.

Repair of equipment generating hot water and vapour

For in-place repair of equipment the workers of the repair crew must have permission to repair boilers and equipment which work under the pressure.

An important part of the repair technological process of the equipment generating hot water and vapour is cleaning from scale.

Purification of the equipment from scale is carried out by chemical and mechanical methods (Fig. 5, a). The most common method of chemical cleaning for boilers is cleaning by hydrochloric acid solution, solutions of phosphoric and chromic acids are used less often. Mechanical cleaning is carried out using devices with electric or pneumatic actuators (Fig. 5, b). Boilers are cleaned with metal brushes from loose deposits; with heads – from solid deposits. Ellipsoidal heads (Fig. 5, c) are used for coarse purification of heavily clogged pipes. Final cleaning is carried out with heads of scatter type (Fig. 5, d).

Repair of boilers and vapour formers. Typical defects of boilers and vapour formers are as follows: defects of weld spots; burning and cracks of the boiler grate; cracks in furnace and ash doors; cracks, burning and corrosion damages of smoke chambers and pipes; damages and wear of pump parts and failures of automation systems.

If seams are defected in weld spots, the seam is cut off and welded. Burned boiler grates and reflectors are replaced with the new. Cracks in furnace and ash doors and on the feeding pump frame are welded by electric welding by the method of annealing rollers. Cracks in boiler walls are welded. Patch pieces are welded to the burned walls of the chamber. Burned or destroyed by corrosion cylindrical parts of the smoke box are strengthened with patch pieces from the inner side. Burned pipes are replaced with the new. Damaged water pipes are repaired by welding pipes of smaller diameter into them. Convexities and dints on chamber walls, smoke boxes and boiler flues are flattened.

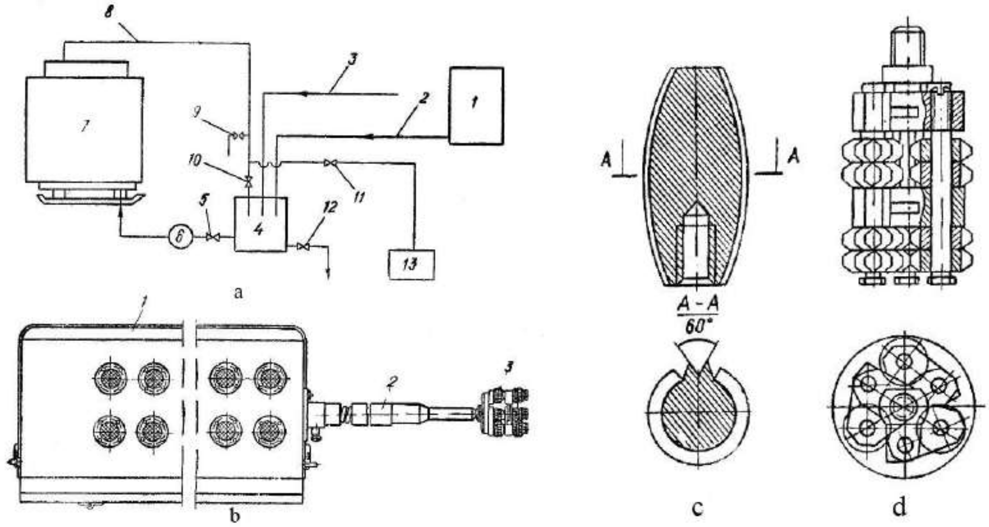


Fig. 5 – Methods of cleaning equipment from scale: a – Scheme of chemical cleaning of boilers with forced circulation of solution: 1 – tank with acid; 2 – acid tube; 3 – water pipe; 4 – washing tank; 5, 10, 11 – tap valves; 6 – pump; 7 – boiler; 8 – return pipeline; 9 – sampling faucet; 12 – escape valve; 13 – drainage tank; b – device for mechanical cleaning of boilers and vapour formers from scale: 1 – power part of device (electric motor with coupling joint); 2 – flexible shaft; 3 – interchangeable head; c, d – ellipsoidal and scatter heads for mechanical cleaning of boiler water tubes from scale

Wear and marks on working surfaces of safety valves, valves and feeding pump valves as well as their jacks are eliminated by mechanical processing (grinding, broaching or milling) followed by reseating of mating parts by abrasive pastes. Each repaired safety valve is tested for tightness.

Assembled units and the boiler are subjected to hydraulic testing. The assembled boiler is testes under the pressure of 0,2 MPa for 5 minutes.

<u>Repair of water electric heating units.</u> Main defects of water electric heating units can be cracks of casings and reservoirs, damages of

pipelines, burnout of heating elements, wear and damages of the temperature relay.

Cracks of the casing are welded by gas welding and reservoirs – by electric welding. Burned-out heating elements are replaced with the new or produced of nichrome, fehrale or constantan wires. Worn parts of temperature relays are replaced with the new with the following check of operation of the contact mechanism and adjustment to turn off heating at 85-90°C.

The reservoir and the cold water pipeline are tested by water pressure of 0,5 MPa for 5 minutes. Assembled and grounded water electric heating units are tested for duration of water heating and the operate values of the temperature relay.

Repair of processing equipment

Processing equipment to repair machines includes the following: metal-cutting lathes, press-forging equipment, equipment for welding and building-up works, galvanic and other equipment to carry out technological processes in repair production.

The preventive maintenance system of equipment provides periodical technical maintenance, overhaul inspection and repair of the processing equipment.

There are three types of planned repair: small (current), average and overhaul.

As some types of equipment (including machining equipment) are produced in small series, their typical repair technology may be absent. In order to maintain mutual placement of parts for next assembling, parts are marked with a steel stamp, a core sample or an electrograph, while disassembling.

Special methods of repair determination of machining equipment parts (such as beds) must ensure accuracy of flatness and mutual placement of working surfaces at considerable overall dimensions. Fig. 6 shows the test set-up of straightness, parallelism and concavity of guide beds using a universal control axle.

While equipment parts are repaired (restored), we primarily use the same technological methods as in machinery repair. We also use scraping, restoration of broken-off parts by additional casting, building-up of worn parts with self-hardening substances (plastics based on acrylic resins – acryloplasts).

For machining equipment, the operations to check machines for accuracy are important; they are carried out according to special methods.

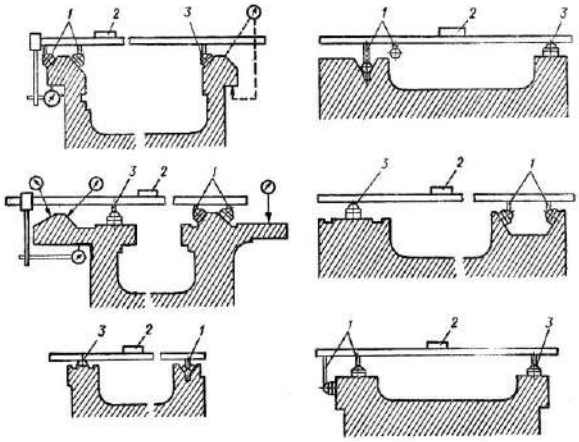


Fig. 6 – Test set-up of straightness, parallelism and twistedness of guide beds of different cross-sections and sizes with a universal control axle:

1, 3 – supports;
2 – level.

<u>Repair of beds and supports of metal-cutting lathes.</u> A cross-section of a typical bed of a turning machine is shown in Fig. 7. The surfaces 2 and 3 of the front support guide outwear most of all, the lower surfaces 1, 5, 6, 9 and 10 outwear less intensively. The surfaces 4, 7 and 8 of guides where the tail block is located outwear slightly. This wear is not identical at the length of guides and depends on the size of parts processed on the machine. When scales form parts, cutting waste, dust and wear products appear on the surfaces of beds' working planes, it leads to abrasive wear and local depletion.

When beds are repaired, first thing, scorings and dints are sealed. For this we use a paste based on epoxy resin ЕД-6 with the addition of the filling compound (aluminum powder, cast iron grit, etc.). Scoring and dints are eliminated also by brass or bronze seal followed by processing of the seal aflat with the guide surface.

Deep scorings in guides are eliminated by pressing-in of an cast iron plug into the hole obtained after preliminary drilling and reaming. After pressing-in, the protruding part of the plug is processed at the level with the guide plane. Deep dints are eliminated by fitting inserts on screws.

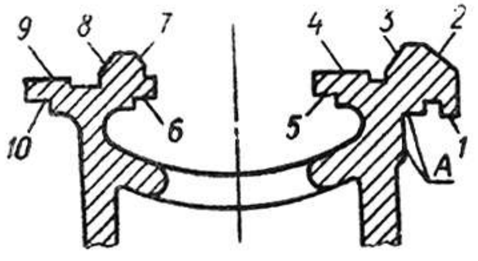


Fig. 7 – Cross-section of guides of typical turning machine beds:

1-10 – wear surfaces;
A – lower guide planes that wear least of all.

The choice of the way to restore guide beds depends on the wear size. Thus, wear is less than 0,1 mm, guides are scraped or lapped with paste ГОЇ; if wear is 0,1-0,3 mm, they are ground or scraped; 0,3-0,5 mm – we carry out flatting followed by grinding or scraping; more than 0,5 mm – they are subjected to rough shaping and then flatting with the following grinding or scraping.

Supports are repaired by the same methods as beds. In case wear is significant, inserts are fitted into the support guide after milling. Materials of inserts: plastic mixtures – textolite ПТ, paper-based laminate; metal alloys – monel metal, brass ЛМцС58-2-2, Zinc alloy ЦАМ10-5. Inserts of plastic mixtures are adhered with glue БФ-2 or БФ-4, and inserts of metal alloys are overlaid or metalized.

Repair of the headstock and the foot block of screw-cutting lathes. If parts of the headstock and foot block are worn, it is disturbed the dimension chain which determines the distance between the front and rear centers of the lathe. As a result of wear of guide planes, it is disturbed the difference of heights between its front and rear centers. If we set spindle bearings in special frames and flanges, wear of holes for bearings is compensated by replacing the corresponding frames and flanges with the following adjustment of the inner diameter behind bearings and measuring the radial runout (allowable deviation is 0,01 mm). If wear is big, holes are bored and pressed-in or bushings are fitted on glue in the frame of the front block.

While foot blocks are repaired, we restore the alignment accuracy of axle surfaces with the bed and the frame, accuracy of the frame hole and the height of the headstock and foot block centers; we repair or produce movable sleeves, feed screws and other parts. Holes for movable sleeves in the frame are repaired by lapping, boring with the following reduction and pouring with acryloplast. Slightly worn holes are repaired by lapping and movable sleeves are replaced with the new. Meanwhile, the height of centers is restored by fitting compensation covers on axle guides.

Assembly, running-in and testing. After assembly and adjusting of separate assembly parts, we start general assembling. We fix a base part (bed), adjust its position, and check the guides. Then, we fasten separate units consecutively to the bed. At the same time, it is kept their reciprocal location relatively to the bed and to each other following admissible deviations specified in the passport. While assembling, separate assembly parts and units are adjusted, wedges are tightened, bearings are controlled. While assembling, it is provided secure abutment of separate units to the bed (the gap is less than 0,04 mm).

Free running testing (running-in) starts from the smallest turns at the minimum load and continues for at least 0,5 hours. Then lubricants are changed. Testing main motion mechanisms of machinery is carried out at all turns, moving from small to big (twice at each stage). At full power the spindle must rotate for at least 1 hour till the required temperature of bearings is reached (for plain bearings – to 70°C, for rolling bearings – to 85°C).

The feed motion is also run-in at all feeds. During running-in the actual quantity of revolutions, feeds, strokes of slide blocks, replacing speed of units are checked against the ratings. Deviations must not exceed 5%.

Testing machines under load is carried out by processing part-samples at different speeds under load to the value of the rated capacity of the drive for at least 30 minutes and short-term overloading to 25%. It is allowed a slight growth of noise in gear drives but it is not allowed vibrations leading to chipping of the tool cutting edge.

After these operations, tests for accuracy and rigidity are carried out and we define the geometric relationship of the machine, the processing accuracy of products on it.

Repair of electric power equipment

In farm production we use asynchronous short-circuited electric motors of three-phase current with the power up to 132 kW, synchronous generators, electrical equipment of water-lifting wells with submersible motors, welding transformers, generators and converters, magnetic starters, automatic switches, packet switches and changers, knife switches, control buttons, heat and intermediate relay, devices with built-in temperature protection.

Repair of asynchronous electric motors. Possible defects of electric motors are caused by the set of electrical and mechanical damages. Often defects in electric motors are as follows: circuit opening, shorting between winding phases or windings on the frame, turn-to-turn winding short circuit, insulation damages and fractures (breaks) of conductors, wear of bearing shields, deformation of rotor and stator plates, bends of the rotor shaft, breaks of separate rods or locking rings, rotor short-circuit, damages of contact rings of the phase rotor etc.

The damaged winding is removed and a new one is wound to eliminate damages in the electric circuit of the stator.

The stator winding having passed intermediate control tests for correct insertion and joints of coils and the electrical strength of insulation is saturated with lacquer МЛ-92 or ПЗ-933 three times and dried out in an electric furnace at automatic temperature control. After the secondary intermediate control of the insulation electric strength, the stator winding is coated with electrical insulating enamels of ГФ-92ХС, ГФ-92ГС and ЗП-91 types.

To eliminate mechanical damages of electric motor structural elements it is used welding, surfacing, soldering and some mechanical operations.

Worn matching sites for bearings in covers are restored by non-bath dry topping if wear is less than 1 mm for a diameter and there are no dints and dimples; bushings are pressed in into the bored hole in a cover in case wear is more than 1mm of sites. Worn matching sites for bearings on the rotor shaft are restored by surfacing with the following grinding. Cracks in covers and electric motor frames are welded and cracks and fractures of rotor locking rings are soldered. Breaks of rotor rods are eliminated by aluminum refilling. Fused sections of stator's active steel are cleaned from the built-up layer or cut out followed by fitting a part of hard insulation material instead of it. Collector defects are eliminated by turning, grinding and polishing. If defects are big, collectors are disassembled.

Contact rings of a phase rotor in case of burning, dints, abscesses are turned on a turning machine or ground and polished with abrasive cloth №00. The radial runout of rings must not exceed 0,05 mm. Defective insulation parts are replaced.

Having been assembled, electric motors are tested carrying out the following operations: measuring the winding resistance (one against the other and relatively to the frame); measuring the winding resistance against the direct current in the cold state; free running test, testing the electric strength of turn-to-turn winding insulation; measuring the air gap between a stator and a rotor.

Repair of start protecting equipment and distributing devices with voltage less than 1 kV. All kinds of power electrical plants are equipped with starting, safety, adjusting and distribution devices. They include knife switches, changers, safety devices, packet switches, magnetic starters, automatic switchers, thermal relays etc.

Typical faults and damages of these devices are as follows: excessive heating of starter coils, contactors and automatons; turn-to-turn short circuit and frame ground; excessive heating of contacts; their big wear etc.

Defects of knife switchers, changers and safety devices are eliminated by purification of contact surfaces of knives of mounts and jaws from dirt, soot and particles of the fused metal, tightening of fastener means and hinge joints, tightening hard all contact wires etc. Entering knives into switch jaws must not 2-4 mm reach jaw contact areas at the completely turned on mode. The repair quality of knife switches and changers is checked by switching on and off ten-fifteen times.

The overhaul period of contactors and magnetic starters is determined by the operating condition of the holding coil. Their typical defects are drying and burning of insulation, turn-to-turn short circuit and break off. Each of these defects requires coil replacement with a new one or its rewinding according to the ratings.

Defects of fasteners, elastic contact starters and contactors are eliminated the same way as while knife switches or changers are repaired. Burned parts are replaced when spark suppressor chambers of contactors and starters are repaired.

While operability of contactors and starters are controlled, we check mobility of contact systems, mechanical characteristics of devices, quality of coil insulation and density of contact joints.

Repair of handling equipment (HE)

Technical service enterprises use diverse handling equipment: general purpose bridge cranes with the lifting capacity of 5 and 10 tons, single-beam bridge cranes with electric hoists with the lifting capacity of 1-5 tons, monorails with electric hoist of T3 type, walking cranes with the lifting capacity of 0,125-3,2 tonnes, aerial and load-carrying conveyors, hydraulic and electromechanical lifters, jacks, transport trolleys, lifting-transport devices etc.

The crane equipment after repair has to correspond to engineering supervision. Handling equipment is most often repaired by the integrated featureless and aggregative methods.

As for at suitability for repair HE parts are divided into two groups: those which are not possible or not allowed to be repaired, and those which can and allowed to be repaired. The first group includes steel cables, rolling bearings, nuts (if wear in the jaw opening exceeds 10%), bails, springs with cracks and breaks, brake pads, V-belts, twisted shafts and shafts with cracks. The second group includes the rest of standard and non-standard mechanisms and parts of HE.

Repair of shafts and axles. Main defects of shafts and axles of HE are typical for all kinds of machinery, they are eliminated by standard methods. A typical defect of HE is deflection because of long shafts in design; it is eliminated by flattening. If the shaft rotating frequency is less than 500 min^{-1}, the admissible deflection is 0,15 mm for 1 m, but less than 0,3 mm for the entire length; more than 500 min^{-1} – 0,1 mm for 1 m, but less than 0,2 mm for the entire length. Deflection of shafts and axles of less than 0,5 mm is eliminated by mechanical processing, more than 0,5 mm – by flattening without heating. Flattening by heating is also used from the side of convexities. The shaft is rectified under internal stresses.

Repair of drums and blocks. The mentioned parts of HE are not repaired in the following cases: more than 25% reduction of the initial thickness of the drum wall, wear of the groove (gutter) surface of the block for over 50% of the rope diameter; cracks in cylindrical surfaces or hubs of the drum and the block; over 10% reduction of the initial wall thickness of the block groove. In other cases, load drums, crane blocks are restored by groove turning. The aim of such repair is to restore the angle of contact $\alpha_{н}$ (Fig. 8) of the rope to the groove as its shortening at wear to $\alpha_{з}$ and the increase of the specific load connected with it negatively affects the operation of the rope.

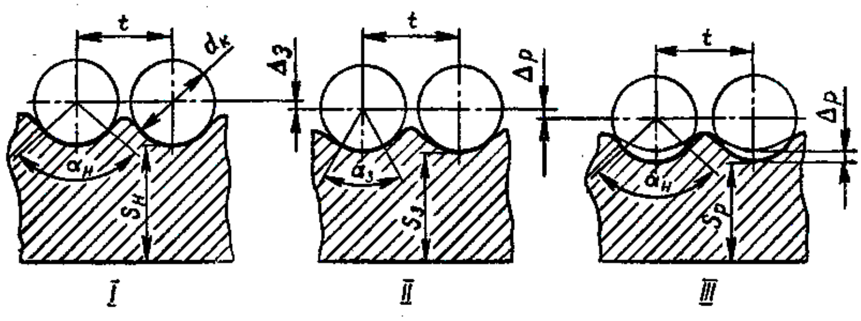


Fig. 8 – Repair schemes of drum grooves of lifting-and-shifting machines: I – new; II – worn $\alpha_{з}<\alpha_{н}$; III – repaired by turning

In case of turning the drum strength is checked by calculation as the thickness of walls Sp decreases $\Delta_{з} + \Delta_{p}$. Welding of local chips and through cracks in blocks is allowed. Welding of the cylindrical part of the winch drum is allowed if there is a crack on it. Surfacing of cast iron blocks and drums and welding of cracks in them is not allowed.

Repair of metal structures. Typical defects are destruction of welded and riveted joints, deformation and cracks in elements, weakening of bolt joints. Cracks, abscesses and other defects of welds are eliminated by their cutting out with repeated welding. Weakened rivets are replaced with the new of the increased diameter. Cracks in sheet elements of metal constructions are repaired by welding of the damaged area. In critical areas welded cracks are reinforced by covers with the thickness of 0,6-0,7 of the element thickness (Fig. 9). Cover seams can not be placed perpendicularly to the tensile force which may cause cracks. They are to be inclined to it. Cane segments are repaired by welding of cracks, their cutting out with simultaneous overlapping diamond-shaped, triangular, box riveted covers, by cutting out a defective section and welding a new one in a butt joint. Welding of crane segments is carried out in the cold state as well as with heating. Slight deflections of structural elements are repaired by flattening without heating. If deformation is significant or a defective element is cracked, it is replaced with a new one.

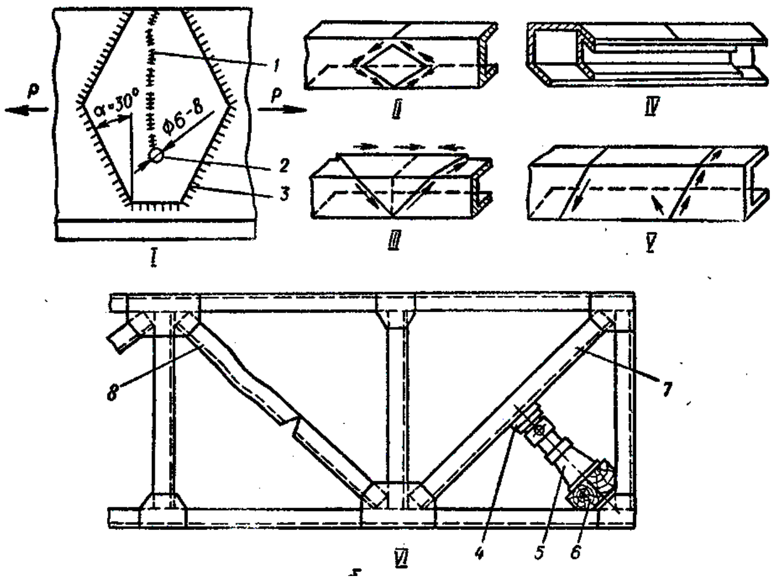


Fig. 9 – Repair schemes of metal construction of lifting-and-shifting machines: 1 – repair of an element with a crack; II, III, IV – placing a suitable diamond-shaped, triangular and gutter covers; V – replacement of defective sections; VI – flattening and replacement of defective crane segments: 1 – crack; 2 – hole-deconcentrator; 3 – cover; 4 – sub plate; 5 – jack; 6 – bars; 7 – element subjected to flattening; 8 – element subjected to replacing.

Bolt joints of elements of metal constructions are restored by reaming of worn holes for an increased size and fitting of bolts of the corresponding diameter.

Testing and handing-over after repair of HE is the same as testing and handing-over for operation after assembling of new machines. Technical examination, static and dynamic tests and crane hanging-over to the customer begins after testing of each mechanism, elimination of defects and adjustment of bridge crane brakes. Static testing is carried out under the load 25% higher than the nominal lifting capacity of the crane. It is determined elastic and final deformations of longitudinal beams using plumb lines with rulers and indexes on the workshop floor.

Counting out is carried out three times: before loads, after lifting of the test load to 200-300 mm high and its holding for 10 minutes and then after lowering the load. If there is no final deflection, the first and last indications must coincide, in case of its presence: the crane is not allowed to operate until deflection reasons are detected and eliminated. In case of positive results of static testing, we carry out dynamic testing with the load 10% higher than the crane lifting capacity. At this, we check operation of all mechanisms at operating speeds first separately and then together. After dynamic tests, the crane is examined again paying attention to operability of the mechanism, heating of bearings, oil leaks in connectors. Test results are drawn by the act.

Lecture № 16
Automation of technological processes of machinery repair

Purpose and nature of mechanization and automation of technological processes of repair

Automation of the technical service system of tractors, motor vehicles and other agricultural machinery makes working conditions easier, improves their quality and efficiency, reduces prime cost and shortens repair terms.

Manufacturing automation (MA) – a process of development of machine production, when management and control functions which were previously performed by human beings, are transmitted to equipment and automatic devices. Manufacturing automation is the basis for development of the modern industry, the main direction of the technological progress. The purpose of MA is to increase operating efficiency, improve the output quality, create conditions for optimum use of all production resources. MA can be partial, integrated and complete.

Partial MA, specifically, automation of certain production operations, is carried out in cases when management of processes due to their complexity or transience, is almost inaccessible to a human and when simple automatic devices replace him effectively. Active production equipment is usually partially automated. With improvement of automation methods and expanding of spheres of their application it has been found out that partial automation is the most effective when production equipment is developed as automatic one. Automation of administrative works also belongs to partial MA.

In integrated MA workshop sections, workshops, plants, power plants operate as a single interconnected automated system. Integrated MA includes all basic production functions of plants, farms, services; it is advisable only at highly developed production based on advanced technology and progressive management methods using reliable production equipment, acting according to the given program or a self-organizing program. Meanwhile, functions of a person are limited by general supervision and control of the complex operation.

Complete MA – the highest automation level that means transmission of all management and control functions of a computer-integrated manufacture to automatic control systems. It is carried out when automated production is cost-effective, stable, its modes are practically unchanged, and possible deviations can be taken into account in advance as well as in inaccessible or dangerous conditions for human life and health.

Determining the extent of automation first of all it is taken into consideration its cost-effectiveness and profitability in the conditions of specific production.

MA is one of the basic factors of the modern scientific and technological revolution that opens for humanity unprecedented opportunities of nature transformation, creation of huge material wealth, multiplication of human creative abilities.

Automation of technological purification operations, diagnostics

Purification efficiency during automation. In order to carry out purification operations of high quality with minimal energy and labor costs, it is important along with the use of effective washing agents and plants to keep modes of technological parameters (temperature, clogging, concentration) in right ranges.

Automatic adjustment system of temperature of washing solutions. In agricultural repair production we use various methods of heating washing solutions: by burning liquid fuel in specialized combustion chambers; passing vapour (gas) through coiled pipes, placing into a bath with a washing solution; an electric one. The latter method as the most economical, reliable and simple is widely used in automatic temperature control systems of liquids and gases. Systems that implement the method of electric heating as adjusting elements usually use TENAS of a submersible type in combination with two-position controls and sensors made on the basis of manometric electric-contact thermometers.

A schematic diagram of the temperature control system of washing solutions is shown in Figure 1.

All TENAS are divided into two groups: 1) TENAS, which are switched on by KM3 contactors that operate only during temperature output of a washing solution to the predetermined value (in what follows switched off TENAS); 2) TENAS, which are switched on by KM2 contactors which operate on the first stage together with TENAS of the first group, and then after the temperature output of a washing solution into the desired area are periodically switched on to maintain the temperature in the desired range. As a temperature transducer for a washing solution it is used a manometric electric-contact thermometer. In case of any malfunctions or failures that can cause increase of the temperature of the washing solution relatively to the upper limit of the control zone, the scheme provides the use of the thermal transducer KK1, which responds to this increase. Meanwhile, the disconnecting contact KK1 deenergizes the relay winding KV5, which turns off heating and turns on the light alarm "Avaria"

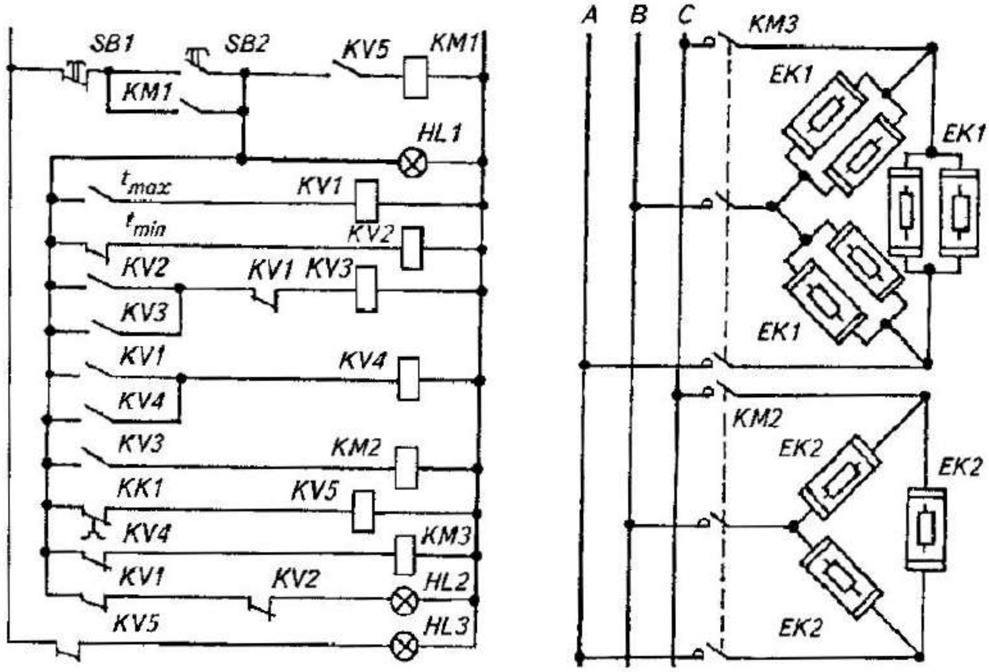


Fig. 1 – Schematic diagram of CAP temperature of washing liquid

<u>Control of concentration of washing agents in solutions.</u> The purification quality is directly dependent on the concentration of washing agents. The reasons of their change during purification is addition of water to compensate the drain of the solution as well as the washing agent to restore concentration of the solution (which changes due to its deposition on parts, chemical reaction with clogging by salts and other random factors).

In modern repair production we use washing agents based on alkali electrolytes. It is known that electric conductivity of solutions (based on such washing agents) has a definite correlation with their concentration and temperature. Therefore, in practice, to measure concentration of solutions we use the estimation method of electric conductivity taking into consideration their temperature error.

The diagram of the device that implements such method is shown in Figure 2. The device operates in the following way. A signal from the impulse generator 1 with the frequency of 2.5 kHz is sent to the bipolar amplifier 2, to the output of which the electrolytic eyelet 3 with supporting resistance$_{оп}$ is connected. Voltage reduced from this resistance is proportional to the current that flows in it, and hence to the electric conductivity of the solution.

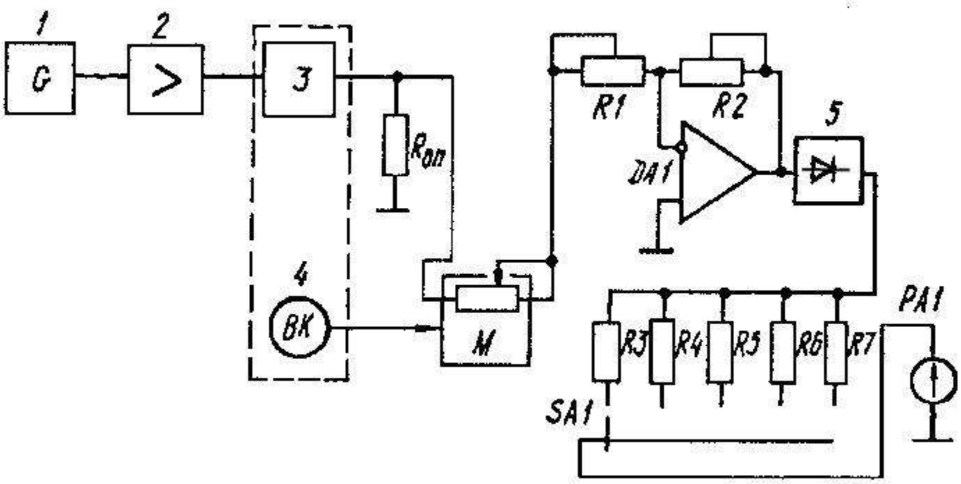


Fig. 2 – Scheme of analyzer of washing solution: 1 – generator; 2 – amplifier; 3 – electrolytic center; 4 – temperature sensor; 5 – amplitude detector

Control of solution contamination. If such parameters as temperature, a concentration level of solutions are subjected to adjustment then the lowered washing ability of solutions (due to exceeding standards of the amount of their pollution) necessitates to replace or regenerate (restore) them.

Due to the absence of simple and reliable means of contamination control of solutions, the need of their restoration (or replacement) is considered subjectively from the visual control of the color of the solution and also from the time of its operation. Quite sensitive, reliable and simple in design optical transducers of contamination control of solutions have been developed. The principle of operation of such transducer (Fig. 3) is based on selective absorption of contaminations of light radiation by particles in visible and infrared sections of the spectrum. The measuring chamber is filled with the solution of the washing medium while the transducer into solution is immersed. The optical characteristics of the transducer are selected that they do not react to components of the detergent. If there are contaminations, the optical density of the solution changes and the sensor converts it into the electrical signal proportional to concentration of contaminations. The electrical signal is registered by the indicator.

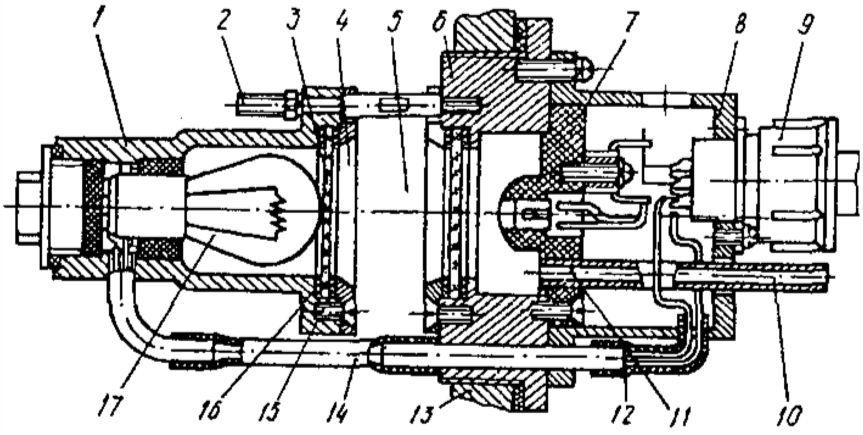


Fig. 3 – Optical sensor to control washing solutions: 1 – block of light radiation; 2 – stud pins; 3 – protective glass lens; 4 – bushings; 5 – measuring chamber; 6 – block of light detector; 7 – basis; 8 – cartridge; 9 –plug; 10 – tubes; II – cell; 12 – wires; 13 – frame; 14 – protective sleeve; 15, 16 – gaskets; 17 – lighting lamp.

The range of values of the measuring concentration of contamination is 0.40 g/L, and the relative error of measurements does not exceed 8% when the temperature of the controlled medium is less than 85°C.

The automatic system of washing control. The washing technology consists in delivering assembly units and parts into the washing chamber, lowering the curtain which closes the hole to turn off spraying of the washing solution, turn on the pump of the solution supply into the nozzle, and ensure relative movement of parts and liquid jets. After ending of the washing term, the pump engine is turned off, the curtain which closes the inlet hole rises, and the basket with parts returns into its original position to remove vapors of the washing liquid.

Diagnostics is divided into three main stages: obtaining information about the operating condition of the object; processing and analyzing the received information; diagnosis and decision-making. On the basis of the carried out diagnostics we determine the shape and volume of repair works, check readiness of machines and bring into the functional state.

During automatic diagnostics, functions of an operator are reduced to turn on the system in the beginning of checking and turn off at the end of diagnostics. Automatic diagnostic systems use vibroacoustic and spectrophotometric methods of control with a set of electronic devices.

Vibroacoustic diagnostic methods allow recording the amplitude of acoustic signals (noises and vibrations) and assessing the nature of their changes. The amplitude and frequency of noises and vibrations change with wear of parts and increase of gaps of related parts. The purpose of the vibroacoustic diagnostic system (Fig. 4) is in enhancing signals generated by emerged defects from numerous acoustic barriers arising when the assembly operates in a normal manner.

For this purpose, it is fitted a sensor of acoustic vibrations (a primary converter) on the object of diagnostics OD. It is sent an electrical signal to the amplifier B and then to the analyzer A. On the analyzer output components (harmonics) of acoustic vibrations are emitted in turns and sent to a square-ware generator SWG as alternating voltage and then to the integrator I and the measuring instrument MI. The square-ware generator provides a power value (as a voltage square) on the output; and the integrator averages the vibration power of the studied frequency range for a certain period of time. A power value is registered by MI.

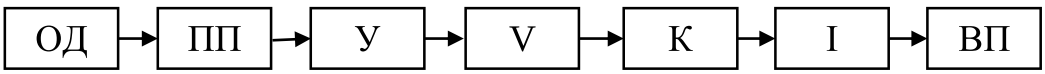


Fig. 4 – Functional diagram of acoustic fault detection system

The spectrophotometric method of diagnosis is based on determining the content of wear products in oil samples by measuring emission spectra while oil samples in the electric arc are burned. Spectra are photographed and then decoded by special spectrograms or using computers. According to the results of periodic tests, we draw charts of the wear rate and forecast the wear rate of diagnostics objects.

Moto-testers estimate operating condition and adjust internal combustion engines. Using these devices, we can determine parameters of the ignition system of carburetor engines, power supply and engine starting systems as well as estimate operating efficiency of its separate cylinders.

Automation of worn-part reclamation, running-in and painting

The restoration technology of worn parts of agricultural machinery by the galvanic method is based on deposition of metals by electrolysis of aqueous solutions of metal salts or acids (chromium coating).

Various methods of changing the polarity and the current form of electrolysis are used in order to get metal building-up of high quality: a) automatic current reversal, i.e periodic change of voltage polarity on parts from negative into positive and vice versa; b) non-central, i.e the rectified current with different rectification factor. Let us consider implementation of one of these methods on the example of a universal power source to power electrolytic baths.

The device allows to carry out the process of metal building-up on a single-phase non-central and three-phase rectified currents with an ability to switch from one mode to another without current interruption and with high precision of stabilization and adjustment of current components.

While electroplating is applied, the opening angle of thyristors is automatically changed using a software mechanism. The process of metal deposition is divided into several cycles. After immersion of parts into the pool and connection of electrodes the software device is turned on and after certain time t_o it establishes for parts current density of direct half-wave (cathode $j_к$) and reverse half-wave (anode j_a). After time $t_1 \leq 1$ min the software relay for $t_2 = 3$ min gradually reduces the current density $j_a$to zero. After this in time t_3 the rectified cathodic current density gradually increases to the limit value $j_{кп}$. The current density $j_к$ and time t_3 are selected and adjusted according to specified parameters of microhardness, cohesiveness and thickness of building-up coatings, as well as temperature, acidity and concentration of electrolytes.

Automatic temperature control is especially important during chromium coating, chemical nickel plating and dry topping. In these processes the temperature fluctuations of electrolyte should not exceed 2 °C. We use two-position controllers for small baths and regulators of a proportional-integral action that drive an electric heater of solution – for large baths.

Automatic control of current density takes place due to changing the opening angle of thyristors. The set value of the current density is determined by the software device depending on the mode of electrolysis, and a factual value is measured and determined by voltage drop on connecting rod resistors.

Automatic control of acidity provides metal deposit on parts of high quality. Acidity is measured in pH-meters and adjusted by adding alkali or acid into the electrolyte.

Automatic control of the set coating thickness is carried out either by an ampere-hour meter or a programed-time relay.

Running-in is a final stage while repair of combustion engines (CE) is carried out. In practice automatic test stands with asynchronous valve amplifier with the power of more than 60 kW are widely used. The stand includes an asynchronous slip-ring motor kinematically connected to the shaft of the tested CE.

For automatic running-mode control stands are equipped with correspondent devices: torque sensors, speed-sensing devices of temperature change, sensors of oil temperature in the lubricating system, RPM sensors, amplifier-converters, rectifier assemblies, generators of running-in program and torque as well as block for pulse-phase control of valve groups of the current inverter. Transition from one mode to the next takes place automatically, depending on the sensor of oil temperature change. As soon as the temperature of oil in the lubricating system ceases to rise, then at cold running-on the rotating frequency increases for one level, and at hot running-in – the torque increases. Signals are made to move to the next level of running-in at restabilization of the temperature.

Painting operations. Automation of these operations is aimed for economy of paint-and-lacquer materials and creating optimal work conditions for people.

For mechanization of the process of application of paint-and-lacquer coatings we offer a plant construction of the paint manipulator, where, while painting, it is automatically kept parameters of coating application and back-and-forth motion of sprayers in a semicircle at continuous motion of products on the suspension conveyor.

For complex automation of painting processes, it is recommended to create robotic paint plants using robots of РП type (for flat products or parts that are moved to them) and РБ type (for volumetric products).

A defining parameter of any type of automatic painting is a painting step, which is directly dependent on the size of the spray.

In order to achieve a complete and uniform in thickness coating, the sprayer has to move along or across the product and paint the surface line in width equal to the width K of the flat sprayer. Then, a sprayer or a product that is being painted (depending on the taken painting scheme) are to be displaced by the value of the painting step S to paint the next line (Fig. 5). In order to achieve the most uniform coating in thickness it is necessary to keep the following ratio:

$$S = 0{,}7\ K, \qquad (1)$$

where S – a painting step, mm (for airless spraying S = 0,95 K);
K – a width of the flat spray created by the paint sprayer, mm.

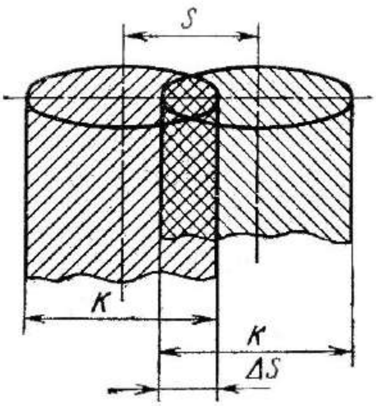


Fig. 5 – Scheme of painting with a flat sprayer

To determine the motion speed of the paint sprayer and a product, as well as the rotating frequency of cylindrical products in automated painting we use a speed coefficient *C*:

$$C = \frac{Q_k}{q}, \qquad (2)$$

where C – a speed coefficient, m^2/min;

Q_k – performance of the sprayer at a certain diameter of the nozzle and a working toughness of the material, g/min;

q – consumption of paint-and-lacquer materials for 1 m^2 of the plane painted, g/m^2.

Use of industrial robots in repair production

Combining small-scale or serial production in machinery repair with the constant assortment of processed parts makes it possible to use automatic of cyclic or copying type (such as industrial robots with numerical control, which are simple in design, reliable and easy to operate and do not require a lot of time for resetting).

Automatic manipulators with program control – industrial robots (IR) – a new universal method of complex automation of production processes characterized by the ability to reset sequences, speed and content of manipulation operations quickly.

Experience shows that integrated use of industrial robots allows to increase work productivity at an average 1.5-2 times, interchangeability of equipment operation – 1,5-1,8 times.

The use of IR offers prospects to create fundamentally new technological processes which are not related to restrictions imposed by direct human intervention.

Practically any process can be represented as a set of simple operations:

- change of the motion direction;
- retention of controlled parameters within standards;

- turning devices on and off.

Characteristics and structure of IR. An automated technical system usually consists of four main elements: a working body, a converter, a power source and control systems.

Depending on the methods of objectives and realization of the program, control systems are divided into two groups: cyclic control systems and control systems with programmable movement. Cycle systems are not complex in carrying out of the program, they are of low cost and can store information when power is turned off.

Kinematic schemes that determine the motion manner of the manipulating hand come to the following common options:

- only progressive motion in the volumetric-rectangular area;
- only rotational motion;
- one rotational and two progressive motions at different coordinate axes;
- one progressive and several rotational motions at different coordinate axes.

The most versatile are IRs with autonomous control systems, where mini computers or microprocessors are used. In the most general form of the idea of the robot motion consists in that sensors representing the system of perception learn and form a vector of observations. The IR position, its coordinates received from sensors are compared to the program that determines its further motion.

The technology of the use of robots and schemes of working movements of their actuating mechanisms are described by the control chart – a graph of the working cycle.

Robotization of repair production is used at its concentration and a high degree of specialization: cleaning machinery and parts; disassembling of assemblies under repair on units and parts; control-defective operations; worn-part reclamation (for operation in composition of production lines); painting works; unloading-loading and stocking operations.

Nowadays Gudel AG (Switzerland) is a worldwide leader in creating robots and robotic systems. Gudel robots are used in enterprises Airbus and Boeing, as well as in productions that are part of EADS and NASA. Gudel assembly lines are placed in plants Audi AG, Caterpillar Inc., DaimlerCrysler AG, Fiat Auto SPA, Ford Motor Corp., Hyundai Motor Co. and Toyota Motor Corp.

Robots of Mitsubishi Electric Company are a wide range of models and versions to meet all the requirements of most modern industrial plants, and they also provide exceptional flexibility required for rapid reconfiguration of production systems.

Quality indexes and methods of estimation of quality level of restored agricultural machinery

According to the International Standardization Organization (ISO), quality is a combination of properties and characteristics of products (or services) that meets the established or anticipated needs.

Each type of products (services) is characterized by its assortment of quality figures, depending on the purpose of this product. As for the new agricultural machinery manufactured by factories of tractor and agricultural mechanical engineering, quality is determined by 11 groups of individual quality figures (QF), particularly indexes of purposes, reliability, efficiency, processability, transportability, standardization and unification, safety and ergonomic, ecological, aesthetic as well as patent and legal indexes.

The reliability index (RI) describes the object properties to save and restore its working capacity on-stream. Consumers need products with high quality indexes to save them for a long period of time.

The efficiency index (EI) describes labour inputs and resources while an object is manufactured and on-stream. The first EI describes the labor content of production, steel intensity of the construction, adaptability of component elements of the construction to mechanized production.

The second EI describes the specific consumption of fuels and lubricants on-stream, efficiency, labour inputs and costs for maintenance and repair.

The processability index (PI) describes suitability of the design to its production and operation. The first of the PI (suitability for production) is called production workability, and the second (suitability for carrying out production functions, maintenance and repair) – maintenance workability.

The transportability index (TI) describes object suitability for transportation, for example, during its transportation by railway or when moving for far distances.

The TI includes such estimating factors as an average duration (labor content) of the object preparation for transportation, fitting it on means of transportation, unloading from a particular type of transport. TIs are determined for a particular type of transport: railway, road, water and air.

The standardization and unification index (SUI) describes satiation of an object with standard, unified and original parts as well as unification with other products. Component parts of the product produced according to the state or branch standards are considered to be standard. Unified component parts are produced according to the standards of a company or received in a ready-made form as assembly or component parts.

Object parts designed only for this product are considered to be original.

The safety index (SI) describes peculiarities of the object design which provide safety of the service personnel on-stream. Their account is required to ensure safe working conditions for a person if there are mechanical, electrical and thermal effects as well as acoustic noises.

The SI is evaluated in quantity and quality. Quantitative SIs include the pressure of the booster valve wear of hydraulic control valves, insulation resistance of current-carrying parts etc. Qualitative characteristics of SIs are availability of seat belts, alarm etc.

The ergonomic index (ERI) describes not a single object but the system "man – machine" in terms of convenience and operation comfort of a particular product. It includes correspondence of machine control elements to capabilities of a person and creation of comfortable conditions on-stream. To do this, for example, pressurized cabins with heating and air conditioning devices which reduce the level of noise and vibrations are placed on tractors and combines.

The ecological index (EI) describes another more complicated system "man – machine – working medium" from the viewpoint of harmful effects on a person, nature arising while machines are operating, that takes into consideration the entry of aqueous wastes and other harmful emission into the environment to reduce of pollutants in the atmosphere, water reservoirs, rivers and soils to the amount that does not exceed their limiting permissible concentrations (BPC).

While evaluating EIs in quantity, we determine the probability of emission of harmful particles, gases, radiations and other pollutants into the environment. It is allowed to use qualitative characteristics such as availability of treatment facilities, dust generators etc.

The aesthetic index (AI) describes rationality of forms, integrity of compositions and perfection of industrial product manufacturing.

They are gaining more and more importance while monitoring the quality of technology. AIs are assessed by an expert committee consisting of qualified experts with the experience of industrial designs.

The patent and legal index (PLI) describes an amount of updating technical solutions used in a particular object, their patent protection as well as the possibility of unimpeded implementation of the product abroad. Main of them are patent protection and patent clearance.

Comparing these indexes for different products (different brands of tractors, combines and other machines) we can quantitatively estimate the level of their quality. The quality level – a relative characteristic based on the comparison of values of quality figures of estimated products and relative product figures adopted as a base for comparison.

The assortment of quality figures of overhaul plant products have some peculiarities compared to products of enterprises manufacturing new products. They consist in that for overhaul plant products quality indexes have to characterize in quantity only those properties of the product which may change as the result of the effect of factors of manufacturing repair processes.

Thus, the design of a machine does not change when it is repaired; hence, such quality indexes as processibility, transportability, indexes of assignment, standardization and unification, patent and legal indexes also are not applied.

All other indexes, including reliability, efficiency, safety, ergonomics, ecological compatibility, and aesthetics change while machines are repaired. The quality level of repaired products should be estimated according to their values.

The quality level of repaired products according to the listed individual indexes is controlled comparing it to the corresponding index values of the quality of new products.

When the quality level of repaired products is being estimated, beside comparison of values of individual indexes, it is allowed to use other methods of assessment.

While assessing the quality level of repaired products according to defective factors, we use the coefficient of defectiveness of products:

$$K_{\partial} = \frac{1}{n}\sum_{i=1}^{a} m_i r_i, \qquad (3)$$

where n – a number of product units (sampling);

a – a number of types of defects;

m_i, – a number of defects of this type;

r_i, – a weight ratio of each type of defects defined by experimentation or by the cost of elimination of the defect of this type.

While estimating the quality level of repaired products according to the factors that characterize repair, it is estimated the quality of design documentation, manufacturing equipment and tooling, measuring tools and test equipment, as well as labour quality of people who repair the product.

The quality of design documentation is estimated by its total or selective examination according to indexes that describe: meeting the requirements set by the technological normative documentation; validity and fullness of the established plans of control and tests; correspondence to assortment standards of technical documentation, their registration, record order, storage and alteration.

The quality of repair and manufacturing equipment is determined by selective measurements of basic parameters of equipment and tooling, their comparison to ratings as well as verification of implementation of maintenance and repair schedules of this equipment.

The labour quality of people who repair products is estimated as follows: selective check of compliance of maintenance procedures of operations; by measuring parameters of parts and assembly units after being repaired; by analysis of the data on in-plant defects presented by the enterprise and reclamations; by analysis of regulations in force, orders, instructions regarding material and moral incentives; acquaintance with production standards and workplace organization in workshops and on sites.

To improve the quality of repairing products it is necessary to combine all effects into a single target system, which provides a set of organizational, technological, economical and social measures. This system can be represented as a graphical model (Fig. 6).

System and organizational principles of product quality control at overhaul plants

According to the international standards ISO of series 9000, a quality system is a set of organizational structures, methods, processes and resources required for the joint management of quality, that is those aspects of the joint management that determine the policy on quality.

The operational quality control in the international standard ISO is defined by the term "quality control", that means operational methods and activities used to fulfill requirements on quality. The long-term quality control and plant management are generally defined by the term "total quality control" – an approach to the plant management, focused on quality and based on the participation of all its members to achieve long-term success by meeting customer requirements and benefits for members of the enterprise (organization) in general.

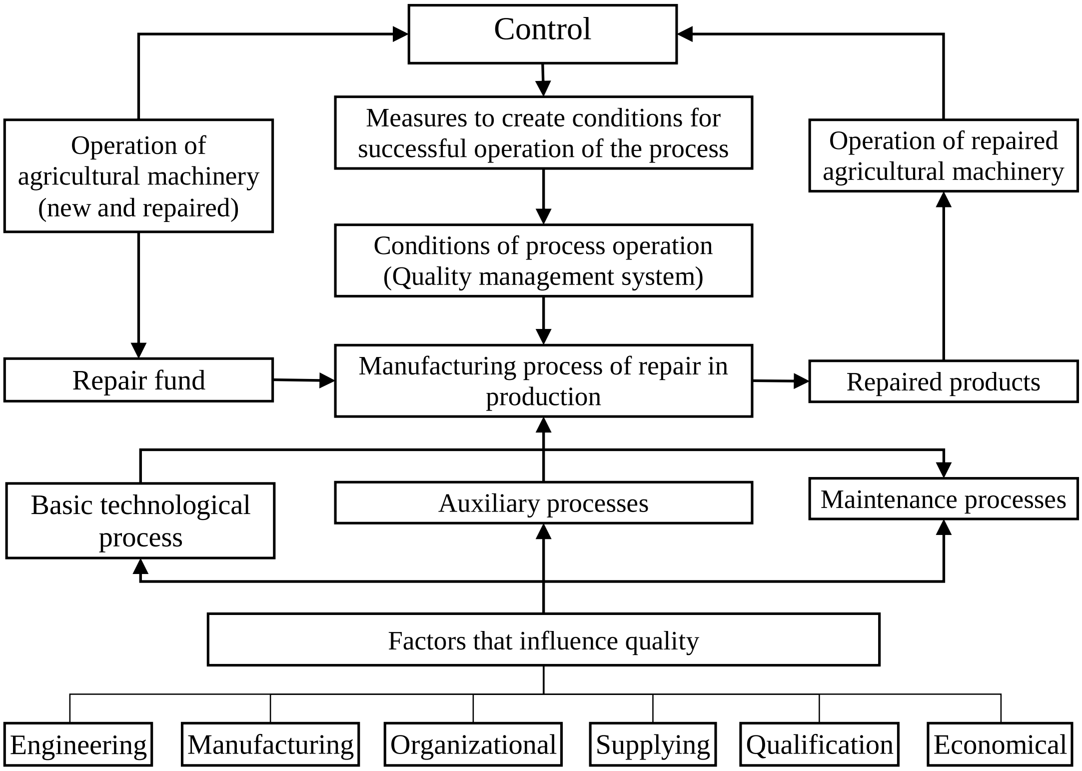


Fig. 6 – Scheme of system to form product repair quality

In Ukrainian enterprises quality control systems of products are set up and operate on three hierarchical levels: national, branch-wise and enterprise.

The repair quality control of machines is considered as creation, provision and maintenance of the optimal quality when a technology is developed and repair, storage, transportation and operation of machines are carried out according to the systematic quality control and purposeful action on the affecting conditions and factors.

A condition of quality improvement is considered as circumstances or a medium where factors influencing the quality act.

Basic conditions favorable to appear factors of quality improvement of machinery repair are as follows: material and moral stimulation of performers for the work quality, relation between the price for repair and the quality of repaired products, work organization.

The organizational basis for the quality control of products and services is a standardization system including national, branch-wise standards, specifications, technical requirements, main technical materials, standards of enterprises.

Types and methods of product quality control

An important component of the quality control system of products on manufacturing stage is organization and implementation of technical quality control.

Technical control is checking the correspondence of a product or technological process which the product quality depends on to the set standards or technical requirements. Technical control is carried out at all stages of manufacturing: from the quality control of supplied materials, spare parts and component parts to release of finished products. At overhaul plants the quality of releasing products is usually controlled by the personnel of the technical control department (TCD).

The main task of the technical control department is timely acquisition of complete information about the quality of products, plenty of equipment and technological processes in order to prevent defects and deviations that could lead to violations of standard requirements, specifications and release of defective products.

Repair quality control is various at overhaul plants. It is classified as follows:

- by stages of the manufacturing process – incoming inspection, operational inspection, acceptance inspection and inspection checkup;
- by order of covering – complete and sampling inspections;
- by the time of implementation – casual, continuous and periodic inspections.

Incoming inspection – a product control of a supplier received by a consumer or client and intended for use while repair is carried out or during operation of products. Spare parts, materials and products repair of which was carried out by other partner enterprises are subjected to such a control.

Operational inspection – control of a product or process during or after technological operations. They are performed on the operations where new defects are most likely to appear.

Acceptance inspection – control of products by the results of which it is taken a decision on its suitability for use.

Inspection checkup – control carried out by specially authorized persons in order to check effectiveness of the control carried out earlier.

Complete inspection – control of every product unit in the batch. It is applied in the following cases:

- launching the new production;
- if stability of quality is not ensured;
- if a defect is absolutely unacceptable;
- a number of objects is insufficient to obtain samplings.

Sampling inspection – control when the quality of production-run is estimated by the results of inspection of one or more samples. It is applied in mass and large-scale production at the large labor content of control and when controlled products are broken. It is based on statistical methods of control.

Casual inspection – control carried out at random. It is used to check maintenance procedures and correctness of the carried out control.

Continuous inspection – control when information about controlled parameters is supplied continuously. It is carried out by automated means.

Periodic inspection – control when information about controlled parameters is supplied within fixed intervals. It is carried out while products and technological processes are controlled in stable production.

Statistical method of inspection – product inspection based on probability theory and mathematical statistics.

The essence of statistical methodы of inspection consists in that from the controlled batch of N objects only some of its parts n are directly checked, what is called sampling.

Depending on the number or proportion of suitable parts in this sampling the whole batch is received (considered to be suitable) or rejected (discarded).

The most advanced one is a statistical method of quality control of products, which includes;

- statistical analysis of accuracy of technological processes by learning qualitative characteristics of the most repaired products;
- statistical adjustment of technological processes by adjusting its parameters by the results of sampling inspection of parameters of repaired products to ensure the required quality level;
- statistical acceptance inspection used as a sampling method

when quality reliability of the whole batch of repaired products is determined by the quality of the sampling (the use of effective repair technological process).

Classification of spoilage in production; stability, technical control and certification of products

Spoilage in production is products that do not correspond to standards, specifications and other technological normative documentation.

In production we determine reclaimable and irrepairable rejects. In addition, we determine internal spoilage detected in the production process and external spoilage detected outside of the enterprise and was detected in the process of implementation or use of the product.

By reasons we determine rejects caused by violation of maintenance procedures (negligent attitude of workers to their job), errors in technical documentation, work on defective or improperly adjusted equipment, using low-quality tools, defects in the basic material, passing of defects of the TCD on subsequent operations etc.

By persons responsible for rejects we determine rejects caused by the fault of a worker-operator, a service technician of equipment; departments of a production manager, master mechanic; toolmaker's shop; the department of technical quality administration.

Stability – a feature of the technological process to keep quality indexes of manufacturing products in the set limits for a certain period of time.

Stability of product quality is achieved by:

- periodic inspections of equipment and tooling for technological accuracy and timely implementation of preventive maintenance of this equipment;
- providing and supporting maintenance procedures;
- periodic estimation of the quality of repaired products.

Their quality is estimated periodically (at least one time every six months) to control stability of the product quality and their correspondence to technical requirements. This includes: control of the correspondence of technical and design documentation for the repair to requirements of technological normative documentation; analysis and technical expertise of the batch of repaired products to check their correspondence to technical requirements for repair; analysis of plenty of work to ensure the product quality; short-time testing of repaired products.

Technical control – is checking the correspondence of a product or process which the product quality depends on to the set technical requirements.

The purpose of the technical control on overhaul plants is to accept on time complete and accurate information about the repair quality of products and a state of the technological process.

For each repair object (part, unit, assembly, component part) we chose a type of the technical control which is the most correspondent to plant conditions.

By stages of the production process we determine the following types of control:

- incoming inspection – checking spare parts and semi-finished products, component parts and materials supplied to an enterprise;
- operational inspection is carried out after finishing certain technological operations. While this control is taking place, the product quality or a technological process are checked for its correspondence to the set requirements. For example, inspection of the quality of washing, control of hole diameters of connecting rod heads after processing, shaft deflection after grinding etc.
- acceptance inspection is the most crucial stage of the whole technological process of restoration or production of parts, assembly units, assemblies or repair of machines in general. In this case we check all basic indexes provided by technical requirements, standards, drawings and we make a decision if the repaired product is suitable to be used. Testing of units, assemblies and machines on special equipment is a type of the acceptance inspection;
- field inspection is intended for checking the correctness of the running-in period of repaired assemblies or machines by a customer, control of the compliance of the rules of operation and maintenance, gathering and analysis of information on reliability of products.

Depending on the order of covering of products, the limit inspectation can be complete and sampling.

Control methods relatively to the object checked are divided into visual, geometrical, physical, chemical, metallographic, mechanical.

The word "certification" in Latin means "done right" (certum – right, fasere – to do). To certify that the product is "done right" and of high quality, it is necessary to show that it meets certain requirements and obtain credible evidence of this correspondence.

Product testing is necessary to define the correspondence of quality indexes of products or services to set requirements. The most reliable ones are test results made by the "third party" – a person or an element independent from any supplier (manufacturer) or from a buyer (consumer).

Certification means activities carried out to conform the correspondence of a product to set requirements. It can be obligatory and facultative.

Obligatory certification – confirmation of the correspondence of products (works, services) to obligatory requirements of the standard by the authorized body.

Facultative certification – certification carried out on the facultative basis on the initiative of a manufacturer (executor), a seller (supplier) or a consumer of products.

Lecture № 17
Application of nanotechnologies in manufacturing

Technicalities

Before considering the application of nanotechnologies in various branches of the national economy, let us get acquainted with the terminology.

Allotropy – existence of the same element in forms different in structure and properties.

Almazoid – a diamond-like structure constructed from carbon atoms by synthesis which has the strength and chemical inertness of diamond. It is used as the basic material while designing nanorobots. This is hydrocarbonate where carbon atoms form a spatial grid, the same as in diamond. It occurs in crude oil.

Assembler (from: to assemble) – cybernetic nanometric scale equipment capable of collecting a set of atoms of the molecule by mechanochemistry according to the given program. This is a molecular machine that can be programmed to build any molecular structure.

Balk technology – a technology based on manipulation of sets of atoms and molecules rather than individual atoms.

Geomodifiers (geos – land from Greek) – special micro- or nanoadditives in fuels and lubricats and technological environments on the basis of minerals of the geological origin that can interact with contact zones of parts lots and them form a cermet layer, which partially restores defects of the friction surface.

Heterostructure (from Greek. hetera – connection) – a combination of multiple heterojunctions (a contact of two different semiconductors) which is used to generate potential wells for electrons and holes in layered semiconductor structures; it is used in semiconductor lasers and light emitting diodes.

Graphene – a carbon nanomonoball, where connections C – C form regular graphite hexagons ("honeycomb").

Diamondoids – polymer organic molecules where carbon atoms of the skeleton bonded with each other in the same way as fragments of diamond crystal lattices.

Disassembler – cybernetic equipment of nanometric scales, able to separate atoms of molecules according to the set program and simultaneously record their location at the molecular level. An "assembler–disassembler" pair can make copies of any micro objects.

Dissipation (lat. Dispersion) – an irreversible energy dissipation process gained by the system during various processes (e.g., friction).

Fullerene Arc – an arc method of producing fullerenes based on thermal decomposition of graphite during electrolytic heating of the graphite electrode or laser irradiation of the graphite surface.

Quantum – an indivisible part of a matter (light quantum). Inherently the concept is the idea that any physical quantity can accept only certain and not arbitrary values (i.e., physical quantity is quantized).

Kevlar (Eng.) – synthetic fiber stronger than most steels, established in the US. It is used in aerospace design, bulletproof vests and in cases where it is necessary to provide low weight with high strength.

Cluster (Eng.) – a set of two or more homogeneous elements (atoms or molecules) that can be regarded as an independent unit that has certain properties.

Claytronics (Eng. – Smart clay) – a new branch in science and technology which considers an opportunity to build different constructions from individual unified building block-robots of microscopic sizes.

Conglomerate (lat. – clustered, assembled) – a mechanical combination of something diverse.

Metal conditioner – a matter and an impact mechanism on the metal (surface), allowing to modify, structure, restore a structure, composition, properties that are affected, delivering necessary components from outside sources. Meanwhile, the work surface is provided with antifriction properties.

Lonsdaleite (Eng.) – a hexagonal modification of carbon with a crystal lattice of the wurtzite type (a = 0,252 nm; c = 0,412 nm) and the density of 3,51 g/cm^3. It is opened in a meteorite in 1967, then artificially obtained.

Lotus – (from Germ – effect) – an effect of almost complete impermeability of the solid surface with liquid that occurs due to the nature of the surface relief at the micro and nanolevel, which help to reduce the contact zone of the liquid with the surface of the body. Later it is a complex of technical and technological solutions that are widely used in automotive service.

Metamaterials – a composite that has properties not found in nature, has a negative permittivity and magnetic permeability. Materials of this type can be used to develop "invisible cloaks" using nanotechnology.

CVD method – a modifying method with reinforcing fibers, i.e.

"chemical vapor deposition" of metals, alloys and chemical compounds on the given surface.

Nano (from Greek – Dwarf) – nm = 10^{-9} m = 10 angstroms.

Nanotechnology – a process of distribution, assembling and changing material properties by influence of an atom or a molecule of a substance.

Nanotube (Eng.) – a tube of the nanometric size composed of individual atoms and has an artificial structure. It is assigned for communications, power transmission and signals, as well making new materials based on carbon.

Soot (amorphous carbon) – a product of incomplete combustion or thermal decomposition of hydrocarbons in uncontrolled conditions, such as operation of diesel engines. Soot particle sizes are 50-180 nm.

Light-emitting diode – a device based on nano dimensional heterostructures, which converts electricity into light radiation.

Fullerenes – a class of chemical compounds whose molecules consist only of an even number of carbon atoms. Chemically stable closed surface structures of carbon whose atoms are arranged at the vertices of regular hexagons or pentagons that cover the strengthening surface in a regular way.

Fullerites – solid fullerenes C_{60} hard, crystals with a face-centered cubic crystal lattice and rather weak intermolecular bonds. There are octahedral voids in the crystal where there may be foreign atoms that affect all properties of the material.

Entropy (from Greek – turn, transformation) – a measure of disorder of large systems. For example, the theory of heat engines and the part of energy that is dissipated in space without making useful work.

Development of innovative methods to diagnose nanoobjects preceded the progress of nanotechnology. This is modern electronics, tunneling and atomic-force microscopy, equipment to measure and determine the modulus of elasticity. Developments which revealed that nanomaterials have specific magnetic, electrical, optical and other properties associated with manifestation of quantum effects have become important.

Application of nanotechnology in various branches of the national economy allows to minimize technical equipment and save resources.

History of nanotechnology

Mankind has been used nanomaterials since ancient times.

Nanoparticles can explain incredible properties of materials manufactured several centuries ago and sometimes inaccessible to modern science.

E x a m p l e :

1) gold (nanoparticles plus a glass matrix) – the ruby color;

2) decorative coating with gloss – medieval pottery;

3) colors used by Australian aborigines for bright combat paints, hair dyeing (resistant paints).

The first scientist who used the measure in nanometers was Albert Einstein (1905). He theoretically proved that the size of sugar molecules is 1 nm.

The idea to create special devices that can penetrate into depths of a matter to the boundaries of the nanoworld was of an American electrical engineer, inventor, physicist, philosopher of the Serbian origin, Nikola Tesla (predicted creation of an electron microscope).

In 20s of the twentieth century an American physicist of the Russian origin George Gamow first proposed an equation that described a possibility of overcoming a potential barrier provided that its energy was less than its height.

This is a unique property for quantum particles, including electrons. Their penetration through the barrier with losses of energy is a "tunnel effect" (called "tunneling").

A Dutch Professor Frits Zernike discovered a method of phase contrast (1933) and created the first phase-contrast microscope (Nobel Prize, 1953).

In 1986 Ernst August Ruska (1939), Max Knoll (German Physicists), developers of an electron microscope with the resolution of 10 nm, were awarded with the Nobel Prize.

In 1956 it was created a scanning microscope where the light comes out of the hole in the opaque screen and illuminates the object. The light passed through the sample or reflected from it, and that gets back into the hole is recorded during reciprocating movement and captures an image of parts less than half of the wavelength.

Soviet scientists Dmitri M. Garkunov and Igor V. Kragelskyi discovered a phenomenon of selective transfer during friction in the accident of aeronautical engineering in 1956. The feature of the process lies in forming a so-called "servovytniy film" with the thickness of about 100 nm capable to ten time decrease friction losses and wear intensity of connections in machines.

In 1959 Richard Feyman, a professor of the University of California, lectured "There's a lot of space at the bottom" (Nobel Prize, 1960). It was about manipulation of atoms. So he proposed the idea that nothing interfered us "to change any physical or chemical laws to alter a relative position of atoms", i.e. he suggested using atoms as a normal building material.

The task of creating facilities to study the atomic structure of building materials at the nanolevel remains the most relevant in this case.

An american physicist Russell Young (1966) offered a piezoelectric controlling device (piezoelectric motor), which is used today in scanning tunneling microscopes to find desired objects on the target surfaces.

Gerd Binnig developed a scanning atomic force microscope. In 1986 (till the end of the year) 40 scanning microscopes worked and nanotechnologies began to develop.

To conduct the research, it is necessary to have the equipment, a system of knowledge (physics, chemistry, biology), habits and skills, equipment and expertise in materials science and engineering operations.

In 1989 US researchers Donald Agler and Erhard Schweizer (California Science Center) made a sensation. They presented the name of their company on the nickel single crystal surface purified in ultrahigh vacuum and cooled to 4ºK using 35 xenon atoms of the inert gas. A scanning microscope was used for this. The inscription remained not long. Atoms evaporated.

In 2008 scientists of Israel Institute of Technology created a nanoiconic Bible in honor of the 60th anniversary of his country. The content of the Old Testament was deposited on a silicon particle of a 0,5mm 2 pinhead. The text was typed using a focused ion beam that etched a pattern on a gold substrate (of thickness 200 nm), which covered a stand on silicon. Putting the text took about 1,5 hours, and software to manage the process was developed more than three months. You can read the content of the Bible only through a scanning microscope.

The method of artificial obtaining and removing solid crystalline fullerene was achieved in 1990 by Wolfgang Kretschmer and David Haffman, employees of the German Institute of Nuclear Physics.

Carbon nanotubes were discovered in 1991 by a Japanese researcher Sumio Indzhima (Fig.1). It was revealed by the analysis of soot that forms on the cathode when graphite is powdered in a helium atmosphere while the voltaic arc is discharged.

First synthesized nanotubes – multi-layered compositions – had from two to seven layers. If you add the catalyst (a small amount of powder Co, Ni, Fe), single-layer nanotubes are formed. A metal additive is a catalyst that prevents forming fullerenes in multilayer nanotubes. Additives provide synthesis temperature decrease, as a result the voltaic arc does not exceed the temperature at which nanotubes are sintered or fused together.

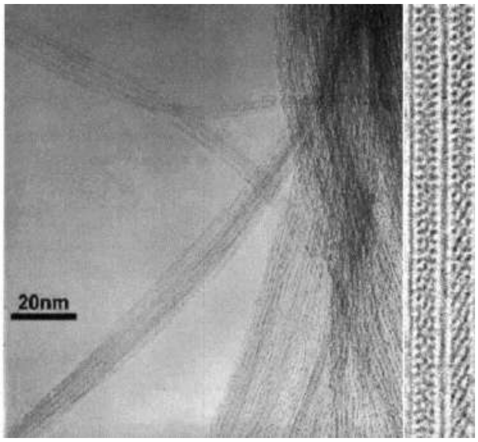


Fig. 1 – Carbon nanotubes

Natural fullerenes were discovered in Schungite, a carbon mineral in 1992. Various nanoparticles and nanostructures were found in natural materials such as ice, meteorites, space stations coverings, soot and other technological materials.

In1992 K. E. Drexler considered, on a scientific level, the problem of practical applications of molecular nanotechnology.

In 1994 nanopowders appeared and nanocoatings, nanochemical drugs (e.g. SINTA, Kulinichi Kharkiv region) were developed.

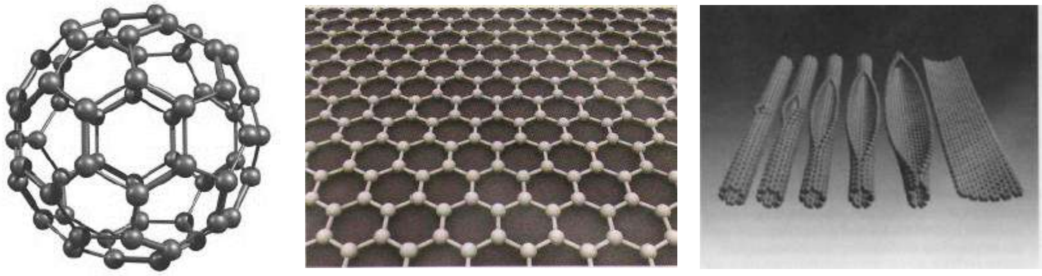
In 1998 Robert Betts Laughlin, Horst Ludwig Störmer and Daniel Chee Tsui were awarded the Nobel Prize for the discovery of tiny Hall effect (there is a fundamental restructuring of the internal structure of e-liquid in very strong magnetic fields).

In 2004 S. Decker joined a carbon tube with DNA and first received a single nanomechanism and opened a way to develop bionanotechnologies.

In 2000 Zhores I. Alferov and American scientists Herbert Kroemer, Jack Kilby (Nobel Prizes in Physics) established semiconductor heterostructures and integrated circuits. LED technology is based on heterostructures.

For a breakthrough in the two-dimensional material (Fig. 2) Andrey Geiman and Konstantin Novoselov received the Nobel Prize in 2010.

In 2011 D. Schechtman (Israel) was awarded the Nobel Prize for discovery of quasicrystals. The fulfilled investigations have revolutionized the idea of how atoms and molecules can be placed. These materials can be used to create a super-strong and heat-resistant coatings, and provide various alloys with completely new properties.



a b c

Fig. 2 – Structure of fullerene (C60) (a), crystal lattice of graphene – a graphite layer of one atom thick (b), the deployment process of nanotubes (c)

Nanotechnologies in novelties of tomorrow

Nanotechnologies give the mankind an opportunity to adapt natural conditions more effectively and with fewer side effects to their needs.

Nanotechnologies are able to adapt and structure processes in the right direction. An important unit in evaluation of nanotechnologies is an atom. Depending on components they are different in shape, size and weight.

Nanotechnologies studies shells of the atom as well.

In the food industry atoms can be palatable. Tiny holes in cheese where microorganisms of 0.1 microns are placed. They give them the taste of cheese and can be seen in a biological scanning microscope.

In medicine, application of nanoparticles is effective in new drugs that provide blocking bacteria.

In nature, one of the thinnest technology in the scale of an atom is the process of photosynthesis, which accumulates energy for life on the Earth on the decomposition of graphite. If you are able to reproduce this process, it is possible to obtain an unlimited amount of energy.

The Max Planck Institute for Intelligent Systems (formerly Max Planck Institute for Metals Research, Stuttgart) discovered the secret of attachment of beetles, flies, spiders and pecan legs to vertical surfaces and ceilings (Fig. 3). They are kept using tiny hairs that form a Van der Waals bond with the surface on which they sit. The heavier the substance, the thinner and more numerous hairs (it is nanotechnological ways of couplings).

A starfish, for example, hides without an eye that sees if it is in danger. It turns out that its thick disk-shaped shell is entirely covered with areas of improved microlenses. This is nanotechnologies. How are they formed? A small amount of Mg prevents undesired color edges, i.e. it uses tricks that made famous the Carl Zeiss Company once.

Nanotechnologies can be used beyond capabilities of nature, i.e. their production requires additional human intervention.

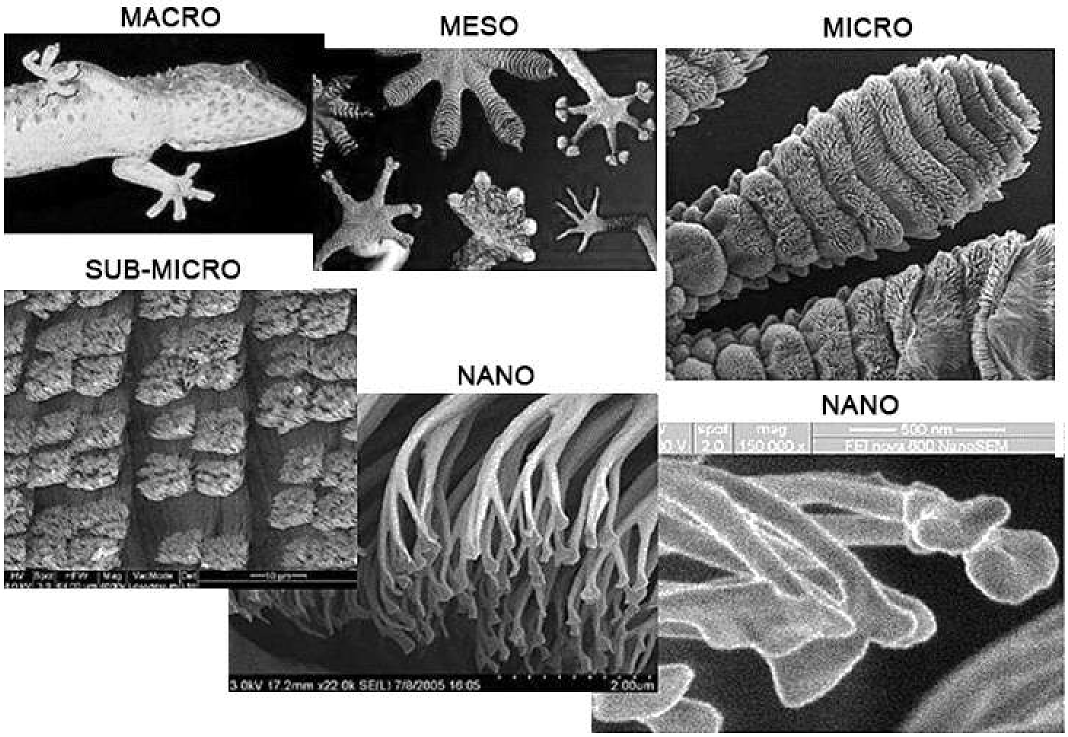


Fig. 3 – Structure of gecko paws ([K. Autumn et el. American Scientist 2006, 124])

For example, magnetite nanoparticles (oxides of Fe) placed in oil and with a special coating make it into ferroliquid. The form, whose liquid can be changed by a magnetic field.

These liquids are used as a sealing material for rotary seals in vacuum containers and during installation of hard disks or regulated oscillation dampers for vehicles and equipment (nanoparticle of 20-900 nm are used).

Particles of cadmium tellurides are fluoresced, and the emitted color depends on a particle size (a body color of machines).

<u>In engineering</u>, nanotechnologies are used in scanning probes that serve as eyes in space. The telescope "Newton" catches gamma rays from distant objects with 58 reflectors of the size of a trash can. Reflectors are shaped as the products placed into each other like onion layers

and filled with vapor of gold. A layer is less than 0.4 nm (record for nanotechnologies). This is a development of the Carl Zeiss Company. A scanning tunneling microscope, the father of all scanning probes, is based on this principle.

In lithography, nanotechnologies are used as a way to manufacture computer chips with the help of light. A chip is a three-dimensional structure. All its elements are placed on separate layers; their number is up to 25-30 and each needs its own template. The structure of the template is projected onto the wafer with light and a lens system followed by installation of a step serial device that resembles an epidiascope. Each new template adds a new function to the chip, increasing its complexity.

In the industry, nanotechnologies are used as research facilities:

– Electronic micro X-ray analyser

– Spectrometer for X-ray spectral analysis. This is the basic tool of learning the nanoworld.

– Measurement of microhardness for a homogeneous structure – with small loads (nanohardness).

Designing matter at the nanolevel is a variety of sauces of nanoparticles of the filler; it is a typical representative of the colloidal solution.

A colloidal solution is a composition where many small particles are in a stable, suspended state in another substance.

Example:

Béarnaise sauce is vinegar drops suspended in melted butter. Creams and paints are also colloids. Sol/gel – technologies allow colloids to be implemented in the area of high technologies.

Nanotechnologies in Society:

– Nanoelectronics – laptops;

– Electronic communications;

– Notebooks – a transistor technology used in computer processors, indicated CMOS (computed metal-oxide-semiconductor). It made possible to reduce computer transistors to 20 nanometers. The wave properties of electrons begin to show in very thin structures; they are described by the quantum theory. Due to minimization of structures to 45 nm, a single chip can fit more than a billion transistors;

– Electronic watches;

– Magnetic memory crystals.

Nanotechnologies of future in everyday life:

– Magnetic layers for compact storage devices;

– Fuel batteries of cell phones and transistor products for energy supply;

– Bicycle frames with marker nanotubes, which are notable for their lightness at high strength;

– Clothing that is able to measure the motion pulse and breathing;

– Hip joints made from biocompatible with the body materials;

– Piezosupports precluding unwanted vibration;

– Window glass with a special coating against scratching and ensuring the effect of "Lotus";

– Light-emitting diodes, which in its power can compete with incandescent lamps;

– Powders for treatment of cancer, including the spine.

Nanotechnologies in Machine building:

– Coatings made using the sol/gel technology, containing solid nanoparticles can make the windscreen of cars resistant to scratches and remain transparent, because nanoparticles are so small that do not scatter light;

They can also regulate the microclimate in the cabin, reflect light and heat radiation, provide lighting, including headlights (light-emitting diodes);

– coating (paint) – upper layers can be converted into a photocell.

The resulting energy can be used to recharge the battery while parked or to provide coolness;

– Strengthening coatings on parts;

– Finished products with strengthening while being manufactured;

– During repair and restoration.

Main methods of producing nanomaterials

Main methods of producing nanomaterials are the following:

– Fullerene arc – synthesis in plasma of the arc discharge.

– The gas-phase method of obtaining fullerene C_{60}.The temperature of the process is 4000ºC.

– Catalytic decomposition of hydrocarbons. Blowing a quartz tube with the metal powder at 700-1000ºS with a mixture of gaseous hydrocarbons (carbon filaments, laminated nanotubes, metal particles coated with the graphite shell).

– Powder Technology – Glater method (vapor deposition, compaction), electric discharge sintering, hot plastic working, high static and dynamic pressure for different temperatures.

– Intensive plastic deformation. Metals and alloys are gained.

– Crystallization from the amorphous state. Originally we obtain an amorphous material, and then conduct processing using conventional and high pressures.

– The film technology. Chemical deposition from the gas phase or the sol/gel technology.

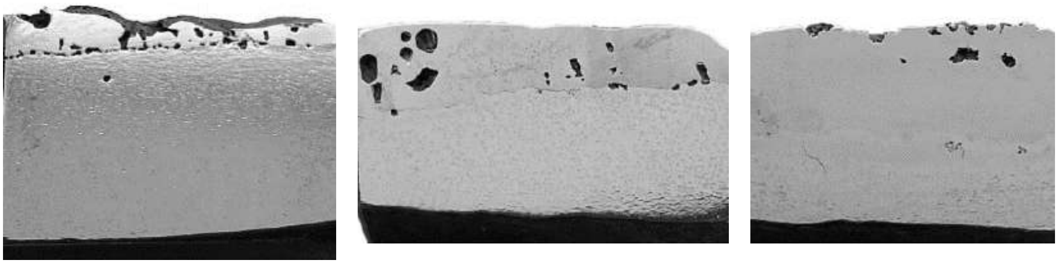
We obtain metals, alloys, polymers, chemicals and fragments of substances, crushed to nanosizes.

One of the main chemical elements that scientists are interested in nanotechnology is carbon and its allotropic forms.

Strengthening and worn-part reclamation

The Department of Repair Technological Systems develops new ways in application of nanotechnologies while strengthening and worn-part reclamation from various types of steel and cast iron. Special equipment that provides the dosed addition of powder compositions, nanodiamonds and specially prepared detonation charges of ammunition utilization has been created for this purpose.

Research has found that the use nanoadditives for modification allows fundamentally restoring defects in products from gray cast iron. Fig. 4 shows the macrostructure of the areas with welding of defects. It clearly represents that adding a modifying agent in welding 5 times reduces the heat affected zone (from 1000 mm to 185 mm), forms a coating without cracks; no defects and cracks appear on the welding border and the transition zone is characterized by undulating structure that provides adhesion. When defects are welded with a wire or an electrode with a coating of a modifying agent, the microhardness significantly increases: from N-N-50-250 to 50-720 (Fig. 5).



a b c

Fig. 4 – Macrostructure of deposited zones of cracks, a – without introduction of a modifier; b – with modification by a slip casting coating; c – by a modifier with a coating on the electrode

High efficiency is achieved when restoring worn articles of carbon and alloy steel by surfacing adding nanodiamonds (operational stability increases 1,54 times), and when introducing a detonation charge, it 15% increases.

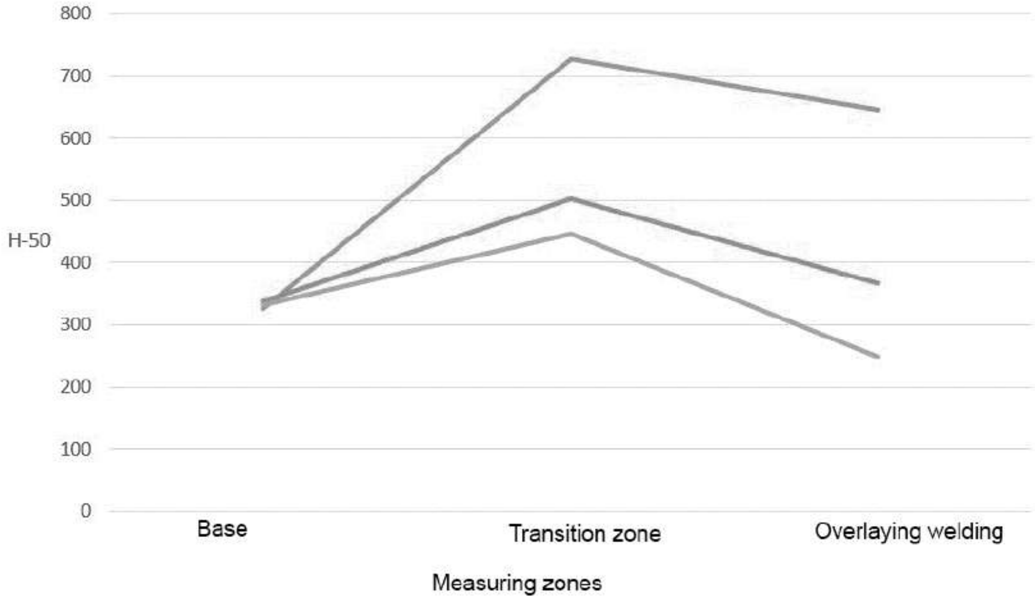
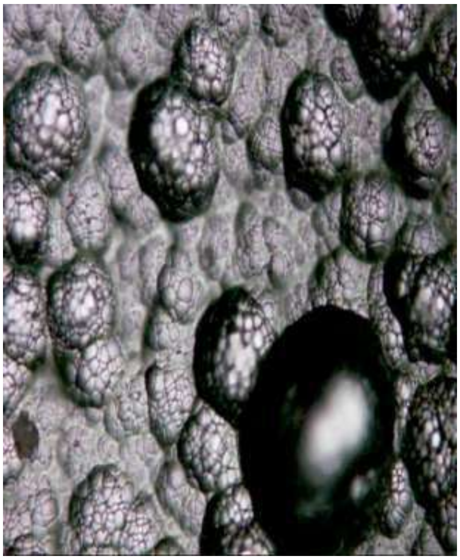


Fig. 5 – Influence of modifying agents on microhardness of cast iron restored by surfacing: 1 – without modifier; 2 – introducing agents into a slip casting coating; 3 – introducing agents by an electrode coating

To restore parts of the fuel system, we offer the modification method by nanodiamonds during electrolytic building-up of the worn layer by chroming. To get the efficient use of such technology we offer a dosed introduction of agents by its constant support in uniform distribution throughout the period of the process. It is achieved by using a magnetic stirrer, which prevents precipitation to the bottom of the bath modifier.

This method significantly reduces gas evolution and contributes to making a compact hardening precipitates of nanodiamonds as separate particles permeated by chromium. Fig. 6 shows forming precipitates according to the existing and given technologies. The new technology enhances the microhardness to H-50-1600.

Developments of the department to strengthen thin knives (Ø68 mm and thickness of 0,64 mm with a cutting edge of 0,1 mm) made a significant contribution to increase stability of thin-walled tools (for crushing nuts) in the food industry. When searching for the optimal technology to strengthen this tool, we examined various approaches like a constructive one (with application of stiffening ribs) and considering the thickness and material of surfaces.



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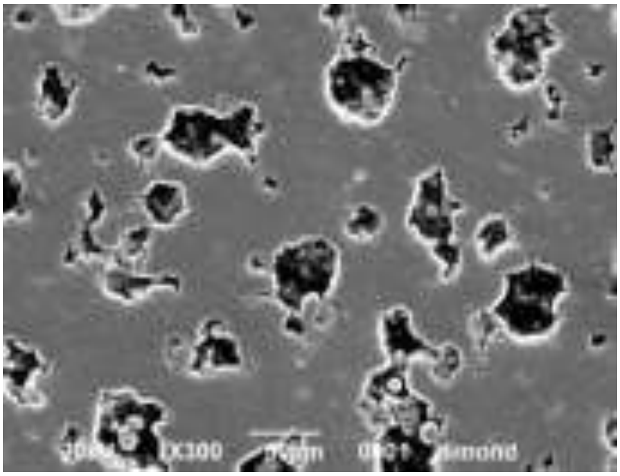


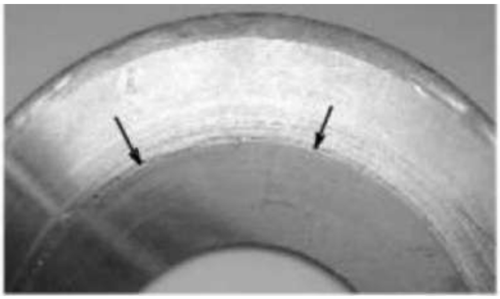
c

Fig. 6 – Structure of chromed coating without nanodiamonds with coarse grains and pores ×500 (a); microstructure of coatings with modification of chrome electrolyte УДА (b); nanodiamonds distribution in chromed coating, using developed technology (c)

As coatings we used WC, CrN, TiN. Meanwhile, we analyzed the thickness of coatings from 50 nm to 3,0 microns. The cheapest and most effective was the TiN coating with the thickness of 3,0 microns.

Under the current technology (without strengthening) such knives are operated for twenty-four hours and collapsed due to fatigue damage, bends of the cutting edge (Fig. 7).

The new technology using nanocoatings provided improving stability to 11-57 times at the first steps of application (see. Fig. 7), and with the increase of the total thickness of the multilayer nanocoating of bodies to 3.0 microns – to 210 times. The vacuum-arc method was used for coatings. Coatings were deposited by specialists of the National Science Center "Kharkiv Institute of Physics and Technology" (KIPT) (Kharkiv, Ukraine).



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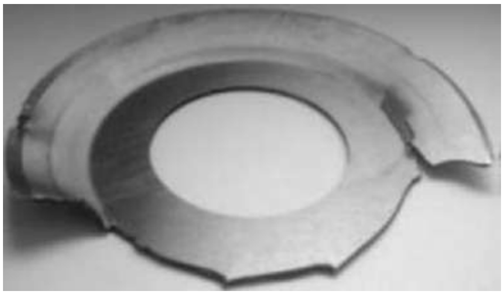

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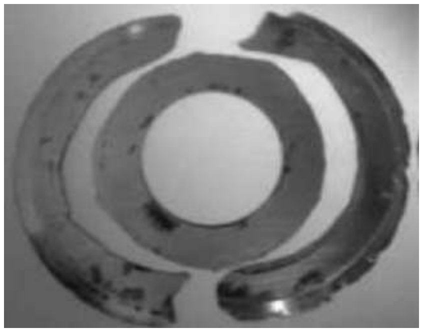

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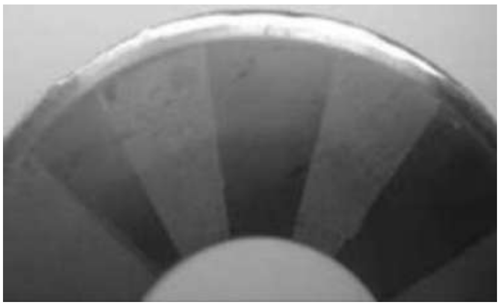

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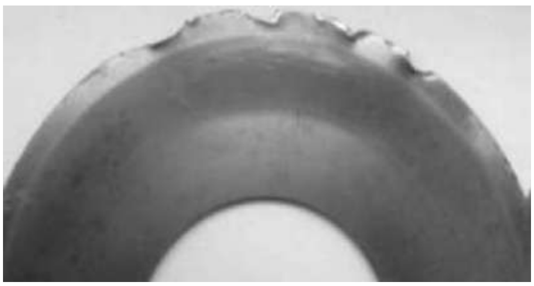

e

Fig. 7 – Fatigue damage of main part of knives: a – circular crack;
b – flatness losses, change in shape; c – demolition of the tool to separate annular components; d –appearance of the knife with stiffening ribs, WC 50 nm thick coating after operation; e – appearance of the knife with WC 50 nm thick coating after operation

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