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PROMISING COAL TECHNOLOGIES

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Abstract The necessity to deal with ecological issues as well as to look for additional sources of energy carriers encourages reutilizing coal cleaning waste. There are a number of conventional technologies of mineral processing which are now exhausted from the point of view of the achieved selectivity of separation. At present the losses of the useful component are rather high. The higher level of separation selectivity can be achieved by utilizing basically new engineering solutions based on oil agglomeration of coal. Oil agglomeration is also employed in combined technologies such as “coal-gold”, “agglomeration-hydrotransport of coal”, “demineralization-agglomeration of salty coal”, preparation of fuel suspensions etc. Ukraine has developed technological principles of these processes. Another promising trend in coal technologies is formulation of highly concentrated coal-water suspensions.

Keywords: Steam and coking coals, oil agglomeration, theoretical bases, adhesion, chemical bonds, aggregate-forming, experimental results, fuel coal-oil suspensions, fuel coal-water suspensions, hydrotransport, demineralization, dewatering, “coal-gold” technology.

Introduction. Exhausting natural reserves of oil and gas as well as increase of coal consumption have aroused a keen interest of researchers in coal technologies worldwide. A great attention is given today to studying special processes of coal preparation and formulation of efficient coal-based fuel, which open new possibilities of processing low grade raw materials to conditional ecologically clean products [1].

Over the recent 15 years the process of selective oil agglomeration of coal and coal-water fuel technology have been developed at a great rate. The interest shown in these issues is considerable not only on the part of specialists in the preparation of fossils but also on the part of coal chemists, heat-power engineers and those involved in hydrotransport [2-5].

We consider the oil agglomeration as a promising highly efficient means of the preparation of low grade coals for coking, burning, pyrolysis and also liquefaction. Besides, some investigators have demonstrated advantages of utilization of techniques and technologies of oil agglomeration in long-distance hydrotransport systems of steam and coking coal [6, 7].

In 1980-2004 years Ukraine has carried out a series of research work related to applied and theoretical aspects of the coal oil agglomeration process and formulation of coal-water fuel. The investigations were conducted in the Donetsk State Technical University, some research institutes of the National Academy of Science of Ukraine(NAN), the UralVTI Instiute, the VNIIPIHidrotruboprovod Institute, the LenNIIkhimmash Institute, the Kharkiv Polytechnic State Institute, the Institute of Biocolloid Chemistry of the NAN of Ukraine, the Scientific Industrial Corporation "HYMEC" and also at coal preparation plants and heat power plants of the Donbas. As a result, theoretical fundamentals of new promising technologies have been developed, experimental results obtained.

Theoretical fundamentals of the process of selective oil agglomeration are developed on the basis of the contemporary state of physical chemistry, physical-chemical hydrodynamics, adhesion theory, solid fuel chemistry. The elaborated theoretical principles and experimental data served as a basis for developing about 40 new methods and devices, that allow implementing the process of selective oil agglomeration of coal.

Experimental Part

Initial raw materials and reagents. Steam and coking coals from Donetsk (UKRAINE) of different rank with ash from 10 to 34 % have been investigated. The furnace residual oil (M100) has been used as a reagent-binder. Studies of the coal-water fuel preparation technology were carried out with slimes of coals with different degrees of coalification.

Parameters of oil agglomeration process: The agglomeration process has been carried out in a laboratory granulator of impeller type at the solid-liquid ration = 1:3, pH = 7, t = 18-20 ^{o}C, the rotational speed of the impeller of 1500 min^{-1}, the binder concentration ranged from 3-5 to 25-30 % by weight, the size of coal particles ranged from 0 to 200 microns.

Methods of Investigation

- pelleting of coal in water,
- optical microscopy of agglomerates (microscope NEOPHOT-21);
- photocolorimetric methods
- methods of hydrodynamics, rheology and heat engineering

RESULTS AND DISCUSSION

1. **Laboratory Research**

Microscopic investigations of coal-oil structure polished microsections (flocculates, agglomerates, granules) allowed to select 4 principal structure types of coal aggregates (Fig. 1, 2): I – *pellicle* – compacted formations, with thin broad pellicles of oil binder between individual grains of coal. II – *meniscus* – structures with concave meniscus of binder between coal grains on the aggregates surface. III – *powdered* – when binder drops are filled with coal grains. IV – *bridge* – friable formations of coal grains which are bonding with oil binder "bridges".

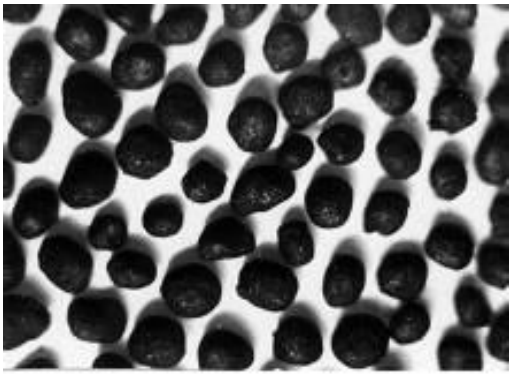


Fig. 1. Oil-coal agglomerates (x 5 times).

The photocolorimetric method (using methylene blue solution) [8] allows to determine a part of coal grain surface covered with a binder: in case of the structures Type I - 57-79 %, Type II - 86-95 %, Type III - 100%, Type IV - 40-44%. The coal particle surface of Type I features oxi-pellicle ("white border" around a coal particle) whereas it is absent in case of other types.

Microscopic investigations allow to confirm the penetration of a binder in pores and fissures of coal substances (Fig. 3). It is obvious that this process is accompanied by infiltration phenomena, during which light fractions of binder penetrate into micropores whereas the heavier ones remain on the surface of coal grains. This promotes the formation of a viscous layer of the binder on the coal surface.

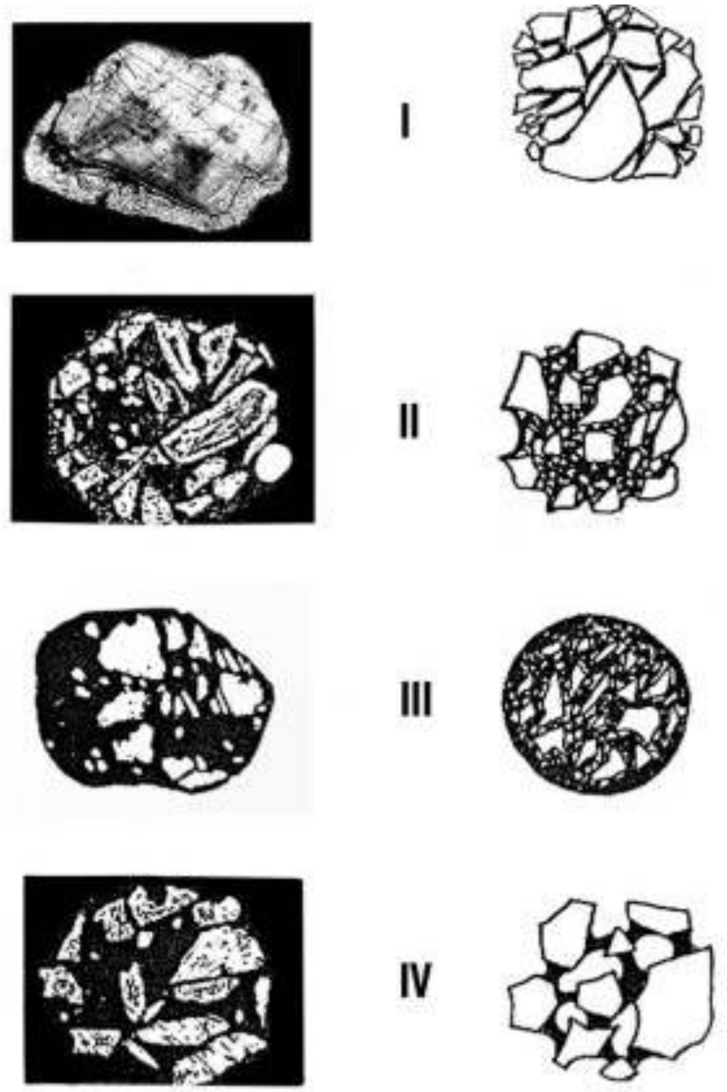


Fig. 2. Photos and polished microsections of principal types of coal aggregates.

Fig. 3. Polished microsections of oil-coal granules with the penetration of oil into the coal substance.

As a result, the cohesion of binder pellicles is improved, and the stability of aggregates (agglomerates, granules) is also improved.

The most interesting is the determination of intensity of effect of hydrogen and chemical bonds between sinter ingredients. For this purpose we have investigated coal of various types, binders and their sinters by the IR-spectroscopy method in the wave band of 3800-400 sm^{-1}. There have been studied coking coals of the Kusnetsk coal field and its sinters obtained on the basis of oil and coal. The character of changes in the spectrum of sinter as compared with those of coal and oil enables to determine that in addition to physical interactions there are also H-bonds in the interphase zone [9].

2. Industrial Testing

The theoretical principles devised and experimental data obtained have served the basis for the development of about 40 new methods and devices which allow implementing the process of selective oil agglomeration of coal. The oil agglomeration process was run at a demonstration plant with a capacity of 3 t/h and at an industrial plant with a capacity 6 t/h (at the Avdiivsky By-product Coke Plant) and 30-40 t/h (at the Coal Washing Plant "Rossia", Donetsk Region). The results are indicated in Table 1.

Table 1. Oil Coal Agglomeration Research Results

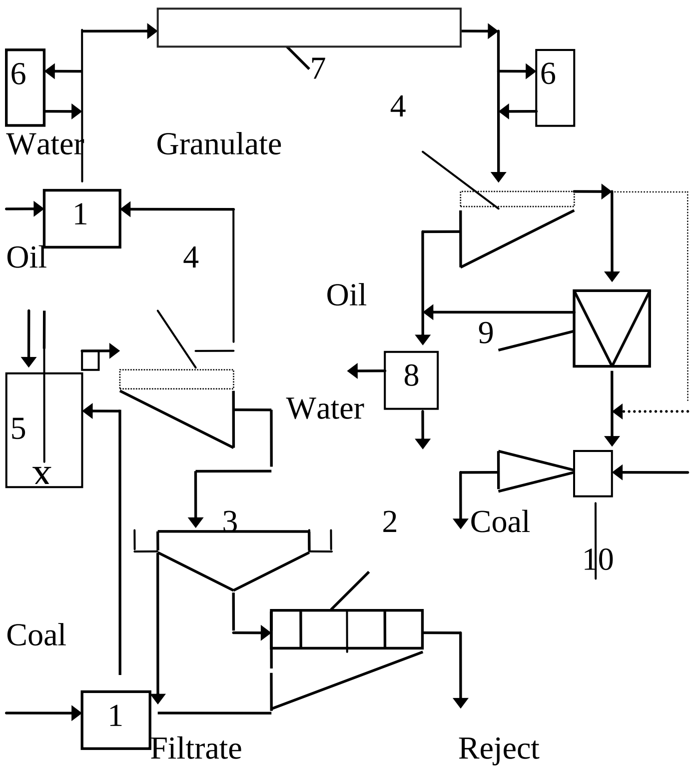
Project	Coal	Granulate (agglomerate)	Rejects
Demonstration plant	0 - 0,2 mm 14-16%- 60-70 % *	0,5-5 mm 6 - 15% *	0-0,2 mm 75-90%* 15-18%**
Avdiivsky By-Product Coke Plant	0 - 1 mm 60-80%*	0,2-1,2 mm 11,3-18,7%*	0 - 1 mm 73-86%*
Plant "Rossia"	0 - 6 mm 53%*	0,2-6,3 mm 18-23% *	0-0,2 mm 76-77%* 19-20%**

* $\mathbf{A}^{d}$,%; ** $\mathbf{W}^{r}_{t}$,%.

3**. Promising Alternatives for Application of Oil Agglomeration and Coal Water Fuel**

3.1. *"Agglomeration-hydrotransport of coal"* (Fig.4). We have investigated six major technological alternatives (schemes) in hydrotransport. Analysis and summary of investigation results allow to draw a conclusion as to obvious attractiveness of the hydrotransport-agglomeration technique.

Utilization of granulation technique for coal conveyed through long-distance hydrotransport system (LHS) allows the following (Biletsky , Papayani & Svitly 1995):



1. Mixer
2. Filter press
3. Thickener
4. Dewatering device
5. Granulator
6. Accumulator for coal water slurry
7. Pipeline
8. Oil separator
9. Centrifuge
10. Ejector

Figure 4. The process of oil agglomeration of hydraulically transported coal.

Utilization of the oil granulation technique for long-distance hydrotransport systems (LHS) allows the following [10]:

- to decrease the moisture content of sedimentation centrifuge cake by a factor of 2-3 at a transportation distance of 250-1700 km;
- to substantially reduce losses of coal fines in sedimentation centrifuge centrates at the LHS end terminal and ensure that the ash content of a centrate solid phase be > 80%;
- to maintain technological properties of coking coals while transportation in water flow at a distance of 500 km.

Oil agglomeration is therefore a promising process for coal preparation and long-distance hydrotransport.

3.2. Ukrainian technology "coal-gold" (Fig. 5) compares favorably with the well-known Australian technology "coal-gold". Testing of the Ukrainian technology on Russian ores at the Deposit "MNOGOVERSHINNOYE" (IRGIREDMET, IRKUTSK city) has shown the potentiality of achieving the concentration depth of virtually up to "0". The extraction of the most difficult micrometer classes of gold with its content of 72 g/t reaches not less than 80%. The technological advantages of the "coal-gold" technology in comparison with conventional leaching are very essential. This technology can be used for other hydrophobic materials, for example diamonds [11].

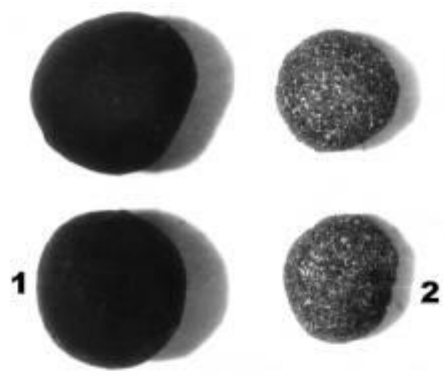
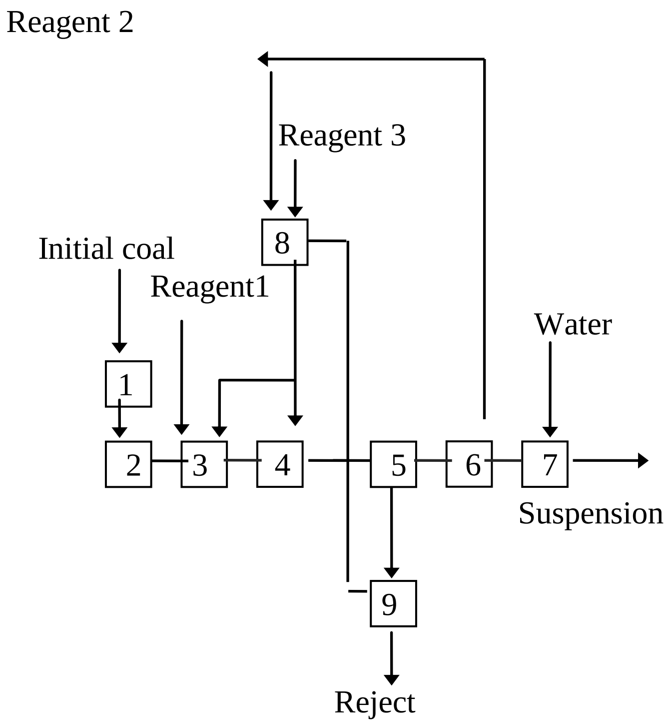


Fig. 5. Coal aggregates (1) and coal-gold aggregates (2).

3.3. Preparation of Fuel Suspensions

3.3.1 The technology "Oil agglomeration of coal – preparation of fuel coal-oil suspensions" (Fig. 6). Due to a stable ash content of coal-oil granules (6-8%), high dispersivity and homogeneity of the solid phase (0-100 micron), the process of oil agglomeration of coal has advantages in terms of fuel suspensions preparation technologies. We consider the oil agglomeration as a promising highly efficient means for preparation of low grade coal to obtain fuel coal suspensions.



1. Metal separator
2. Screen
3. Grinder
4. Mixer
5. Sieve for agglomerates
6. Oil separator
7. Suspension conditioner
8. Emulsifying unit
9. Thickener

Figure 6. The process of agglomeration of coal in technologies of fuel suspensions preparation

3.3.2 Utilization of coal slimes through the production of coal water fuel

The acute shortage of coal resources in the country dictates the necessity to use secondary raw materials. Numerous coal waste heaps and slurry sumps of coal washing plants result in dust-laden atmosphere, pollution of natural and artificial water reservoirs, occupy large territories and make it virtually impossible to ever use this land. Each year cleaning plants of Ukraine dump to slurry ponds about 3.3 million t of waste. Operating costs for transporting waste and maintaining slurry ponds approximate 6.6 UAH/t. Coal cleaning wastes that go to the dump and spoil heaps constitute a major part of coal industry wastes. By now the amount of the latter on the territory of Ukraine approaches 3 bln. t. The average ash content of wastes is usually considered to range from 70 to 75 %. But in view of natural oxidation of the mineral matter of the wastes which is difficult to take account of as well as losses associated with recleaning the recovery of carbon will not exceed 10 % of the initial amount of the wastes even in case of anthracites, the least susceptible to oxidation.

The recleaning process of wastes incorporates various methods excluding crushing, their efficiency determining the cost of the recovered fuel. The cost of the secondary anthracite with 35 % ash is very roughly estimated at about one third of its cost price in terms of equivalent fuel.

Meanwhile, the present-day requirements to the improved quality of coal dictates its more efficient cleaning which is associated with the necessity to dump and dispose of large amounts of high-ash coal fines in the form of balance slimes (up to 45 % ash) or out-of-balance silty slimes (the ash ranging from 45 to 65 %). This entails certain losses of fuel in the first place, considerable expenditures on transportation of slimes as well as construction and operation of slime ponds (hydraulic dumps) in the second place, ecological problems (dust-laden atmosphere, pollution of natural water reservoirs, danger of breaks of dams and dikes during autumn and spring floods) in the third place. Anthracite slimes alone amount to over 11 mln. t in Donetsk and Lugansk regions.

World experience shows that these coal fines can, however, become an additional reliable source of energy at a comparatively low cost, the more so, as the fluidized bed combustion, for example, requires no recleaning to reduce the ash content. The complication here is carbon losses with fine particles of coal in flue gas flow. The problem can be solved by formulating CWF from slimes and cofiring it with coal dust or gas.

High-ash coal is most efficiently burnt in fluidized bed and circulation fluidized bed combustors, both under atmospheric and pressurization pressure. This technique is, however, applicable only with boiler units that have been substantially retrofitted or specially designed, the regulations strictly observed. The initial (capital) investments here can be quite high. Coal in this case requires no precleaning.

Another way of utilizing coal cleaning wastes in the form of high-ash coal slimes is formulation of a low solids CWF (50-55 % by weight) after precleaning by the least power-consuming techniques with no expensive plasticizers employed (or without precleaning). The slimes are reclaimed either from impoundments or directly from fine coal cleaning circuits.

The above coal-water suspensions are the most efficiently utilized as a reburning fuel for pulverized-coal fired and gas-and-oil-fired boilers. The efficiency of the latter is then greatly improved and emissions of noxious gaseous substances cut down. The cleaning costs are compensated by no need to use expensive chemical additives (plasticizers). Combustion of CWF above the fluidized bed has yielded promising results for utility, industrial and power-generating boilers [13-15].

3.4. The technology "demineralization-agglomeration" eliminates losses of fine classes of coal (in the conventional technology they reach up to 10-15%) and radically increases the effectiveness of mechanical dewatering (~ twice). However, in case of salty coals (SC) these high parameters are achieved only through a special treatment of raw materials with oil agent (know-how). With no special treatment, the cover of the coal surface with a binder fluctuates between 0-5% only. This fact can be interpreted as a poor natural agglomeration ability of SC [12].

CONCLUSIONS:

1. A major priority of the Ukrainian state policy is the improvement of the ecological situation in the country. The issue gains particular topicality in industrially developed densely populated regions such as the Donbas and the Dnieper River area where the ecological background is greatly affected by intensive operation of companies of the fuel and energy complex.

2. This work shows the topicality of unconventional methods for the processing of raw materials by means of oil agglomeration. It has been showed the necessity of utilization of oil agglomeration in the technology of gold processing, in the hydrotransport technology for the efficiency of coal dewatering and retaining the coal coking properties in long-distance pipelining, in the demineralization of coals and preparation of fuel suspensions. These technologies have been successfully tested under commercial and pilot conditions.

3. Coal-water fuel made of high-ash coal slimes can be successfully used in industrial and utility boiler furnaces.

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