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ANALYSIS OF DESIGN OF SUBWAY CAR UNIVERSAL JOINT

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Abstract. This article discusses various designs of universal joints used in the rolling stock of the Kharkiv subway. We also analyse the weaknesses of the coupling design used in the traction drive of unmodernised rolling stock. A comparison of the basic model of the cardan coupling with couplings that have a more promising design for operation in the subway is made.
Keywords: subway, railway, rolling stock, bogie, traction drive, universal joint.

Introduction. In modern railway vehicles, there is a problem of misalignment between the axis of the traction motor and the small gear of the gearbox pinion, because in motion, vibrations occur which cause displacements of the axis of the motor shaft and the gearbox pinion shaft. To eliminate this problem, various design solutions are used, in particular, the use of couplings. The design of couplings can vary depending on the technical requirements of the traction drive.

Topicality. A car bogie is a very important element of rolling stock, the design of which affects not only traffic safety but also the culture of passenger transportation. Therefore, in order to ensure traffic safety, it is necessary that all the components of the bogie design are very reliable, durable, easy to maintain and repair. That is why it is important for us to find new technical solutions for trolleys and their components.

The object. A bogie of the subway electric rolling stock.

The subject. Cardan coupling of the motor-axle unit.

The goal. To find new technical solutions that would help improve the design of the connection between the traction motor and the bogie gearbox of a subway car.

The tasks. To analyse different designs of cardan couplings used in the Kharkiv subway and to evaluate all the disadvantages and advantages of these units.

The novelty. The idea of compensating for the misalignment of drive shafts by means of gearing is quite interesting - when the teeth not only transmit rotational motion, but also operate in a transverse plane to the teeth. This technical solution is clearly demonstrated by the German-made Flender gear coupling, which has proven itself in operation not only in the subways of Ukraine but also in other European countries.

Methodology.

Subway rolling stock plays an important role in the transport infrastructure of a large city. All elements of subway cars must be maintained in terms of strength, stability and technical condition to ensure safe and smooth train movement at the highest speeds as defined by the technical specifications for a subway car, and elements of utility rolling stock must comply with the technical specifications for the construction and modernisation of the said rolling stock [1].

A bogie is a key element of an electric train that ensures the movement of the car along the rails. It distributes the load from the body to the rails, transmits traction and braking forces, and ensures smooth movement. Each car is equipped with two biaxial bogies with individual wheel drive. These bogies are equipped with a frame-mounted traction motor suspension, axial gear suspension, as well as axle and central spring suspension [2].

An important component of the trolley is the universal joint, which connects the traction motor to the wheel set gearbox. It transmits torque and compensates for misalignment between the motor shafts and the gearbox gears. These displacements can occur both in the horizontal and vertical planes while the car is moving [3].

The paper considers the design of the cardan coupling used on the rolling stock of the Kharkiv Metro utility company and compares it with the Flender coupling used on modernised electric trains. The article also analyses the design features of couplings from different manufacturers and draws conclusions based on the experience of operating this unit.

The traction motor is mounted on the trolley frame bracket and is fully sprung with the frame on axle springs. The gearbox, in turn, is mounted on the axle of the wheel set. As a result, the shafts of the traction motor and the gearbox move relative to each other in all directions during the movement of the car and when the axle springs sag. Therefore, only a hinged connection of the shafts is possible, for which a cardan coupling is used, which allows a parallel displacement of the shafts relative to each other by 8 mm, an angular displacement of up to 2.5 degrees, and a mutual longitudinal displacement (convergence and divergence of the shafts) of up to 11 mm [4].

The universal joint consists of two identical coupling halves that are bolted together at the shaft ends of the traction motor and gearbox [5]. This allows the gearbox to be rotated downwards on its bearings after disconnecting the coupling halves.

Each half coupling consists of a two-pin bushing with two rollers and two caps, a retaining nut with washer, a plug, a cup, a retaining ring, a sealing plate and three long bolts and nuts.

The rollers that fit on the sleeve are of needle design, where the needles are mounted tightly together. They are used to rotate the roller on the journal.

During the periodic maintenance of rolling stock, the technical condition of the universal joint is checked very carefully. The moving parts, namely rollers and bushings, are subject to the greatest wear. They are repaired by replacing worn-out needles with new ones in the rollers and by welding metal onto the bushings to restore the operating dimensions. This work is quite labour-intensive, as the universal joint must be removed and completely disassembled from the trolley. It is also necessary to periodically add lubricant to the coupling to ensure its normal operation.

Flender gear couplings are well established in railway transport worldwide. In particular, in Ukraine, the subways use such models as ZK-306 and ZBG [6], which are used on modernised trains of the Kharkiv and Kyiv subways, as well as on new rolling stock manufactured by Kryukiv Carriage Works.

The gear coupling also consists of two half couplings, which have bushings with teeth that engage with teeth cut inside the coupling body. It is through the teeth that the torque is transmitted from the motor shaft to the trolley gearbox. Due to the slight misalignment of the shaft axes, the teeth remain in engagement, which compensates for this misalignment.

The torsionally rigid coupling has a robust, weight-optimized design. Heavy parts are directly attached to the motor or gear unit shafts; the coupling’s inner components compensate for any operational misalignments so that only the slightest unbalanced forces and oscillations apply. The patented slip hub protects the drive system. Sealed grease chambers prevent the lubricant from escaping and eliminate the potential fire risk.

Advantages of the gear coupling [7]:

- Long service life and low maintenance expenses.
- Maintenance-free for up to three million kilometres of vehicle travel or 12 years.
- Wear-resistant and service-friendly with very long maintenance intervals.
- Main inspection combined with gear unit and motor checks.
- On request, initial lubricant filling can occur on delivery.
- Simple and rapid relubrication using the grease nipple.
- Good emergency running properties thanks to sealed grease reservoirs.

- Clear load reserves, even after extremely long running times.
- Optimized seal system to prevent dust from penetrating.
- Reliable running if the chassis is icy and at temperatures well below zero.
- Heat-resistant, even in extreme conditions.

This gear coupling design is widely used in railway transport around the world, in particular on metro and high-speed trains.

Conclusions. After analysing the basic design of the universal joint and summarising the accumulated operating experience, the following conclusions can be drawn:

- the cardan coupling is a very important component in the design of the bogie and, in particular, the motor-axle unit;
- the design of the coupling is quite complex and requires careful maintenance and periodic restoration or repair to ensure a reliable connection between the shafts of the traction motor and the gearbox gear;
- the basic design coupling often requires repair and is one of the most problematic components of the bogie.

Couplings of a more modern design with a toothed gearing have proven to be more reliable and easier to maintain compared to the basic version of universal joints. However, gear couplings have a more complex production technology due to the requirements for tooth accuracy and strength, which inevitably affects the cost of this product.

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