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# Features of Operation of Cardan Shafts of Automotive Equipment

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Cardan gears of automotive equipment, the structure of which includes cardan shafts, are designed to transfer torque from the power plant to the chassis. The design features of cardan shafts are considered in detail in a number of monographs.

A characteristic element of cardan gears is the presence of a spline connection designed to transmit torque with a continuously changing shaft length due to changes in the terrain of the roadway.

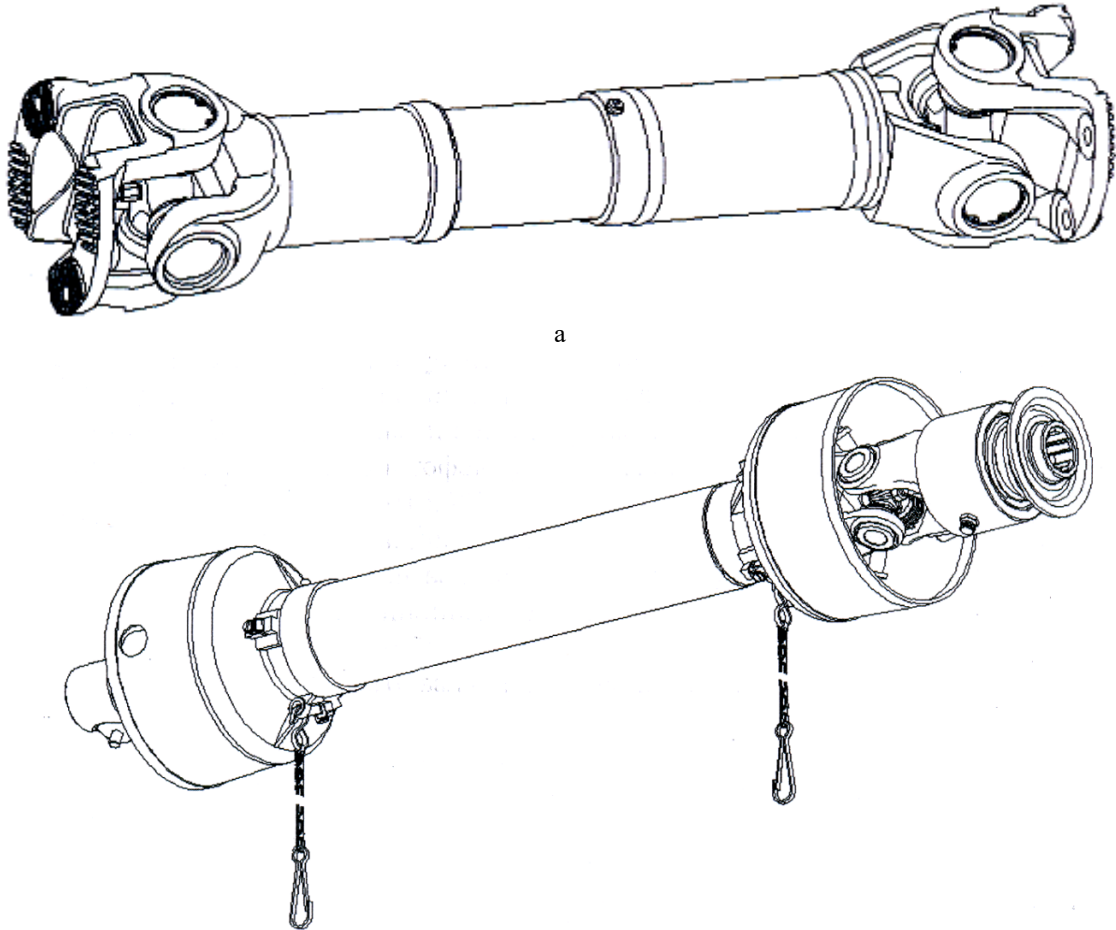
The cardan transmission is subjected to the complex influence of unfavorable operational factors – power surges when starting, braking and sudden acceleration of the vehicle, shock loads when hitting an uneven road, vibrations, corrosive and abrasive media, reverse movement of the splined joint elements, etc.

Therefore, to optimize the designs of cardan shafts and increase the parameters of their durability and ergonomics, an integrated approach is necessary, including various aspects: materials science, technological, and structural.

In the research of V. I. Kravchenko and G. A. Kostyukovich, effective directions for improving the driveshafts of trucks and agricultural machinery have been developed, which involve the use of new composite materials based on polymer matrices, lubricants, high-strength carbon steels and methods of their heat treatment.

At the same time, the solution of the problem of creating perfect technical, technological and economic parameters in terms of a combination of technical, technological and economic parameters cannot be achieved at present without the use of modern computer technologies that allow searching for optimization solutions at various stages of the creation, production and operation process.

The most important node of the gimbal transmission, along with the universal joint, is the spline joint (Fig. 1). To ensure the required resource, a composite coating is applied on the surface of the spline joint parts, which provides optimization of the geometric parameters of the "bushing – spline end" interface, reducing the coefficient of friction, reducing shock loads when the nature of movement changes and reducing the probability of wedging. For the application of composite multifunctional coatings on splined joints, aliphatic polyamides are used, mainly polyamide PA 11 "Rilsan". In the research of V. I. Kravchenko, coating compositions based on polyamide 6 of domestic production were developed, which significantly exceeds PA 11 in terms of strength characteristics and wear resistance, but has a higher moisture absorption and requires a special technology for preparing the surface of a metal counterbody.



The analysis of the operational features of the spline joints shows that with an optimal design and a selected interface, the wear mechanism of the coatings is due to fatigue phenomena due to the reversible nature of the relative movement of the interface parts. Therefore, for the formation of composite coatings, not only thermoplastic, but also cross-linking materials can be used, which in their basic parameters, first of all, wear resistance and heat resistance, are significantly superior to thermoplastics. Such coatings are used in brake cylinders and have shown high operational reliability.

Of particular interest in the nomenclature of cardan shafts are units designed to transfer torque from the power plant to the actuator. Such cardan shafts are used in agricultural production.

A characteristic feature of cardan shafts for agricultural machinery (Fig. 1) is the presence of a protective casing that prevents unwanted contact of maintenance personnel with rotating elements, which can lead to injury. One of the problems of such structures is to ensure the durability of the protective covers during the service life of the shafts.

Control of the functional characteristics of polymer materials by introducing polymer modifiers into their composition is one of the most common technological techniques in polymer engineering materials science. There are several principal methods (technologies) for obtaining polymer-polymer mixtures. One of the most common and relatively simple technological support is the thermomechanical combination of polymers in the melt, carried out in the working area of the technological installation (cylinder of the injection molding machine or extruder) at a temperature above the glass transition or melting temperature of polymers. The obtained materials are composites consisting of a matrix in which dispersed fragments of the alloying component are distributed. The content of these fragments, their dispersion and shape have a very significant impact on the characteristics of the composite – deformation-strength, tribotechnical, adhesive. It is established that during thermomechanical combination, not only mechanical mixing of the components occurs, but also the formation of copolymer products as a result of recombination of macroradical products

of mechanical cracking and thermal destruction of macromolecules under the influence of shear stresses and elevated temperatures in the material cylinder. The content of the forming copolymer product has a significant effect on the properties of composites. Therefore, a technology has been developed to intensify the copolymerization processes during thermomechanical combination, for example, using a special design of the screw of an extruder – mixer.

Another method of intensifying copolymerization reactions in polymer-polymer composites is the introduction of functionalized components containing active functional groups into the composition. The technology of creating functionalized polymer modifiers is currently being intensively developed and is becoming increasingly widespread in the technology of composite materials based on polymer matrices. For example, a number of structural and tribotechnical materials based on mixtures of "polyamide 6-polyolefin" (HDPE, PP) with the use of functional modifiers have been developed at the Grodno software "Himvolokno".

Another method of obtaining polymer-polymer composite materials is the copolymerization of the corresponding monomers or polymer-oligomeric compositions. A classic example of such materials are impact-resistant styrene plastics such as UPS, ABS, which are products of the synthesis of styrene copolymers with elastomers. The particle size of the dispersed phase is less than 1 microns, however, they provide the composite with a combination of physical and mechanical characteristics: tensile strength, impact strength, frost resistance, etc. The method of grafted copolymerization is widely used in modern technology for the production of polymer materials. However, it requires significant material costs for production. Therefore, it is used by large concerns BASF, Du Pont, Bayer, Elf Atochem, etc. In the Republic of Belarus, multi-tonnage industrial production of such materials in the coming decades is unlikely. Therefore, the most promising method is the modification of thermoplastic matrices with thermoplastics-materials that combine the properties of elastomer and thermoplastic. The main feature of thermoplastics is the formation of physical bonds in the solid state, which provide high strength characteristics in combination with frost resistance and chemical resistance. When heated, such bonds are destroyed, and the material passes into a visco-fluid state. Most commercially produced thermoplastics – divinyl styrene (DST), polyurethane (TPU), polyolefin (SEVA) are well combined in the melt with thermoplastic matrices (PA6, HDPE, PP, SFD, etc.). This makes it possible to regulate the service characteristics of composites in a given range. One of the first works in this direction in the republic is a comprehensive study of A. F. Manulenko. Abrasive-resistant materials based on PA6-DST, PA6-TPU mixtures have been created, which have been used in mechanical engineering. At the same time, the mechanism of modifying action of thermoplastics in other types of thermoplastic matrices (PVC, PP) requires further deepening, including when introducing nanoscale modifiers of various nature into the composite. Of particular interest are studies of the effect of modifying additives on the properties of products under prolonged exposure to static loads or alternating deformation. Taking into account the possibility of the formation of adsorption-type physical bonds by nanoscale modifiers, it should be assumed that a synergistic effect like this can be realized.

Currently, this effective scientific direction of mechanical engineering materials science is being intensively developed by the staff of the scientific school of Prof. Pesetsky S. S. in the State Research University "V. A. Bely Institute of Mechanics of Metal-Polymer Systems of the National Academy of Sciences of Belarus".

Wide possibilities of obtaining composite materials are realized when using polymer components with functional reactive groups as modifiers. For example, the introduction of polyurethanes into the polyamide composition will significantly increase the strength and impact strength of the composite.

A large number of studies are devoted to the development of methods for increasing the wear resistance of polymer materials. The traditional approach to the problem of creating polymer tribocomposites, based on the addition of dry lubricants, has almost exhausted itself. New technological techniques are required to ensure a combination of strength and tribotechnical characteristics. One of the effective methods for solving this problem is the study of polymer mixtures of the "polyamide-fusible polyolefin" type. At the same time, it is possible to use both a thermomechanically combined mixture and a pre-functionalized polyolefin. Powders of fluoroplast-4, metals, mica significantly reduce the wear of polyamides. Metals obtained by thermolysis of a precursor in a matrix polymer melt have a complex effect on the structure, leading to an increase in strength, wear resistance and resistance to thermal oxidation.

In recent years, intensive research has been carried out on the creation of composite functional materials of a new generation – polymer nanocomposites. Such materials contain as modifiers components with the sizes of single





aggregates no more than 10 nm and clusters no more than 100 nm. According to the classification of Academician Vityaz P. A., nanocomposite and nanophase materials are divided. Sialons and ultrafine ceramics, carbon of detonation synthesis, mica subjected to thermal splitting, zeolites, flint, etc. are widely used as nanomodifiers. components. The synergistic effect realized in nanocomposite materials is associated with the active action of nanodispersed or nanophase particles with an uncompensated charge. Such a charge causes the orientation of the boundary layers of polymer matrices, increasing the degree of their ordering, which leads to an increase in the strength, tribotechnical and adhesive characteristics of nanocomposites. At the same time, the mechanism of formation of boundary layers is not clear when using nanophase fillers with relatively large geometric dimensions of individual particles, for example, mica or thermally split graphite, flint, zeolites, shungite.

New types of nanofillers and modifiers are being synthesized, the mechanism of action of which has not yet been clarified. Therefore, it is necessary to systematically study the features of the low-dimensional state of substances of various compositions, production technology and structure in order to establish general principles for the creation of machine-building nanocomposite materials. A fruitful approach to solving this problem is to establish correlations between the characteristics of the activity of nanoparticles and fundamental criteria such as the Debye temperature. It should probably be expected that the study of the features of low-dimensional structures will allow us to develop easy-to-use criteria for choosing a specific modifier for a composite with certain functions.

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