UDC 621.22:538.975

ON THE WEAR MECHANISM OF CARDAN GEAR JOINTS

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Abstract

In connection with the improvement of vehicles, power plants, an increase in their power, operational life, requirements for reliability and safety of use necessitate the development of new modifications of the main components and assemblies, incl. drive shafts. In this paper, an analysis of the main types of wear of cardan gears operating in various conditions is carried out. It is shown that the main types of wear of universal joints are: fatigue and abrasive wear, false brinelling, pitting, fretting. To reduce the effect of these types of wear, a comprehensive approach has been proposed, which consists in the development of highly effective methods for hardening the working surfaces of parts, the creation of thin-film composite coatings for friction parts, the development of new compositions of new generation lubricants based on mineral and synthetic oils.

Keywords: design, cardan shaft, wear, friction, materials.

О МЕХАНИЗМЕ ИЗНАШИВАНИЯ ШАРНИРОВ КАРДАННЫХ ПЕРЕДАЧ

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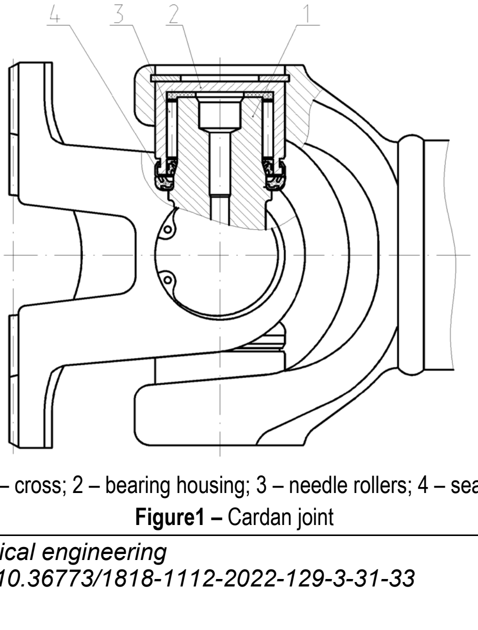
Реферат

В связи с совершенствованием транспортных средств, энергетических установок, увеличением их мощности, эксплуатационного ресурса, требований по надежности и безопасности использования возникает необходимость разработки новых модификаций основных узлов и агрегатов, в т.ч. приводных валов. В данной работе проведен анализ основных типов изнашивания карданных передач, эксплуатирующихся в различных условиях. Показано, что основными видами изнашивания универсальных шарниров являются: усталостный и абразивный износ, ложное бринеллирование, питтинг, фреттинг. Для снижения влияния данных видов изнашивания предложен комплексный поход, заключающийся в разработке высокоэффективных методов упрочнения рабочих поверхностей деталей, создания тонкопленочных композиционных покрытий для деталей трения, разработке новых составов смазочных материалов нового поколения на основе минеральных и синтетических масел.

Ключевые слова: конструкция, карданная передача, износ, трение, материалы.

Introduction

Cardan gears are currently an integral part of the transmission of modern vehicles such as cars, tractors, heavy motorcycles, diesel locomotives, etc., as well as some stationary installations, such as rolling mills and others, in which it is necessary to transfer torque between units that have relative movements during operation.



1 – cross; 2 – bearing housing; 3 – needle rollers; 4 – seal

Figure1 – Cardan joint

The reliability of the driveline is determined mainly by the reliability and service life of the hinge (Figure 1), i.e. the service life of the pair of needle bearing - cross spike. In this regard, the issue of increasing the resource of cardan joints should be given great attention [1–3].

The purpose of this work is to determine the mechanism of wear of the needle bearing of the driveline.

Research methodology

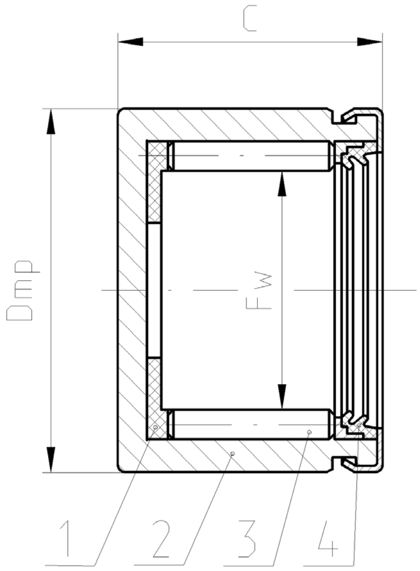
Structurally, the cardan needle bearing is made in the form of a cup, which is the outer ring, and a set of needle rollers (Figure 2). The spike of the cross serves as the inner ring (Figure 3). Bearing rings are made of steel 15G1 TU 14-1-3938-85, ShH15N15, ShH15SG GOST 801-78; needle rollers made of steel ShH15 GOST 801-78. The cross is made of steel 20HGTR TU 14-1-704-72, 60PP TU 14-1-1926-76. The hardness of the surfaces of rings, needle rollers, cross spikes should be 62...66 HRC. The roughness of the raceway should be no more than R_a 0.63 μm, needle rollers not more than R_a 0.16 μm, cross spikes not more than R_a 0.32 μm. The difference in size of the needle rollers in the bearing should be no more than 2 microns.

Research results

A feature of the kinematics of a needle bearing is that the nature of the movement of the rollers along the treadmills during rocking motion is determined by the fact that the rollers both slide and roll, and the rolling takes place mainly in the loaded zone. The nature of the movement of the needle is strongly influenced by the viscosity of the lubricant. A viscous lubricant "extinguishes" the inertia of the rotation of the needle; with lubricants with a low viscosity, the needles show a tendency to rotate in the unloaded zone.

The needle bearing has a large number of small elements (needles) that form narrow slots, which contributes to the capillarity of the entire system and the retention of lubricant near the contact points of the bearing elements. The oil cushion between the needles and the treadmills is continuously crushed under load, as a result of which semi-dry friction prevails in the bearing and there is no hydrodynamic floating of the layer of needles. This is facilitated by the operating conditions of the oscillating motion with small oscillating angles, as well as the relationship between the sizes of the elements, which makes it unlikely that the formation of oil cushions between the needles and the raceway [3–5].

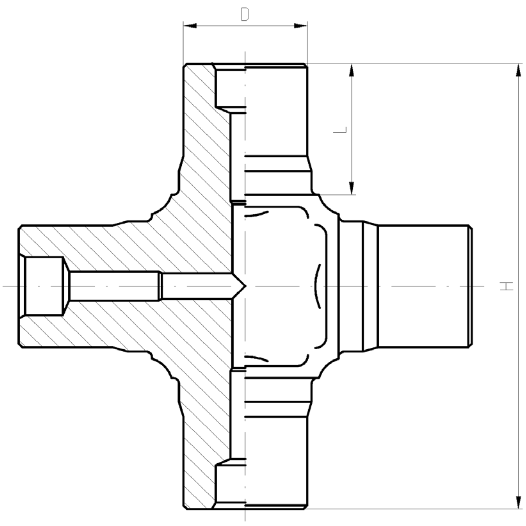
The loading of cardan needle bearings is determined by the magnitude and nature of the torque of the cardan shaft, bending vibrations caused by the imbalance of the cardan shaft, torsional vibrations of the transmission, as well as the forces arising in the spline connection of the cardan shaft during movements.



F_w – hole diameter of the needle roller;
D_{mp} – outer diameter; C – bearing width

1 – washer; 2 – outer ring; 3 – needle roller; 4 – seal

Figure 2 – Pivot bearing cardan transmission



D – is the diameter of the spike of the cross;
L – is the length of the spike of the cross;
H – is the distance between the ends of the spikes of the cross

Figure 3 – Joint cross drive line

During the operation of cardan needle bearings, rolling, rolling with slipping and axial micro-movements of bearing parts relative to each other under load in the presence of lubricant take place, and the penetration of moisture, abrasive particles, as well as access of atmospheric air to the contact zone is not excluded.

With the relative movement of bodies under the action of a compressive load, there is resistance to their mutual movement, i.e. we have external friction. When cardan needle bearings operate under normal operating conditions, two types of external friction occur in the contact zone:

1. Dry friction, when the surfaces are covered with hard films that are less durable than the base material;
2. Boundary friction when surfaces are covered with liquid films.

Friction has a dual molecular-mechanical nature. It is due to the overcoming of the adhesive bond between two surfaces, usually between the films with which solid bodies are coated, and the volumetric deformation of the material (mutual penetration) occurring in a thin surface layer at a depth comparable to the penetration depth.

Depending on the magnitude of the adhesion forces and the depth of penetration, five types of violation of frictional bonds that occur in the process of friction can be distinguished:

1. chip-cut material;
2. plastic pushing;
3. elastic deformation;
4. destruction of films (adhesive destruction);
5. destruction of the base material (cohesive destruction).

Repeated violation of frictional bonds causes the process of destruction of the material. The predominant type of fracture during friction depends both on the properties of rubbing bodies and on external conditions (loads, speeds and amplitudes of displacements, media, etc.). In this regard, it is possible to classify the types of wear. The main types of needle bearing wear are:

1. grasping of the 1st kind;
2. oxidative wear;
3. thermal wear;
4. abrasive wear;
5. smallpox (fatigue) wear.

Let us consider in more detail the types of wear encountered during the operation of needle bearings.

Seizure wear of the 1st kind is a process of destruction of rubbing surfaces, expressed in plastic deformation of surface layers and the occurrence of local metal bonds, welding bridges with their subsequent destruction, accompanied by transfer, spreading of metal on a harder surface and separation in the form of wear particles of this transferred layer metal.

Oxidative wear under boundary lubrication conditions with dry friction is a process of gradual destruction of the surfaces of a needle bearing during friction, which is expressed in a complex combination of oxygen adsorption phenomena on friction surfaces, oxygen diffusion in surface layers, simultaneous plastic deformation of the metal with the formation of chemically adsorbed films, solid films solutions and chemical compounds of metal with oxygen and their separation from friction surfaces.

The oxidation process on the surfaces of a needle bearing occurs when plastic deformations of the order of 0.1 ... 0.01 μm of the thinnest surface layers of the metal and the phenomena of chemical adsorption and diffusion of oxygen into the plastically deformed surface layers occur together. The resulting new structure upon repeated repeated deformation is brittle destroyed, after which new layers of the underlying metal enter the process.

When working with small angles of inclination of cardan gears in conditions of vibration, cyclic loads, the presence of micro-displacements and slippage of rolling elements, as well as the difficulty in removing wear products from the contact zone due to the design features of the hinge lubrication system, a characteristic type of wear of cardan needle bearings is fretting - corrosion.

Fretting can be defined as a type of wear that occurs when two surfaces in contact, nominally stationary with respect to each other, periodically move slightly relative to each other. A feature of fretting is that the products are not removed from the contact zone. A necessary condition for the occurrence of fretting is the presence of a relative displacement or sliding of surfaces with a certain amplitude. The magnitude of damage for

doi.org/10.36773/1818-1112-2022-129-3-31-33

steels is directly proportional to the magnitude of the slip amplitude within 0.010 ... 0.229 mm. The value of wear particles for steels lies in the range of 0.1 ... 1.0 mcm. Particles formed in the presence of air are red-brown in color. Chemical analysis showed that the product of contact corrosion (fretting) is iron oxide Fe_2O_3, the presence of ferrous oxide FeO and magnetite $Fe_3O_4$was also found. The initial wear products also contain metallic iron. A significant increase (12 times) in air nitrogen absorption by friction surfaces during fretting was also established: In the absence of oxygen and moisture, fretting has much in common with friction wear, such as first-class seizing.

Thermal wear or wear by seizure of the 2nd kind is a process of intensive destruction of the surfaces of a needle bearing during sliding friction, due to local heating and softening of the metal, desorption and combustion of the lubricant, resulting in seizure followed by tearing of the metal, its smearing and separation of microparticles from the surface friction. Thermal wear takes place in cardan needle bearings only during operation of bearings that already have wear and do not have a built-in polymer washer between the end of the cross and the bottom of the bearing.

Abrasive wear is a process of destruction of the friction surfaces of a needle bearing, due to the presence of an abrasive medium in the friction zone and is expressed in local plastic deformation, the presence of micro-scratches, micro-cuts by abrasive particles of the friction surfaces. Abrasive wear takes place during the operation of cardan needle bearings in dusty conditions in violation of the tightness of the seals.

Smallpox (fatigue) wear is a process of destruction of the friction surfaces of a needle bearing, due to plastic deformations, internal stresses, metal fatigue phenomena and is expressed in the formation of microcracks, cracks, depressions, etc. on the friction surface.

In most cases, fatigue failure of needle bearings cannot be explained by any single mechanism and is the result of several independent processes, including corrosion, abrasive wear, etc. Fatigue failure under contact stress conditions is a consequence of the combined action of several types of damage that occur and propagate at different speeds and independently of each other. Consider some of the types of destruction of needle bearings [4,5].

Destruction from oxide non-metallic inclusions causing stress concentration. Damage is characterized by:

- subsurface propagation from the source;
- spalling (pitting) after fatigue fracture reaches the surface from a small depth;
- Fatigue crack propagation under load.

Destruction from the geometric stress concentration, which occurs due to:

- low viscosity lubricant;
- tangential forces of prevailing sliding.

Peeling (pitting) is characterized by a limited penetration depth of fatigue cracks under the surface and their predominant propagation over the surface to a depth of no more than 0.013 mm.

Pitting occurs due to:

- low viscosity lubricant;
- a large number of protrusions, the height of which exceeds the thickness of the lubricating layer.

Subcrustal fatigue of case-hardened needle bearing parts is due to:

- insufficient hardness of the core;
- insufficient thickness of the cemented layer compared to the curvature of the contacting elements.

Difficulties associated with detecting the initial stage of the development of the destruction of the joints of the cross - a needle bearing, especially during operation, as well as the variety of operational, technological and load factors that affect the performance of cardan joints, make the task of studying the types of wear and their causes quite difficult. In this regard, at present, in the literature there are various, often contradictory, ideas about the mechanism of formation and development of destruction of parts of cardan joints, especially when considering the initial stages of destruction.

Consider the most common types of destruction of cardan needle bearings, cross spikes and seals, as well as their causes.

The type of wear, the nature of damage, its intensity depend on the type of car, the angle of installation of the driveline, operating conditions. The most common types of damage to parts of cardan joints include the appearance of traces of false brinelling on the cylindrical working surfaces of the spikes of the crosses and bearing cups and fatigue failure of the working surfaces.

As a rule, under normal operating conditions, the destruction of the elements of the hinge does not begin with wear of the seals and the penetration of abrasive particles and moisture into the interface of the needle bearing with the spike of the cross, but with the destruction of the working surfaces of the crosses, rolling elements and bearing cups in the normal state of the lubrication system. Before the appearance of visible signs of destruction, wear of the hinge elements occurs, leading to an increase in the gap and distortion of the shape of the working surfaces. Then there are traces of indentation of the ends of the needles on the bottoms of the glasses, which is explained by the presence of axial components of the forces that occur when the needle is skewed, due to the presence of an inter-needle gap and deformation of the assembly under load. Axial forces lead to periodic displacement (slip) of the needles along the axes. Then there is the formation of initial dents on the surfaces of the spikes and glasses, after which there is an intensive development of false brinelling grooves, fatigue chipping, intensive wear of the needles, in which the needles can acquire a square section or break.

The initial wear on the seals and the stud surfaces under the seals significantly reduces the initial interference. After the development of significant destruction of the elements of the hinge, the seal loses its ability to hold internal pressure and prevent the penetration of abrasive particles and moisture into the interface, the temperature regime is disturbed. As a result of the changes that have occurred, as well as the accumulation of wear products, oxidation and thickening of the lubricant occur.

The final stage of destruction is characterized by extensive chips and scuffs on the working surfaces.

Conlusion

Therefore, it is advisable to look for ways to increase the resource at the first stage of damage formation, i.e. to prevent the occurrence of plastic deformations in the surface layers of the metal, to ensure the tightness of the connection. Therefore, to increase the resource, it is necessary to reduce the loading of the working surfaces of cardan needle bearings, increase the resistance of the surface layer to plastic deformations and contact fatigue damage, reduce the axial components of the displacement forces in the splined joint, and create new designs of sealing elements.

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Accepted 02.11.2022