Development of New Friction Bearing for Swinging Movement in Knots of Transport Equipment and its Processing by Superfinishing

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Abstract. The author proposes friction bearing construction for swinging movement which is provided with mobile inserts in the form of screw-like cylindrical spring (as intermediary element). This bearing in fluctuation mode is rotating only into one direction – in such a way uniform ware-and-tear and grease distributions is achieved. The tension of the spring which is necessary to provide micro-plastic deformations can be achieved by its additional squeezing. Oxidizing processes in this construction are eliminated by means of sealing ring. This bearing can be used instead of needle bearing of the cardan shaft, silent blocks of the suspension, knots of steering control and other joints which operate in swinging mode. For these bearings the author proposes developed way of superfinishing by means of sloped abrasive stone at the final operations. By means of the calculated equation it is possible to obtain points of interaction between the tool and the part. By this it is possible to identify geometric parameters of the item in the process of manufacturing.
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Introduction

Energy basis of normal oxidative friction, as it has been shown by B.I. Kostetsky [1, 2, 3] and developed in our works [4, 5, 6], is the plastic deformation energy (activation of metal), which is partially realized by abrupt emergence of metal oxide film. The other part goes into the potential energy of the oxide film as its internal stresses and accelerates the destruction of another film. The energy basis as it turned out, is also microplastic deformation, which is localized at the normal friction in the surface layer (1-2 microns) and may be implemented both as occurrence of protective structure in the form of the oxide film (for music), and the soft metal (Cu, Ag, Au) at selective transfer. In the environments containing oxygen and moisture, selective transferand normal oxidative friction compete in the capture of surface and can displace each other, depending on the mode and conditions. In the compressor of refrigerator, where the oxidation processes are suppressed and the plastic deformation of micro-roughness (on mild steel) arise in a natural mode of loading, the conditions are favorable for selective transfer. Friction bearings operate in a boundary mode only during the start and stop operation of equipment when the speed of rotation is insufficient to create of oil film. Exactly during the startup and shutdown there is a bearing wear [15]. In internal combustion engines, where the oxidation is supported by fuel burning and unlimited supply of oxygen and moisture, the conditions are favorable for normal oxidative friction and therefore selective transfer gives a temporary effect, and during the continued operation, the intensity of oxidative wear is enhanced by the action of dispersing surface-active substances. The experience of research mechanisms of normal oxidative friction, selective transfer and friction non-conduction phenomena (NF) followed by two co-existing conditions of wear-free effect increase:

1. Activation of work surfaces by plastic deformation.
2. Suppression (restriction) of oxidation processes on the bearing work surfaces.

In conventional bearings working with a gap, these conditions are not met.

The structure of friction bearing for swinging movement in which these conditions can be met [7, 8, 9, 10] was presented. For this purpose, the bearing is provided with a movable insert in the form of helical coil spring (intermediate element), which in the vibrational mode forced rotates only in one direction and thus uniformity of wear and lubricant distribution is achieved. The tension of spring needed to achieve micro-plastic deformations is created by its preload. In the vibrational mode due to the unwinding or twisting of the spring bushing, the elastic tension arises respectively on the inner or outer surface, and it is forcibly rotated in one direction (ratchet effect). The suppression of oxidative processes in the proposed design is easily achieved by the sealing gasket. The positive effect can also be obtained by reducing the adhesion component of friction (friction of rest) and partial implementation of N.E. Zhukovsky's ideas "Flow without friction" (by the rotation of intermediate support) without the use of this external energy source. Such bearings can be widely used instead of needle bearings of driveshaft, suspension silent blocks, steering swivel and other hinged knots operating in a swinging mode.

In the device developed by the group of authors, the task of improving operational characteristics is achieved by the introducing of elastic intermediate element into the bearing - the movable insert in the form of coil spring, by the adjustment of compression force $P_к$, the seal necessary to limit oxidative processes and surface activation bymicro-plastic deformation, is created at work surfaces.

The stabilization of mode and uniformity of wear is achieved by the fact that at swinging movement of the shaft or outer ring due to the twisting or unwinding of spring insert, the braking occurs respectively on the inner or outer surfaces, and spring insert (due to the arise "ratchet effect") forcibly rotates only in one direction depending on the direction of the spring coiling. In addition, constantly in the process of work, the contact line on the working surfaces changes, which also leads to the wear reduction.

For the readjustment of seals, for example to compensate the wear at the repair, the adjusting washers can be optionally installed between one of the support washers and the end of the spring insert.

To excite and maintain the wear-free mode (at the conditions mentioned above), various methods described in the literature can be used: introducing of metal-placking additives into the lubricant, special processing with finish non-abrasive antifriction treatment, techniques, the use of materials containing metal-placking components and other.

The proposed spherical plain bearing, the activation of working surfaces by plastic deformation is performed by the installing of resilient spring insert between the outer and inner sleeves so that the working surfaces of the insert would have light interference (fig. 1A). More over, during the bearing operation (at turning in one direction), the preload increases on one of the working surfaces and decreases on the other to form a nip and slippage (fig. 1B). At turning to the other side (pic. 1C), the interference appears on that surface which had a gap and vice versa. The suppression (restriction) of oxidation processes on the bearing surface must be ensured constructively, i.e. gland seals are installed, eliminating the access of oxygen and other oxidants to work surfaces or technologically - by the introduction of inhibitors into the lubricant.

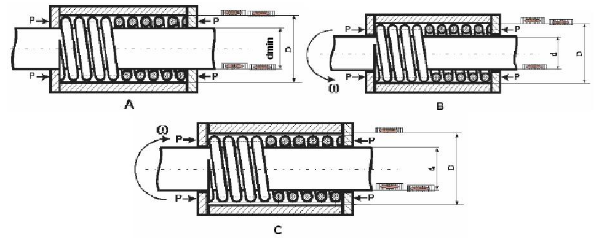

Fig. 1. The fit scheme on the working surfaces of the hinge bearing with elastic spring insert: A - bearing is at rest; B and C - the axis rotation (spigot) in different directions

Execution examples of some components of vehicles nodes using new bearing designs were given below.

Front suspension of most car models - independent, lever-type, on twisted-coil springs, working together with two telescopic shock absorbers and stabilizer bar. It is mounted on a detachable crossbar and represents an independent unit. To facilitate driving, the kingpin is installed on two needle bearings, protected from dirt by rubber rings and thrust force is perceived by the ball thrust bearing, closed with special sealant [11, 12] fig. 2. The axial clearance between the heads of knuckle and strut is selected by shim. The gap after the shim installation should be no more than 0.2 mm. The kingpin is secured at the knuckle by a pin included in the semicircular flattened surfaceat the upper end of kingpin. At driving, the kingpin operating in the oscillation mode, wear on the one hand as a result of indentation needles, abnormal backlashappears and steering stability breaks [12]. According to the instructions, this backlash can be eliminated by turning the kingpin at90°and thus load previously not worked surfaces. To do this, the kingpin has the second semicircular flattened surface. These measures increase the common resource of kingpin suspension, but do not eliminate the fundamental lack of needle bearing.

Needle bearings do not rotate, but only fluctuate with small amplitude (within the contact zone) and will actually function as a clutch between the shafts with variable misalignment. Under the action of torques arising from the transfer through them, the high contact stress on the bearing surface, dents are formed, called "false brinelling" and jamming of the most loaded bearing occurs. The standard needle bearing inner ring is missing, the raceway surface of the needle is the kingpin.

In the traditional bearings these conditions are not met, therefore ИП mode achieved by the introduction of metal-placking additives into the lubricant acts temporarily and at work continue is superseded by oxidative process. The wear rate wherein dramatically enhanced by the destructive action of the surfactants contained in metal-placking additives.

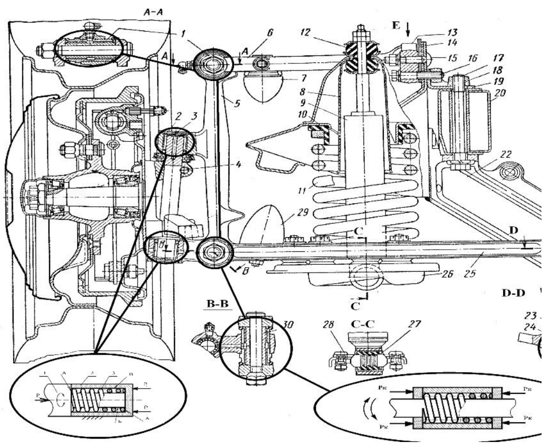

Fig. 2. Front suspension of vehicles with possible options of replace the existing hinges knots with the assemblies of new design

Unconventional bearings are made based on needle bearings 943/20 with the best possible use of bearing parts. Thus, the bearing 943/20 special spring insert is used instead of rolls. This insert is installed in the bearing outer race.

The outer ring of the bearing can be done (especially for a vehicle suspension kingpin bearings) without removing the bottom. This design provides better sealing of the bearing and prevents installation of special caps used in this node.

Structurally, the bearing ring is performed without upper shoulder as open shoulder is rolled in 90º with the already installed spring insert.

The design of the ring misses so-called "keyway", used for the filling of ring with needles at assembly operation.

The advantages of new bearings:

- The curling of unconventional bearing is carried out at the angle 90°, thus simplifying the bearing design. Application of closed bearing design increases its performance.
- Application of resilient spring insert allows the simplicity assembly of bearings - no operation of picking bearing with needles on selective basis.
- Manufacturing process of bearing by reducing the number of operations and changes is significantly facilitated.
- Specific load reduces and bearing load capacity increases and the conditions for performing wear-free friction are provided.
- The repair and restoration of kingpin assembly facilitates - bearing new design allows using old kingpins (with traces of "false brinelling") complete with new unconventional design bearings.
- The assembly of knots using a new bearing design significantly facilitates.
- Bearing life increases due to the use of new principles and tribological effects.

This bearing is characterized by co-existing conditions and additional effects:

- The establishment of interference instead of clearance on the working surfaces for their activation by plastic deformation and suppression (restriction) of oxidative processes on them.
- The effect of reducing adhesion component of friction (friction of rest);
- Partial implementation of N.E. Zhukovsky's ideas of "Flow without friction" (rotation of the intermediate support) without the use of this external source of energy due to the internal friction energy.

The quality of these friction bearings is highly demanded and along with the methods of quality processes control according to the international standards it is necessary to improve continuously the technology using new methods of reworking. The authors have developed the method of superfinish with sloping bar applicable for these bearings.

The most important factor affecting the durability of the bearing ring is its optimal geometric shape. Achieving the optimal geometric shape without improved methods of treatment is extremely difficult. Therefore, for superfinish of rings with rational geometry, the method of developed superfinish with sloping abrasive bar is proposed [13].

As this method is universal and is applicable not only for friction bearings, the example we consider will be the bearing with raceway. During the superfinish, worksurface of abrasive bars and processed surface are treated to each other and acquire the proper geometric shape.

The scheme of the superfinish process is shown in fig. 3 [14]. As it can be seen, the workpiece 1 rotates around its axis and abrasive bar 2 presses to the surface of the workpiece 1 with the force P. The axis of bar oscillation is inclined at the angle to the workpiece axis. Working surface of the abrasive bar covers the treated surface and the workpiece and contact with it on a complex curve, located along the working surface of the bar. As pre-processing of the ring carried with inclined grinding wheel having a toric surface, then after the running to the treated surface, abrasive bar also acquires a toroidal shape. Thus, the original source profile of raceway will remain in the process of superfinish and the uniform stock of removal along the profile treated surface will ensure.

To construct the layout of the bar and billet, we'll introduce two Cartesian coordinate system

$Oxyz$ and $Ox_b y_b z_b$. Both systems have the general beginning O, located at the workpiece intersection of symmetry axes. The axe OZ is directed along the axis of rotation of blank 1. Axes Oy and Oy_b pass through the central point of contact of the abrasive bar, and the treated surface (Fig. 3).

As sharpening stone acquires toroidal shape, the equation of its toroidal working surface in parametric form will be as follows:

$$\begin{cases} x_b(\delta,\psi) = (R_o + r - r\cdot\cos\delta)\cdot\cos\psi; \\ y_b(\delta,\psi) = (R_o + r - r\cdot\cos\delta)\cdot\sin\psi; \qquad a \\ z_b(\delta,\psi) = r\cdot\sin\delta;\ \text{at} -0,5\cdot B \le z_b \le 0,5\cdot B \end{cases}$$

$$t\,\delta \le \arccos\frac{r-h}{r}\ \text{и}\ 0 \le \psi \le 2\pi, \quad (1)$$

where R_O - radius of the raceway on the trough bottom, mm;

r - profile radius of abrasive bar, mm;

δ - polar angle of the abrasive bar profile, degree;

ψ - polar angle of diametrical section of the working surface of abrasive bar, degree;

B - width of abrasive bar, mm;

h - depth of race way, mm.

From the equation (1) it is not difficult to convert the equation to the normal view.

As

$$\cos\psi = \sqrt{1-\sin^2\psi} = \sqrt{1-\frac{y^2}{(Ro+r-r\cdot\cos\delta)^2}},$$

and

$$\cos\delta = \sqrt{1-\frac{z^2}{r^2}},$$

substituting the expression data in the equation (1), we'll obtain:

$$x = (Ro + r - r\cdot\sqrt{1-\frac{z^2}{r^2}})\cdot\sqrt{1-\frac{y^2}{(Ro+r-r\cdot\sqrt{1-\frac{z^2}{r^2}})^2}}$$

After transformations we'll find:

$$x^2 + y^2 - (Ro+r)^2 + 2\cdot(Ro+r)\cdot\sqrt{r^2-z^2} - (r^2-z^2) = 0 \quad . \quad (2)$$

From the equation (2) it is not difficult to determine:

$$R_z = (Ro+r)^2 - 2\cdot(Ro+r)\cdot\sqrt{r^2-z^2} + (r^2-z^2) \quad , \quad (3)$$

where R_Z diametrical sectional radius of raceway at the fixed value Z.

We'll express the equation of working surface of the abrasive bar in a coordinate system $Oxyz$. Transformation formulas have the form:

$$\begin{aligned} x_b &= z\cdot\sin\alpha + x\cdot\cos\alpha; \\ y_b &= y; \qquad (4) \\ z_b &= z\cdot\cos\alpha - x\cdot\sin\alpha. \end{aligned}$$

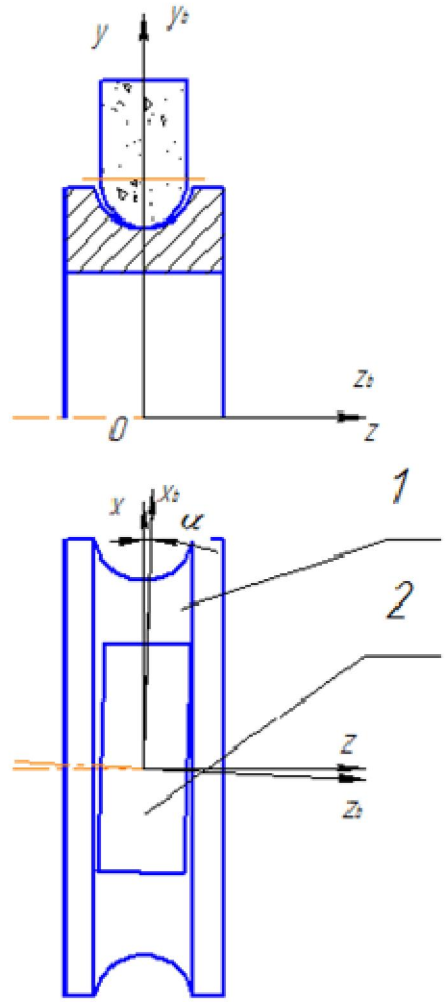

Fig. 3. The scheme of blank-1 and sharpening stone arrangement -2

We'll express the equation of the working part of bar surface, taking into account that the working surface of the bar corresponds to the working surface of the work surface, and generally satisfies the surface of torus.

$$x_b{}^2 + y_b{}^2 - (Ro+r)^2 + 2\cdot(Ro+r)\cdot\sqrt{r^2-z_b{}^2} - (r^2-z_b{}^2) = 0 \quad (5)$$

Taking into account the inequalities (4) and (5) the equation of the bar surface in the system $0xyz$ after the rotation to the angle α will be:

$$(x\cdot\cos\alpha+z\cdot\sin\alpha)^2+y^2-(Ro+r)^2+2\cdot(Ro+r)\cdot\sqrt{r^2-(z\cdot\cos\alpha-x\cdot\sin\alpha)^2}-$$
$$-(r^2-(z\cdot\cos\alpha-x\cdot\sin\alpha)^2)=0 \quad (6)$$

After some transformations and the use of differentiation theorem of implicit functions, from the equation (6) we can determine the coordinates of the point (x, y) of the abrasive interaction with the product of the bar in the plane *z=const* at preset valuesR_0, *r*. The workpiece passing through the point (x, y) in a given cross section z describes a circle of radius $\rho_z=\sqrt{x^2+y^2}$. Thus points (ρ_z, z) form the workpiece profile. The equation of the raceway ring of bearing profile processed with abrasive bars, and obtained in an implicit form. To determine its geometric parameters, features of the program MathCad were used.

As can be seen, superfinish processing technology of the rings bearings profile requires special control. Further improvement of friction bearings for swinging movement and superfinishing operations for its processing.

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