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Improving the durability of moving joints working in conditions of intensive wear

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Abstract

The article discusses the method of surface plastic deformation of steel parts by rolling them with rollers. The positive effect of this method on the wear resistance of friction pairs under conditions of intense abrasive wear and with abundant lubrication has been established.

Key words: wear, surface plastic deformation, friction pair, abrasive, durability.

Introduction

The durability of units containing a movable force contact can be increased both by increasing the wear resistance of the material of the parts and by optimizing the relief of the contacting surfaces [1, 2]. Technological processing methods have limited possibilities of influencing the parameters that determine the wear resistance of the material of the parts, but can be used to obtain a relief of the surface of the parts that is favorable in terms of wear resistance. Using various processing methods, it is possible to obtain surfaces that differ not only in height, but also in the shape of irregularities [3].

Research methodology

Let us consider the results of the study of the influence of some processing methods on the wear resistance of parts in widely used units:

1) steel shaft - bronze inserts;
2) piston with rubber seals - steel sleeve;
3) screw pair, steel screw - bronze or cast iron nut;
4) steel block - hardened steel rope.

The study of the friction pair shaft - insert was carried out on samples: shaft made of 40 steel with a diameter of 40 mm, inserts - made of tin bronze Br. OCS 8-21.

Steel samples were processed in three ways: polished (surface roughness Ra = 2.5 μm); rolled with a roller with a finishing mode with a force P = 1.25 kN, selected according to the method [4] (surface roughness Ra = 0.63 μm); rolled by rollers with a hardening mode at P = 10 kN (surface roughness Ra = 2.5 μm). The surface of the liners (bushings) after boring had a roughness Ra = 2.5 μm.

Tests of a friction pair were carried out on a friction machine MI in a mode close to the mode of operation of a shaft with a sleeve and a crushing cone body with a thrust bearing in medium and fine crushing crushers (peripheral speed 25 m/min, nominal specific load 5 MPa); the samples were liberally lubricated with machine oil. Roughness measurements and surface profilograms were taken on a profilograph-profilometer of the Kalibr plant. The research technique and the technology for making samples are described in [5].

Research results

In Fig. 1 shows the graphs of the dependences of the wear of the samples on the friction path, built for the friction path up to L = 9000 m on the basis of tests of 10 pairs of samples, and later on two pairs of samples for each processing option. During the first two hours of testing (L = 3000 m), bronze smearing was observed on the working surfaces of ground steel samples and samples rolled with a roller at P = 10 kN, which led at the beginning of wear to low weight wear of the ground samples and even to an increase in the weight of the samples, run in at P = 10 kN; on the samples rolled with a roller with P = 1.25 kN, the smearing of bronze was not noticed. The friction coefficient f at the beginning of the tests was 0.127 for ground specimens, and 0.047 and 0.12 for specimens rolled at P = 1.25 kN and P = 10 kN, respectively. Subsequently, the friction coefficient reached a minimum (f = 0.016) for specimens rolled at P = 1.25 kN - after 2 hours (L = 3000 m), and at P = 10 kN - after 6-7 hours (L = 10000 m), for polished samples even after 42 hours (L = 58000 m) (f = 0.027), i.e. during the testing of this friction pair, the running-in period has not yet ended.

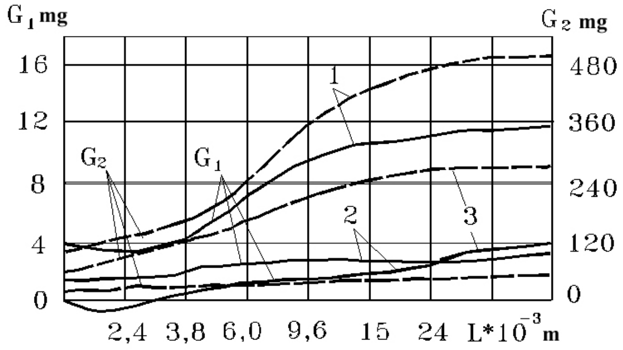

Fig. 1. Wear (loss of weight) of steel shafts G_1 and working with them in a pair of bronze inserts G_2, depending on the friction path L:
1 – ground shaft;
2 – shaft rolled with a roller at P = 1.25 kN;
3 – the same, but with P = 10 kN

As you can see, the running-in of rolled steel samples occurs several times faster than polished ones; at the same time, the wear of polished samples for a significant period of operation is 3 - 3.5 times more than that of rolled samples. Since the roughness parameters Ra of the samples ground and rolled at P = 10 kN are the same, the lower wear of the latter can be explained by their increased hardness and a larger supporting surface area as a result of rolling with a roller.

The specimens rolled with a roller at P = 1.25 kN had the minimum wear; this is due not only to the hardening effect, but also to ensure the optimal roughness with this processing method. The reference area of the surface of the rolled samples in the upper layers is 1.5 - 2, and in the lower layers - 1.1 - 1.2 times more than that of the polished ones with a corresponding increase in the radius r of rounding of the tops of the protrusions and a decrease in the angles β° of the profile at the rolled surfaces (see Table 1). Profilograms of sample surfaces before and after tests are shown in Fig. 2.

Table 1

Surface roughness parameters of the shaft, liner and sleeves

Sample	Roughness parameters		Profile angle β°	Vertex radius r, μm
	Ra, μm	Rz, μm		
Steel shaft:				
polished	1.8/1,5*	6.7/5.5	7/8	250/260
run-in at P = 1.25 kN	0.9/0.5	3/1.8	5/5	800/700
Bronze insert	2.1	7.9	11	160
Liners:	0.8 – 0.6	3.1 – 1.8	6-2	250 – 650
squandered	3/2.8	12/10	15	150
bored and grinded	1/0.9	3.8/3.4	15	70
bored and rolled	0.8/0.8	3/3	9	850
* Numerator - before testing, denominator after testing (for the liner, the first digit is after working with a ground shaft, the second is after working with a rolled shaft)				

The height of the roughness of the rolled surface has decreased by 1.5 - 1.8 times, and the ground - by 1.2 times. The wear of the rolled surfaces led to a slight decrease in the radii r, the rounding of the tops at almost unchanged angles β° of the profile, and the polished ones - to an increase in both the radii and the angles of the profile. Analysis of the nature of changes in the support (bearing) area shows that on the polished surface with more intense wear than on the rolled surface, a new roughness is created with a height that does not differ much from the initial one. On the rolled surfaces, the roughness arising during their wear is formed mainly due to the smoothing of the tops of the protrusions without a significant spread of roughness into the underlying layers of the hardened metal. Due to this, the difference in the size of the support area between the ground and rolled surfaces increases even more during their wear.

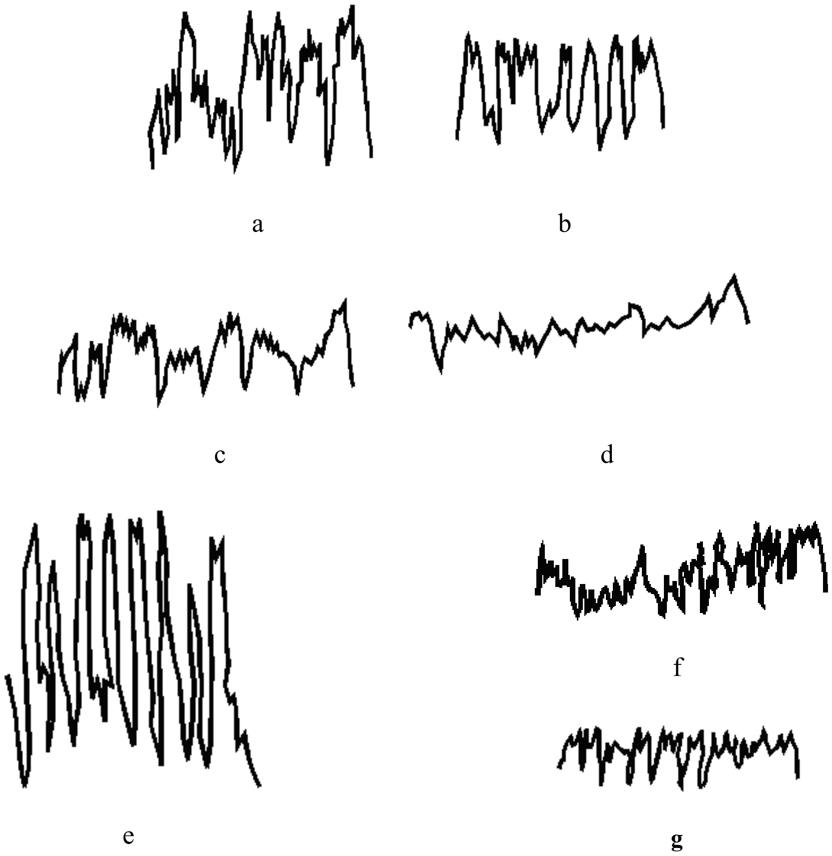

Fig. 2. Profilograms of the surface of the samples taken before and after the tests (along the vertical ×4000, along the horizontal ×40):
a, b – polished steel shafts before and after the tests;
c, d – steel shafts, rolled at $P = 1.25$ kN before and after tests;
e – bronze inserts before testing;
f, g – bronze inserts tested in tandem with a ground shaft and with a shaft run in at $P = 1.25$ kN

The wear of the bronze insert is determined, as can be seen from Fig. 1, mainly by the parameters of the roughness of the steel shaft paired with it. Thus, the most wear was observed in the inserts coupled with a ground shaft, the surface relief of which is characterized, in comparison with a rolled shaft, by smaller radii r of rounding of the tops of the protrusions and large angles β° of the profile. In this case, the wear of the liner increases, in addition, it is accompanied by caricature of the ground surface with abrasive grains. The least wear was observed in the bushings coupled with the shafts run in at $P = 1.25$ kN.

In all cases, a new surface relief is formed on the surface of the liners due to the fact that their linear wear is many times greater than the height of the irregularities of the original surface. In this case, in the case of work with a rolled shaft, the radii r of rounding of the tops sharply increased and the angles β° of the profile decreased. When working with a ground shaft, a similar phenomenon was observed, but the degree of change in the roughness parameters of the liners was less. In both cases, after testing, the curvature of the tops of the roughness of the liner surface was close to the curvature of the tops on the surface of the mating shaft. If the profile angles for a liner paired with a ground shaft become approximately the same with their values for a shaft, then for a liner mated with a rolled shaft, a greater smoothing of the tops was observed, which led to lower profile angles on the liner than on the shaft. This resulted in the creation of a larger bearing surface area of the liners, working in tandem with the rolled shaft, which is the reason for their greater wear resistance.

In a pair of piston with rubber seals - steel liner, the effect of liner processing methods on the wear resistance of seals was investigated.

The test procedure carried out on special stands was close to the operating conditions of pneumatic cylinders in operation [6]. For research, we used rubber cuffs in accordance with GOST 6678–65. The processing of the inner surface of the sleeves (steel 40) with a diameter of 80 mm was carried out according to three options: boring with roughness parameters, Ra = 3 μm, Rz = 12 μm, boring and grinding (Ra = 1 μm, Rz = 3.8 μm), boring and rolling with rollers (Ra = 0.8 μm, Rz = 3 μm). The rolling mode was determined according to the method [4].

Tests have shown that the wear of the cuffs working in contact with bored or bored and ground sleeves is significantly greater than that working in contact with bored and then rolled sleeves. The wear of these cuffs is especially intense during the first period of operation ($L = 10 \div 15 \cdot 10^3$ m); wear products of the cuffs during this period are small rubber shavings cut off by the sharp tops of the ridges of the liner surface irregularities. Note that the wear of cuffs operating in bored sleeves turned out to be somewhat less than in polished ones, although the latter had a lower surface roughness. In sleeves bored and then rolled, the wear of the cuffs from the very beginning of their operation proceeds uniformly, wear products of the cuffs are observed in the form of oil-polluting rubber abrasion particles, and the amount of wear is 5 - 10 times less than in ground sleeves. Periodic check of the seals of the cylinders disconnected from the network found that the pressure drop in cylinders with polished and rolled liners occurs at the beginning of the work of the seals in approximately the same way, after $L \approx 20 \cdot 10^3$ m of the friction path in cylinders with polished liners, the pressure drops within 3 minutes from 0, 64 to 0.2 MPa, and in cylinders with rolled sleeves even after 40 minutes it remains at the level of 0.24 MPa. Obviously, the test results of the pair under consideration should also be evaluated in connection with the roughness parameters of the sleeves processed by various technological methods. In this case, the presence of abrasive grains on the surfaces of the ground liners should be taken into account.

Fig. 3 shows profilograms of the surface of the sleeves prepared for testing. After the tests, there is a slight decrease in the height of the surface irregularities of the bored and ground sleeves after boring; the surface of the sleeves, processed by boring and subsequent rolling, did not undergo noticeable changes in the process.

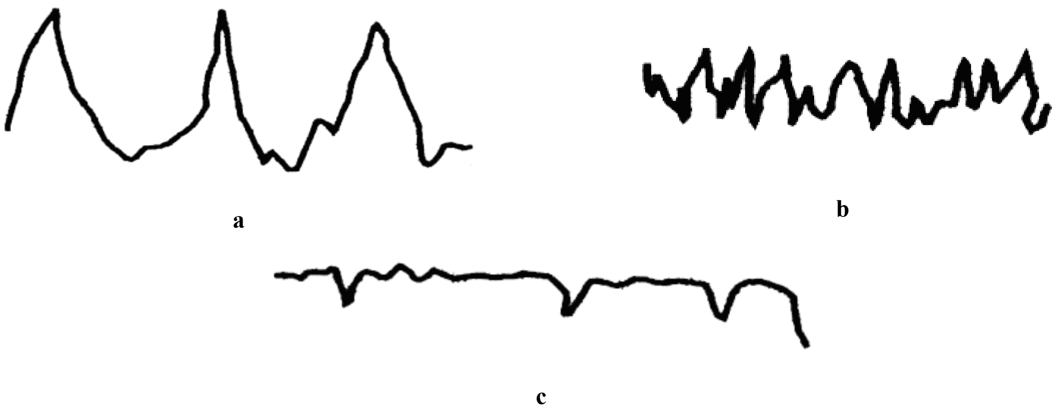

Fig. 3. Profilograms of the surface of pneumatic cylinder liners processed:
a – boring;
b – boring and grinding;
c – squandering and rolling (vertical ×1000; horizontal ×40)

At the same time, a significant difference in the radii of curvature of the tops of the protrusions of the surface roughness of the sleeves, processed by various methods, remained (see Table 1). The profile angles in all cases remained almost unchanged. The increased wear resistance of the rubber seals was also facilitated by the creation of a larger bearing area at the rolled surfaces.

Data on the wear resistance of screw pairs with screws having a trapezoidal thread with a pitch of 12.7 mm and rolled with finger rollers using the bending method [4] were obtained on the flask tilter of the 27-ton shaking table of the Uralmashplant forming line and on the cold rolling mill of pipes KhPT – 75.

Bronze and cast-iron nuts of the flask tilter operate in an environment dusty with the components of the molding mixture (quartz sand SiO_2 - 90 - 96%, alumina Al_2O_3 - 3%, the rest - MgO, Cr_2O_3, FeO + Fe_2O_3, CaO, NaO), and completely wear out in 1 - 3 months.

The tilting trolley with a flask filled with earth and a model with a total weight of 36 t is mounted on four screws. The screws are made of 40X steel, the nuts are made of AZhMts 10 - 3 - 1.5 bronze or gray cast iron. The design pressure in the thread with uniform loading of all four screws is 2.55 MPa. The sliding speed in screw pairs when raising and lowering the flask is 30 m/min.

Before installing the nuts, bronze threaded extensions are screwed to them. The purpose of the extensions is to partially relieve the thread on the nuts and increase the turnaround time of the tilter. After a certain time of operation of the nuts with the extensions, the latter were removed and the wear of the nuts was estimated by the amount of their wear. Then the extensions were replaced with new ones. After complete wear of the thread in the nuts, the load was taken up by some extensions. During this period of work, the wear resistance of the extensions was determined [7].

The assessment of the wear of the screws was carried out by measuring the thickness of its turn with a rod tooth meter. Worn nuts and extensions were cut along the generatrix. The measurement of the thickness of the turns in them was carried out on an instrumental microscope. In order to exclude the influence of random factors during the tests of the wear resistance of screw pairs, the rolled screws were installed in various combinations with non-rolled screws at all four support points of the rotator.

The screw wear during the overhaul period was 0.4 - 1 mm. Replacing bronze nuts with cast iron leads to an increase in screw wear by 35 - 50%. With the same wear, the durability of rolled screws working with bronze nuts is 78% higher than that of non-rolled screws, working with cast-iron nuts - by 54%. The wear resistance of cast iron nuts is slightly higher than that of bronze ones [8]. However, due to the low resistance of cast iron to bending load, the durability of cast iron nuts can be reduced as a result of breakage of an incompletely worn coil. The relative increase in the life of the nuts as a result of the screw rolling is the same as for the screws themselves. The durability of the bronze extensions after the wear of the nuts as a result of the rolling of the screws is more than doubled. This is due to the fact that the extensions work in the most unfavorable conditions (the highest dust content and increased loads). It should be noted that the rolling of the screws with rollers completely eliminated the scuffing and jamming of the screw pairs, which before the introduction of the screw rolling operation occurred during the running-in period. Nuts of the feed mechanism of cold-rolling mills are made of bronze AZhMts 10 - 3 - 1.5, screws are made of steel 40X. The design pressure in the thread when removing the workpiece from the mandrel reaches 1 MPa, the sliding speed in the screw pair is 3 m/s. The screw pair works in an environment saturated with dust and metal scale. The monitoring of the wear resistance of screw pairs was carried out at four KhPT - 75 mills, installed in one shop and working with approximately equal productivity. On two mills were installed screws with rolled threads and on two - with unrolled threads. The assessment of the screw wear was carried out by measuring the thickness of the coil with a vertical tooth meter. The wear of the screws after rolling them with a roller decreased 2.6 times.

To strengthen the profile of the strand of the rope block of the ship loader, it was rolled with a wedge roller. However, an increase in the hardness of the surface layer by 25 - 30% of the profile of the stream obtained using work hardening did not lead to a decrease in surface wear. The analysis of the process of wear of the working surface of the block showed that, in addition to abrasion and crushing of the surface, there is a shearing of the surface layer by separate hardened wire wires. It is known from the theory of metal cutting that less work is spent to cut the work-hardened metal than when cutting the un-hardened metal. The same results were obtained by M.M. Khrushchev and M.A. Babichev in comparative tests for wear resistance of work-hardened and non-riveted metals during their wear with abrasive skins [9]. The hardness of the abrasive significantly exceeded the hardness of the wear materials. V.N. Kashcheev [10] also did not find the effect of work hardening on the wear resistance of axial steel, wearing it with abrasive wheels on a ceramic bond. However, studying the wear resistance of materials in the presence of abrasive particles in the contact of rubbing surfaces, M.M. Tenenbaum [11] showed that quartz grains with a hardness significantly exceeding the hardness of the plates compressing them are destroyed. Moreover, the breaking load decreases sharply with increasing hardness of one of the compression plates.

Conclusions

Taking into account the above, to increase the durability of the blocks, the block metal was replaced: steel 25L - for steel 45L and the block was hardened in oil. The hardness of the surface layer of the strand profile after quenching and rolling was approximately 400 HB. The process of cutting off the surface layer by the wires of the rope was eliminated and the durability of the blocks and the ropes working with them increased 2 - 3 times.

The share of the effect in increasing the wear resistance of the work-hardened surface layer, in the absence of the process of its cutting, belongs to the residual compressive stresses formed in the layer as a result of plastic deformation [12].

A.A. Matalin [13] considers the increase in the wear resistance of parts due to the work-hardening of the surface layer to be a consequence of the increased diffusion of air oxygen into the hardened metal, in which solid chemical compounds FeO, Fe_2O_3 and Fe_3O_4 are formed, which are characteristic of oxidative wear proceeding with the lowest intensity. The preliminary hardening of the metal prevents the development of joint plastic deformation of the metals of the rubbing parts, which causes cold welding - seizure, which is the most intense type of wear.

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Марченко Д.Д., Матвеева К.С. Метод повышения долговечности подвижных соединений, работающих в условиях интенсивного износа.

В статье рассмотрен метод поверхностного пластического деформирования стальных деталей обкатыванием их роликами. Установлено положительное влияние этого метода на износостойкость пар трения в условиях интенсивного абразивного изнашивания и при обильной смазке.

Ключевые слова: износ, поверхностная пластическая деформация, пара трения, абразив, прочность.