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IMPROVE THE WEAR RESISTANCE OF BRONZE SLIDING BEARINGS

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Для зменшення сил тертя в процесі припрацювання зі змінними навантаженнями, були запропоновані нові способи формування комбінованих електроерозійних покриттів на поверхнях тертя бронзових вкладишів підшипників ковзання.

Ключові слова: *підшипник ковзання, бронзовий вкладиш підшипника, міцність зв'язку, припрацювальні покриття, зношування.*

Statement of the problem

Most responsible parts and assembly units of centrifugal compressors, pumps, turbines and other machines work under conditions of heavy loads, high speeds, temperatures, and also of corrosive, abrasive and other types of influence of working environments. Solving the problem related to increasing terms of their service directly depends on increasing the wear resistance and reliability of friction units. With the large variety of the operation conditions of the parts, their surface layers are considered as the most loaded portions. Therefore, the real working resource of the machine operation directly depends on the part surface bearing capacity being determined by the quality of its surface layer. Creating coatings with special properties for sliding friction units determines the importance and urgency of the problem and also the need in its solution.

The antifriction properties of the friction pairs depend on the combination of the materials of the shaft, bearings and lubrication.

The bearing materials operate in pairs with steel or cast iron shaft journals. The cost of a shaft is usually higher than the cost of bearing pads (BP), so they should wear less than the bearing pads [1].

The main general requirements to the materials of sliding bearings (SB) are as follows:
- Mutual materials compatibility of the bearings with the opposing members;
- The possibility of obtaining high accuracy and cleanliness of processing;
- Stability and low coefficient of friction;
- High pressure properties;
- High thermal stability, high corrosion and erosion resistance, resistance to vibration;
- Manufacturability, availability and low cost, high dimensional and structural stability;
- Concordance of the linear expansion coefficients of the bearing couple, conformability, and recoverability of properties after forced contact, absence of electrostatic attraction on friction surfaces [2].

The main requirements to the antifriction alloys are determined by operating conditions of the bearing pads. These alloys should have sufficient hardness, but not as high as to cause excessive wear of the shaft; they should be relatively easy to deform under the influence of local stresses, i.e. be plastic; and also they should keep the lubricant on the surface.

To produce the bearing pads, there are used various antifriction materials. Changing the type of alloy grades is influenced by increasingly stringent operating conditions of the bearing assembly units. The bearing copper based alloys exhibit better mechanical properties as compared with the babbit and also the alloys on the base of zinc and aluminum.

To manufacture the bearings for turbines, electric motors, centrifugal pumps and compressors operating under conditions of a constant load, there are applied special kinds of tin bronze (GOST 5017-74), tin-zinc-lead-based bronze (casting bronze) (GOST 613-65) and tinless bronze (GOST 18175-78) [3].

Overheating the bearing is considered the main cause of its destruction, as with increasing temperature, there reduces the viscosity of the oil and increases the likelihood of jamming the bearing journal, which ultimately results in melting out of the pad [4].

In the workshop for production of weak nitric acid of the JSC "Nevinnomyssky Nitrogen", to provide the proper equipment for the gas turbine unit GTU-8 which design of the damper bearings made of Babbitt B83 could not withstand a short-term rise in temperature up to 250 ^{0}C, the above said bearings were replaced by the bearings wherein there was used bronze composition BrO10S10. Analyzing of their work has shown that the damageability of the bronze pads is exposed in the form of constrained running, high wear and high probability of scoring.

Thus, there is need to provide for the bronze bearing pads with special coatings improving the running conditions.

Analysis of the results of recent researches and publications

In order to improve the tribological characteristics at performing the manufacture and repair of a lot of sliding bearings, the running layers of babbit are applied on the bronze layers using the ion-plasma method [5, 6].

In Document [7], there are studied the electrodeposited coatings of alloy SnSbCu, which chemical composition is close to Babbitt B83. The obtained coatings have high wear resistance at the stage of running. Friction-caused losing weight of the resulted alloy is 4 times less than that of the cast Babbitt B83.

A significant disadvantage of babbit is its low fatigue resistance, particularly at temperatures above 100^{0}C. With decreasing the thickness of the bearing filling, its fatigue resistance increases [8, 9].

For applying the antifriction coatings, there is used the quite promising method of electroerosion alloying (EEA), which is increasingly being used in the industry [10].

The complex of the positive specific features of the EEL method, primarily such as the possibility of applying any conductive material firmly connected to the substrate on the metal surface, performing the alloying process at a local site, and the absence of warping of the alloyed products, stimulate its increasing use for improving the quality of sliding bearings [11-20].

One of the main advantages of the EEA method is that it allows to provide alternating alloying of the metallic surfaces by the individual electrodes, and so to form thereon quasi multilayer coatings having desired properties [21-24].

In lead bronzes, lead is practically insoluble in liquid copper. Therefore, after hardening, alloys consist of crystals of copper and lead inclusions. Such a bronze structure provides high antifriction properties. This fact determines the wide usage of bronze BrS30 for manufacturing the pads of sliding bearings working at high speeds and under high pressures. As compared with tin bronze of the bearings, the thermal conductivity of bronze BrS30 is 4 times more, so it is effective in removing the heat generated by friction [25].

Silver has high mechanical and anticorrosion properties, but as antifriction metal, can not be considered good enough. The antifriction properties of silver are improved by a small amount of lead additives. Silver is used in bearings designed to withstand high loads and speeds.

At manufacturing of the bearing pads and bearing journals for the rotors of compressors and pumps, there are always occurred deviations from a perfect geometric shape being called ‘errors’. The additional errors are introduced during the installation of the rotor. Accumulation of errors significantly reduces the real contact area of the shaft journal with the bearing pad causing the overvoltage of the sliding layer, especially during the process of running.

Thus, the purpose of this work is to improve the durability of the bronze nearing pads by analyzing the quality of the quasi multilayer running coatings formed by EEA method.

Research technique

With running coatings being made of soft antifriction material, to investigate the possibility of applying the running coatings onto the bronze pads of the sliding bearings, as a cathode material, there were used tin bronzes Br OCS 5-5-5 and Br OS 10-10. Their mechanical properties according to GOST 613-79 are presented in Table. 1.

Table 1. Mechanical properties and applicability of tin bronzes

Mark	Casting method	Temporary resistance $\sigma_в$ [MPa]	Relative elongation after fracture δ_0 [%]	Brunel hardness HB	Applicability
BrO5C5S5	Kokil (Metal mold)	176,2	4	60	Fittings, antifriction parts, bearing pads
BrO5C5S5	Sand mold	147	6	60	
BrO10S10	Kokil (Metal mold)	196	6	78	Sliding bearings operating under high specific pressure
BrO10S10	Sand mold	176.2	7	65	

The anode materials being used for researching, as well as some of their physical and mechanical properties are listed in Table 2.

Table 2. Physical and mechanical properties of the materials used as the anodes (alloying electrodes) at EEA processing

Mark of material	Melting point [^{0}C]	Brunel hardness HB	Thermal conductivity [W/(m·K)]	Factor of Linear expansion, 10^{-6} [deg $^{-1}$]
Copper	1084	88	401	16.5
Silver	817	25	453	14.2
Tin	232	5	59.8	22
Lead	327	4	35	28.5
Babbitt B83	370	27-30	-	23.0

To study the structure and measure the hardness of the surface layer, there were used thin polished sections of the specimens after the EEA processing. EEA processing of the specimens was performed at the apparatus equipped with the manual vibrator of Elitron 22A model.

When being manufactured, the surface of the thin polished section was oriented perpendicular to the surface to be alloyed. Before manufacturing of the thin polished section, to avoid the edge effect upon alloying, the end of the specimen was milled to a depth of at least 2 mm. To prevent the layer crumpling and stalling its edge, the specimen was fixed with a counter body in the clamp.

The manufactured thin polished sections were examined under the optical microscope of Neofot-2 model, where there was evaluated the layer quality, its continuity, thickness, and the structure of the underlayer zones, namely, the diffusion zone and the heat affected zone (HAZ). Simultaneously, there was provided the durometric analysis for the microhardness distribution in the surface layer and over the depth from the surface of the polished section. The microhardness measurement was carried out with the help of the microhardness metering device of PMT-3 model by indenting the diamond pyramid under different loads.

The thickness of the coating layer was measured by a micrometer, and the surface roughness was determined by taking off and processing the profilograms with the use of the profilograph profilometer instrument, model 201, of the JSC ‘Plant Kalibr’ production.

The qualitative analysis and quantitative composition of the running coatings for the specimens made of bronze OCS 5-5-5 was conducted under the electron microscope of REMMA-102 model manufactured by JSC «SELMI» X-ray spectrometer equipped with silicon and lithium - based solid state detector (semiconductor detector).

The surface micrographs of the specimen areas were obtained at various zoom levels under the imaging mode by the current of secondary electrons at accelerating voltage of the microscope electron gun of 20 kilovolts and at the probe current of 200 pico-ampere. At the same time on the surface of the coating, there were chosen 3 characteristic points (the smooth coating, rough coating and pore), and at each point there was determined the elemental composition of the applied layer.

Besides, the elemental composition of the applied layer was determined over the depth of the layer using different scanning steps.

Under the condition of the X-ray microanalysis, the accelerating voltage was 20 kilovolts, the beam current was 1 nano ampere. Being excited by an electron beam, the characteristic X-rays were detected by a semiconductor detector.

The calculation of the weight percent concentration was carried out by comparison of the test specimens with the standard ones. At the same time, there were taken into account the physical corrections concerning the atomic number, absorption and fluorescence emission (the method of three amendments).

Tribological properties of the running coatings were determined by the Tester T-01M scheme of ‘ball – disk’ (Fig. 1).

The specimens for testing (discs) were represented by the ring sized as 42 x 25 x 6 mm and made of bronze BrO10S10 (Fig. 2).

The following series of specimens were tested:

- Specimen A without coatings (0);
- Specimen with coating of copper + silver + copper (No. 1);
- Specimen with coating of lead + copper (No. 2);
- Specimen with coating of lead + silver + copper + silver (No. 3).
- The ball Æ = 6.3 mm made of material 100Cr6 (Table. 3) was changed after each test.

In the course of the investigation, there were used the following operating parameters of the above mentioned tester:

ω = rotational speed of 120 r.p.m.;

Load T was changed after each 50 m and was 0.5 kgf (4.91 N); 1.0 kg (9.81 N); 1.5 kgf (14.72 N); 2.0 kgf (19.69 N) and 2.5 kgf (24.53 N).

Before each increase in load, the specimens were lubricated with a drop of paraffin oil. Frictional force F had been being recorded for al the period of testing.

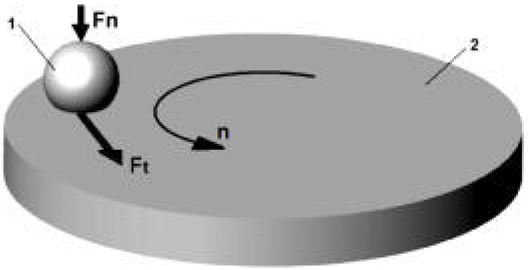


Fig. 1. Diagram of a pair of friction
for tribological tester T-01 M: 1 - ball, 2 – disc

a b

Fig. 2. Bronze specimen before (a) and after (b) testing

Table 3. Composition of the ball material

	C	Si	Mn	Cr	Mo	Ni	S max	P max
min	0.95	0.15	0.20	1.35	-	-	-	-
max	1.10	0.35	0.40	1.60	0.10	0.40	0.025	0.025

In the first experiment, for each of the running coatings, there were only changed the loads, and the tests were carried out with one ball on one friction track, and in the second experiment, for each new load, there was changed the ball and also the surface of coating.

The results of research

As a result of the conducted tests, there was designed and proposed a new method of processing the bronze pads of the sliding bearings, which is carried out as follows. First on the bearing pads working surfaces made of bronze OCS 5-5-5 and having microhardness of 1100 to 1150 Mpa, there is applied the coating of silver using EEA processing at the discharge energy of 0.1 to 0.3 J. In this case, the microhardness of the formed surface layer is reduced and makes 750 -800 MPa.

After that, the silver coating is coated with copper using the same method and at the same discharge energy (0.1 - 0.3 J). The microhardness of the coating after applying copper slightly increases and makes 850-900 MPa.

The third layer is a coating of tin babbit applied by the electroerosion alloying method with pulse energies of 0.01 to 0.04 J. In this case, copper being a part of the coating forms together with tin, which is the main component of tin babbit, the substitutional solid solution providing guaranteed metallic bond.

Applying tin babbit contributes to obtaining, as a result of the eutectic reaction, the silver-based mechanical mixture, which is composed of Son and e phase having a melting point being close to 220^0C.

The microhardness of the structure after applying the electroerosion coating of tin babbit is 350-380 MPa. Lead, which is contained in bronze, is practically insoluble in silver and it actually remains in a free state.

Thus, there is obtained a combined electroerosion coating (CEC), which is not a continuous (homogeneous) layer but represents the structure in the form of discrete zones having maximum thickness of 30 microns, i.e. there is formed a regular surface micro relief with vertices, which structures have microhardness of 350 to 380 MPa.

Fig. 3 shows the uncoated bronze sliding bearings (top row) and the same with a combined electroerosion coating (CEC), (bottom row).

Fig. 4 shows the topography of the surface area of the sample with the CEC, wherein, there are selected three characteristic points (1 - smooth surface, 2 - rough surface, 3 - pore).

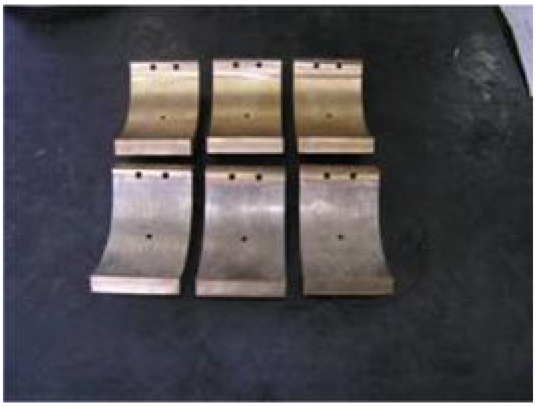


Fig. 3. The bronze pads of the sliding bearings

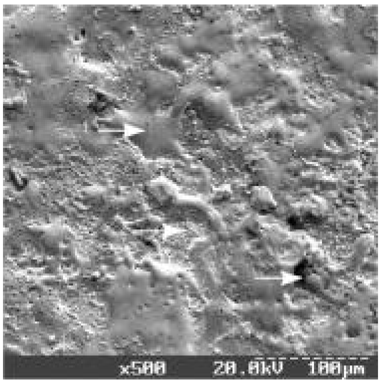


Fig. 4. The topography of the surface area of the specimen with the CEC of silver, copper, and Babbitt B83

The spectrum and the elemental composition of the surface in the characteristic points and from the entire surface being investigated are shown in Table. 4. These data indicate that all the characteristic points comprise elements being parts of the combined electroerosion coating.

Table 4. The elemental coating composition at the characteristic points and of all over the surface being under investigation

The point and area of the surface under investigation	Elements [%]				
	Cu	Zn	Ag	Sn	Pb
1	32.857	1.262	23.939	38.673	3.269
2	25.391	1.448	20.984	49.606	2.571
3	27.97	3.441	15.291	50.094	3.201
S	26.854	2.920	16.939	50.347	2.940

The distribution of the elements at deepening into the surface layer with a scanning step of 5 microns is shown in Table. 5.

Table 5. The elemental coating composition at deepening into the surface layer

The point of the surface under investigation	Elements [%]				
	Cu	Zn	Ag	Sn	Pb
1	61.832	1.909	6.070	27,247	2.942
2	73.057	3.679	3.070	18,269	1.924
3	55.913	2.288	7.430	28.903	5.466
4	63.844	2.828	0.892	26,344	6,092
5	78.721	5.618	0.000	13,13	2.531
6	84.492	5.244	0.737	7.169	1.303
7	86.832	6.084	0.000	5.355	1.729

As it can be seen from Tables 4 and 5, the surface layer of the bronze specimen that is formed by alternately EEA applying silver, copper and babbit consists of the elements of the alloying electrodes and the substrate. The thickness of the running coating is 30 microns.

The application of the bearing pads treated by the proposed method does not always lead to the desired result because of the small thickness of the coating. While reinforcing of the sliding bearing operating condition, high rotational speed and high pressure, in the course of running, there can be occurred scoring of the bearing pad working surface.

When forming the running coating with the use of the electrodes made of lead and silver, the process of applying the combined electroerosion coating is performed s as follows.

First on the bearing pad working surface, there is applied the electroerosive coating of silver at the discharge energy W_u =0.1 to 0.3 J. After that, the silver coating is covered with lead using the same method and at the discharge energy W_u = 0.3 – 0.4 J. The third layer is the applied electroerosive coating of silver at the discharge energy Wu = 0, 04 - 0, 10 J.

Thus, there is obtained the combined electroerosion coating having maximum thickness of 120 microns.

Figs. 5 and 6 show, respectively, the surface and the end surface portion of the bronze specimen with the CEC of lead and silver.

The elemental composition of the coating at the characteristic points of the surface and the distribution of the elements at deepening into the surface layer are presented in Tables 6 and 7.

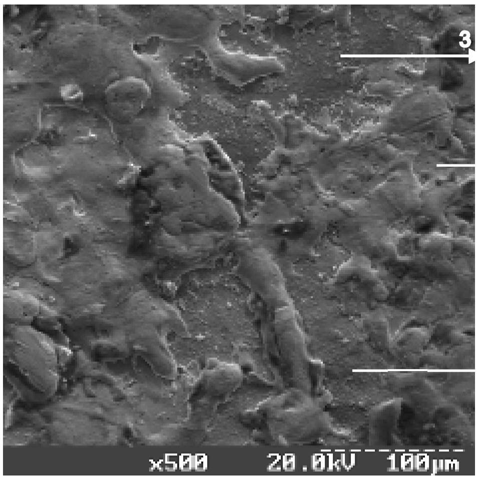


Fig. 5. The image of the bronze specimen surface with the CEC in the secondary electrons

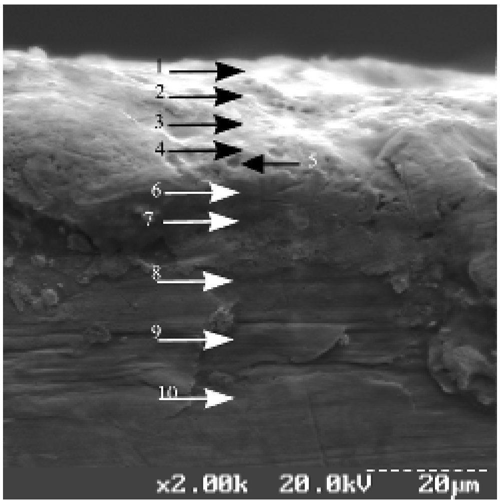


Fig. 6. Points of scanning the elemental coating composition at deepening into the surface layer

Table 6. The elemental coating composition of the combined electroerosion coating of silver and lead at the surface characteristic points

The point of the surface under investigation	Elements [%]				
	Cu	Zn	Ag	Sn	Pb
1	0.911	0.000	16, 472	0.000	82.616
2	20.630	1.818	47.659	3.504	22.827
3	24.399	2.040	49.416	4.838	16.364

Table 7. The elemental coating composition at deepening into the surface layer

The point of the surface under investigation (Fig. 6)	Elements [%]				
	Cu	Zn	Ag	Sn	Pb
1	22.284	0.000	45.894	0.000	31.822
2	52.032	0.000	24.064	0.000	23.904
3	48.569	0.000	24.318	0.000	27.113
4	44.892	0.000	37.820	0.000	17.288
5	60.235	2.011	17.760	0.000	19.993
6	69.678	2.273	9.035	3.384	15.630
7	50.181	1.739	28.917	1.584	17.578
8	83.297	3.998	1.909	2.652	8.144
9	87.348	3.726	0.603	6.749	1.572
10	90.937	3.579	0.166	4.777	0.542

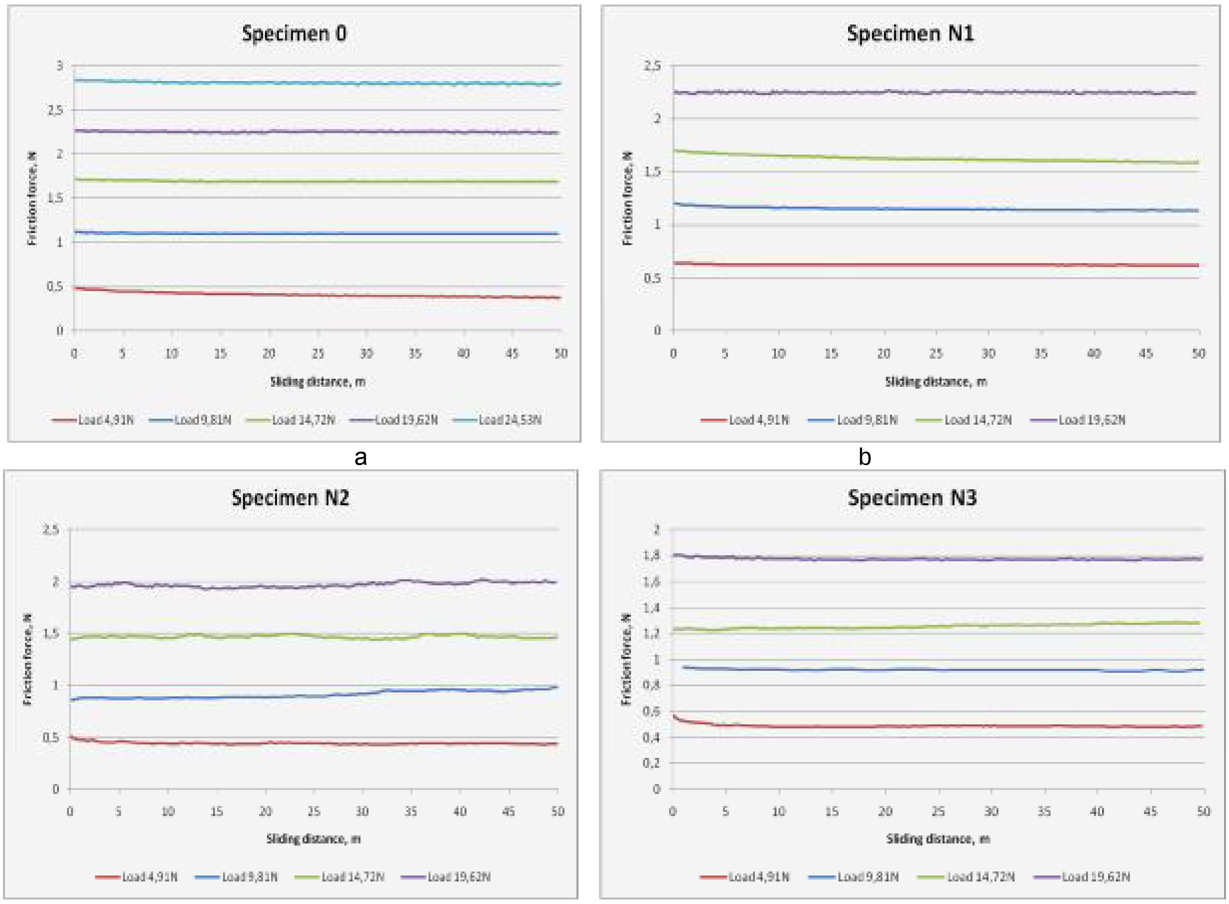
As a result of the metallographic studies, it has been found that at applying the CEC of silver and lead to the substrate of bronze, the surface layer consists of three zones (Fig. 7).

Fig.7. The microstructure and microhardness distribution of the surface layer of the specimen made of bronze OCS 5-5-5.

The upper layer (the layer of low hardness) of 600 MPa microhardness extends to a depth of 70 to 80 µm. Lower, there is a transition zone (the zone of increased hardness) having microhardness of 1270 to 1400 MPa and depth of 50 to 60 µm. The microhardness in the transition zone is enhanced by hardening processes, which occur as a result of electroerosion alloying. With deepening of EEL processing, the microhardness decreases in the transition zone and transfers into the microhardness of the substrate (1050 ... 1100 MPa).

Below, there are presented the results of the tribological studies.

Experiment 1. Fig. 8 shows the nature of changing the friction force for all series of specimens with the use of the steel ball passing the sliding distance of 50 m for each load. In this case, at changing of the load, the contact surfaces of the ball and the specimen were unchangeable. In Table 8, for the represented friction pairs, there are shown the average friction forces F and the coefficients of friction m



a b

c d

Fig. 8. Changing the friction force of the steel ball at moving over the surface of the bronze disc under different loads: a is series 0; b is series No. 1; c is series No. 2; d is series No. 3

Table 8. The friction force and the coefficient of friction of the steel ball while moving on the surfaces of the bronze disc and the running coating

Load, T (N)	Average friction force, F (N)	Friction coefficient m=F/T
Series 0		
4.91	0.41	0.083
9.81	1.11	0.113
14.72	1.69	0.115
19.62	2.25	0.115
24.53	2.81	0.114
Series No. 1		
4.91	0.62	0.127
9.81	1.15	0.117
14.72	1.62	0.110
19.62	2.25	0.115
Series No. 2		
4.91	0.44	0.091
9.81	0.91	0.093
14.72	1.47	0.100
19.62	1.97	0.100
Series No. 3		
4.91	0.49	0.099
9.81	0.92	0.094
14.72	1.25	0.085
1962	1.77	0.090

Fig. 9 represents the summary cross-plot of the friction forces of the steel ball moving over of the bronze disc surface with/without the running coatings *versus* the applied loads.

Having analyzed figures 8 and 9, as well as the data in Table. 8, it has been noted as follows:

- The friction force for all the series of the specimens and loads has been reducing since the moment of starting the path of friction till its completing, which fact testifies to the availability of the period of running;

- With increasing the loads for all the series of the specimens, there increases the friction force;

- The lowest friction force has been found for the specimens of series Nos. 2 and 3, and only at load 4.91 N - for series 0 and series No.2 (see. Table. 8), which is due to the differences in the values of the initial surface roughness (Ra = 0.5; 0,7; 0.8 and 0.8 µm, respectively, for series 0; No.1; No 2 and No. 3).

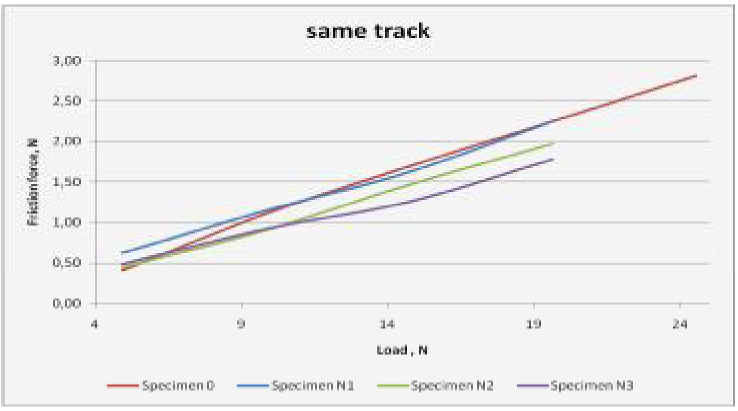
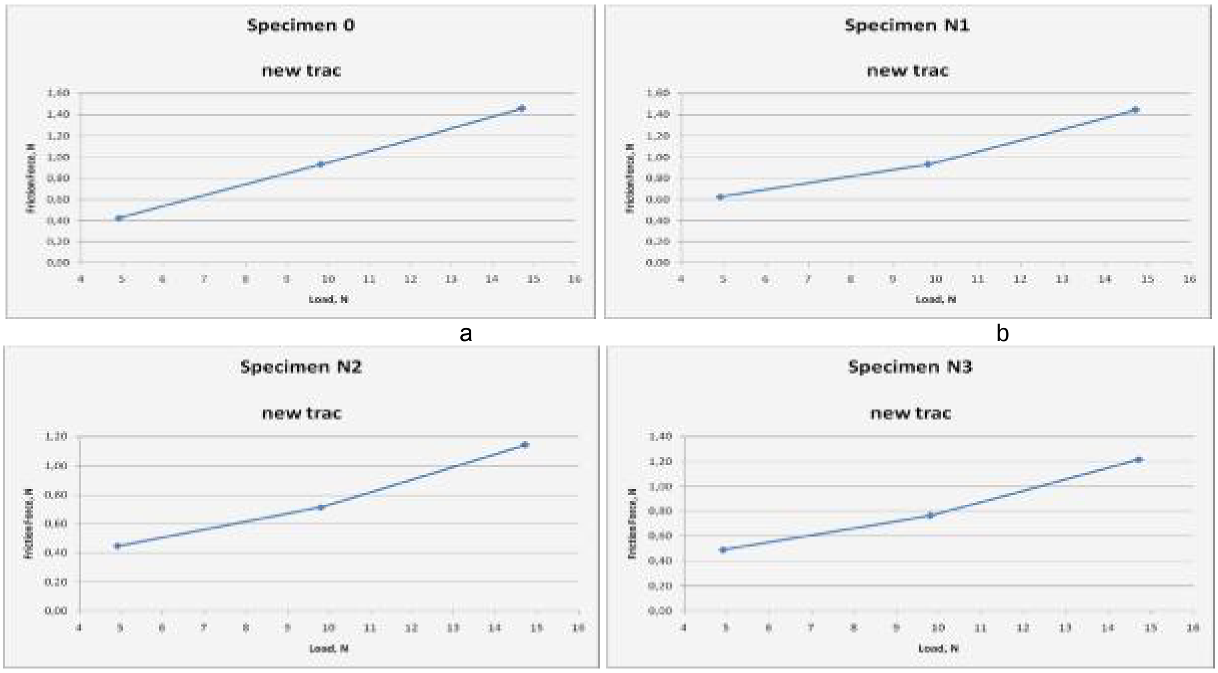


Fig. 9. The cross-plot of the friction forces versus the applied loads

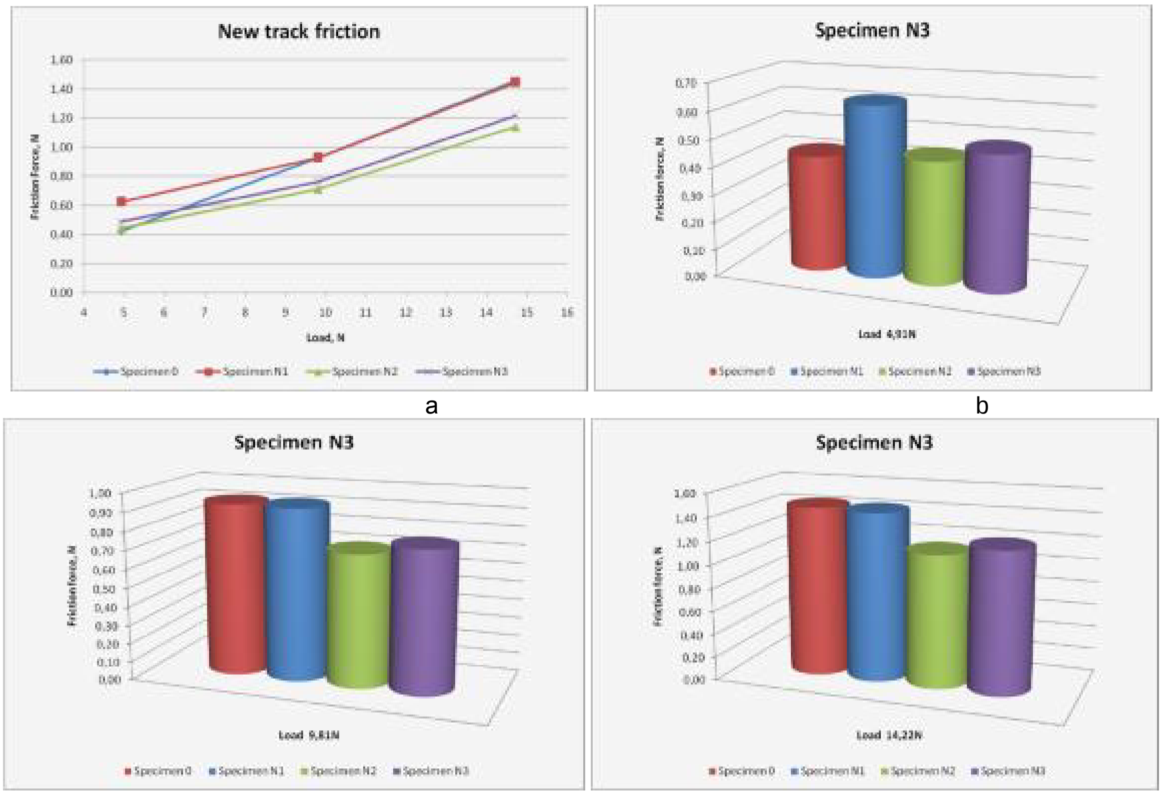
Experiment 2. Fig. 10 shows the nature of changing the friction force for all series of specimens with the use of the steel ball passing the sliding distance of 50 m at various loads, and Fig. 11a represents their summary diagram. Besides Figs. 11b; 11c; and 11d represent the diagrams to compare the friction forces for all the series of the specimens, respectively, at loads of 4.91; 9.81 and 14.72 N.



a b

c d

Fig. 10. Changing the friction forces of the steel ball moving over on the surface of the bronze disc at various loads: a is series 0; b is series No. 1; c is series No.2; d is series No. 3



a b

c d

Fig. 11. The summary diagram (a) and comparative diagrams (b, c, d) demonstrating the changes in the friction forces for all series of the specimens at the loads of 4.91; 9.81 and 14.72 N

Table 9 - The friction force and the friction coefficient for steel over the bronze specimens with the applied running coatings

Load, T (N)	Average friction force, F (N)	Friction coefficient m=F/T
Series 0		
4.91	0.43	0.087
9.81	0.93	0.095
14.72	1,46	0.099
Series No.1		
4.91	0.63	0.127
9,81	0,93	0.095
14.72	1.45	0.098
Series No. 2		
4.91	0.44	0.091
9.81	0.71	0.073
14.72	1.14	0.077
Series No. 3		
4.91	0.49	0.099
9.81	0.76	0.078
14.72	1.22	0.083

Conclusions

As a result of theoretical and experimental studies aimed at improving the quality of the bronze bearing pads for the sliding bearings, it has been stated as follows:

1. Electroerosion alloying (EEA) of the bronze surfaces by mild antifriction metals such as silver, lead and copper makes it possible to form the running coatings on their surfaces, which reduces the friction forces by 20% in the course of running.

2. The thickness of the coating can be altered by the EEA modes in the range of 20 to 150 microns.

3. The bronze bearing pads of the sliding bearings with the combined electroerosion coatings are characterized by high reliability and durability in operation because of the fact that even after the bearing coating having been destructed, the sliding bearing continues operating.

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В.Тарельник, В. Марцинковский, Б. Антошевский, П. Карп Повышение износостойкости бронзовых вкладышей подшипников скольжения

Для уменьшения сил трения в процессе приработки при различных нагрузках, были предложены новые способы формирования комбинированных электроэрозионных покрытий на поверхностях трения бронзовых вкладышей подшипников скольжения.

Ключевые слова: *подшипник скольжения, бронзовый вкладыш подшипника, прочность связи, приработочные покрытия, изнашивание.*

V. Tarelnyk, V. Martsynkovskyy, B. Antoshevsky, P. Karp Improve the wear resistance of bronze sliding bearings

Most responsible parts and assembly units of centrifugal compressors, pumps, turbines and other machines work under conditions of heavy loads, high speeds, temperatures, and also of corrosive, abrasive and *other types of influence of working environments. Solving the problem related to increasing terms of their service directly depends on increasing the wear resistance and reliability of friction units. With the large variety of the operation conditions of the parts, their surface layers are considered as the most loaded portions. Therefore, the real working resource of the machine operation directly depends on the part surface bearing capacity being determined by the quality of its surface layer. Creating coatings with special properties for sliding friction units determines the importance and urgency of the problem and also the need in its solution.*

The antifriction properties of the friction pairs depend on the combination of the materials of the shaft, bearings and lubrication. The main requirements to the antifriction alloys are determined by operating conditions of the bearing pads. These alloys should have sufficient hardness, but not as high as to cause excessive wear of the shaft; they should be relatively easy to deform under the influence of local stresses, i.e. be plastic; and also they should keep the lubricant on the surface. To produce the bearing pads, there are used various antifriction materials. Changing the type of alloy grades is influenced by increasingly stringent operating conditions of the bearing assembly units. The bearing copper based alloys exhibit better mechanical properties as compared with the babbit and also the alloys on the base of zinc and aluminum.

To reduce friction forces in the course of running under varies loads, there have been proposed new processes for forming combined electroerosion coatings on the friction surfaces of the bronze bearing pads of the sliding bearings.

As a result of theoretical and experimental studies aimed at improving the quality of the bronze bearing pads for the sliding bearings, it has been stated as follows:

1. Electroerosion alloying (EEA) of the bronze surfaces by mild antifriction metals such as silver, lead and copper makes it possible to form the running coatings on their surfaces, which reduces the friction forces by 20% in the course of running.

2. The thickness of the coating can be altered by the EEA modes in the range of 20 to 150 microns.

3. The bronze bearing pads of the sliding bearings with the combined electroerosion coatings (CEC) are characterized by high reliability and durability in operation because of the fact that even after the bearing coating having been destructed, the sliding bearing continues operating.

Keywords: *sliding bearing, bronze bearing pad, bond strength, running coatings, wear-out.*

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APPLYING POLYMER COMPOSITES IN THE MACHINE PARTS COMBINED RESTORING METHODS

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Запропоновано новий спосіб відновлення металевих деталей, який полягає в нанесенні на їх зношену поверхню, методом електроерозійного легування, металополімерного матеріалу з його подальшою чистовою обробкою.

Ключові слова: *покриття, ремонт, електроерозійне легування, металлополімерний матеріал, якість.*

Introduction. Among the current trends of modern mechanical engineering, the problems of restoring parts by applying coatings, which have desired properties, and also assessing their qualities are probably the most extensive and branched. A significant number of technological methods for applying coverings and a great variety of fields for their applications as well as a wide range of materials used for the above said purposes make hard taking an objective decision on a choice of a proper coating and an optimal process for its application in a competitive approach.

Meanwhile, the effective use of hardening coatings at manufacturing and repairing of parts is now days considered as one of the most important economic problems, which successful solution would drastically reduce the consumption of complex alloyed steels and alloys and improve operation and service life of machines and mechanisms.

The production aimed at restoring of parts requires a large amount of labor, materials and energy being necessary for applying coatings, providing thermal treatment and machining of the parts. Therefore, cost optimization of the above said resources owing to their best use at timely implementation of production tasks and ensuring normative quality indices are urgent problems.

Analysis of recent research and publications. The majority of methods concerning the surface hardening processes should be considered as