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Non-Wear Effect on Composite Steel-Brass Surface

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The paper deals with the investigation on friction couples sharing one composite surface. The composite friction surface consists of steel 45 and electropulse sprayed brass Л63 coating segments. The investigation objective is to determine the extent of the influence of the ratio of steel to brass coatings areas on the selective transfer effect in this friction surface. In the analysis of the friction surface state the characteristics of the formation of the brass servovite film have been evaluated while varying the areas of steel and brass segments in the friction surface. The latter and the resulting brass film have been analyzed by optical microscope. In the composite surface with no less than 50 % of brass coating segments area the non-wear effect can be achieved. Under 0.6 MPa pressure and 0.72 m/s sliding speed, in a friction couple the servovite film forms in 10…15 minutes. This film reduces the surface roughness from *Ra* 0.60 μm to *Ra* 0.10 μm.

Keywords: sliding, friction couple, electropulse, spraying, copper, brass, composition surface.

INTRODUCTION

The wear of machine parts results in 85…90 % loss of machine efficiency [1]. Even 80 % of machine parts drop their workability due to the friction surface wear up to 0.2 mm [2]. For this reason the friction losses and minimization of wear intensity of functioning surfaces of machine parts is a basic consideration in a good engineering practice.

Sliding friction couples are made of different materials the majority of which, as a rule, are copper alloys- Бр.ОЦС 5-5-5, Бр.ОЦ 10-2, Л63 et al. Their efficiency depends on loads, temperature, lubrication methods and lubricating material properties (also on pollution). These friction couples are efficient when their loads do not exceed 15…25 MPa [3].

The tests have proved that in the range of parameters the coatings obtained by thermal spraying are more efficient than rolled and alloyed metals of analogous composition. The bronze bearings whose antifrictional bronze layer is sprayed can function 3 or 4 times longer than those with alloyed bronze [4]. The realization of a "non-wear effect" has markedly decreased friction in friction couples. In this case, in addition to the decreased surface wear a low coefficient of friction has been observed [1]. To achieve a "non-wear effect", however, certain conditions as treatment by special activating materials are required. Actually, this effect can be obtained with the presence of many vacancies on the friction surface.

Study [5] reflects recent research results in formation of a "non-wear effect" on friction surfaces. The authors have determined that when steel is functioning with electropulse sprayed brass Л63 (61.5…64.5 % Cu, 33…35 % Zn) coating the coefficient of friction is rather low – 0.004…0.006 and the wear of a shaft is unnoticeable. When starting the operation the coefficient of friction of the couples steel – brass, steel – copper is 0.012…0.019 i.e. normal for this type of materials. After some time, however, it falls down 3 times. Since the friction surfaces have not been specially treated a marked fall of the coefficient of friction occurs during the operation of the couple and the formation of a "non-wear effect" can be attributed to the vacancies on the surface.

Energy characteristics of electropulse spraying i.e. high overheating of the sprayed material make it possible to consider the bronze drops with the temperature exceeding the boiling to form the metal layer of 0.005…0.02 mm and cooling at $\sim 2 \times 10^7$ K/s rate when the drops touch the cold being coated surface [6]. Therefore, the layer crystallizes into a very small-grained almost amorphous structure with many vacancies.

In comparison with one-component surface the composite surfaces are more perspective [7].

Development of composite working surfaces and investigation of their efficiency are of great importance.

The goal of investigation is to determine the workability of sliding couples with partial (composite) brass friction surface obtained by means of electropulse spraying.

EXPERIMENTAL

Microscopic examination was made by optical microscope МИМ-8М.

The friction couple of steel – composite surface is made of 45 steel disks and blocks with electropulse sprayed brass coating. Prior to coating the blocks with nominal working surface of 1 cm^2, in their surfaces the pits removing some of steel surface from the friction surfaces contact – by 5 %, 20 %, 50 % and were pressed in by a hardometer ПМТ-3. Polishing the surface the pressed in deformed metal was removed and desirable impressions were attained. Further on in this paper, when describing the friction couples only the ratio of the block surface materials – steel/brass 95/5; 80/20 etc will be given. The block surface having been sprayed by brass coating, the regular surface with periodically repeating steel and brass

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segments was obtained. For comparison two surfaces – one with no coating (100/0) and the other with the entire coating (0/100) were used. The disks were made of steel 45 (7 mm thick and ∅ 60 mm), thermally treated up to 50 HRC and polished up to Rz = 4…5 μm.

The coatings were sprayed by the using electropulse spraying device. The voltage of its batteries is up to 5 kV, capacity – (0.4…2.4) 10^{-3} F, output energy – 5…30 kJ [5, 8]. Brass Л63 wire of ∅ 2.0 mm was used for spraying.

The wear was investigated by means of 1K62 lathe at 250 min^{-1} rotation frequency, which corresponds to mean 0.720 m/s sliding speed. In the device body 2 fastened in the lathe gripper (Fig. 1) a recess for fastening 4 disks was accurately turned. The load was subjected to the block by means of a rolling device having a clock dial head ИЧ 02 1 kl., ГОСТ 577-68. The load was calibrated by a standard dynamometer ДОСМ-1, ГОСТ 9500-75.

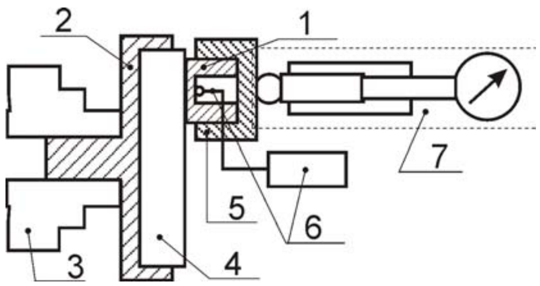


Fig. 1. Scheme of friction experiments: 1 – block; 2 – disk holder; 3 – gripper of the lathe; 4 – disk; 5 – block holder; 6 – microthermal couple with a recording system; 7 –rolling device

By applying the load of 60 N the pressure of 0.6 MPa was reached in a friction couple. The friction couple experiments were made periodically lubricating with PEMCO oil SN 350 ISO 68 L-AN every 5 minutes.

The reference investigation period was 30 min. The most efficient friction surfaces were examined up to 90 min.

Prior to spraying the blocks were treated by quartz sand. For microscopic examination the samples were polished by 3 μm diamond paste and exposed to 4 % phosphorous acid spirit solution.

Roughness of disks and blocks functioning surfaces was measured by means of surface analyzer – profilometer HOMMEL TESTER T500.

RESULTS AND ANALYSIS

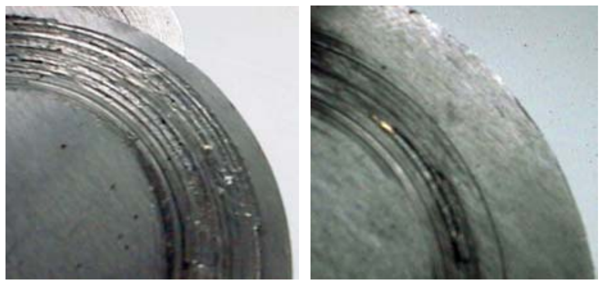
After the electropulse coating spray the microscopic analysis of friction surfaces indicated the structure of coatings to be dense. Due to markedly high fluidity and speed of overheated brass particles the coating perfectly filled the surface of the pits formed on the surface area (Fig. 2).

The boiling temperatures of alloy Л63 components are different: that of copper – 2590, zinc – 907 °C, and fusing temperature is 1083 and 419 °C, respectively. The sprayed wire contains 62.3 % copper, 37.5 % zinc, whereas in the coating there is 79.4 % copper and 18 % zinc because during the cooling process zinc intensively evaporates [8]. When the friction couple is working the quantity of zinc tends to drop.

When testing the wear of 100/0 blocks in the first minutes of the experiment the constant rise in temperature was observed. After 15…18 min tests there appeared on the disk deeper scratches – the traces of friction surfaces adhesion (Fig. 3). The sample started vibrating, the friction force increased so much that the disk used to overturn in the holder.

Fig. 2. Segment of brass coating on the friction surface (cross section)

When testing friction couple 95/5 the instrument was vibrating when the block engaged with the disk (during microwelding of surfaces) and the surfaces were being scratched (Fig. 3 b). The friction couples had been working for 22 minutes until they got stuck. Considering the above-mentioned couple visually, no servovite film was formed either on the brick or the disk.



a b

Fig. 3. Surfaces of the disks working with a – 100/0 and b – 95/5 blocks after the wear tests (2:1)

80/20 blocks were working all 30 minute test period. Actually, the temperature rise is similar to the cases of 100/0 and 95/5 blocks. After 10…15 minutes, however, the temperature rise slowed down. For 80/20 friction couple vibration originated at the end of the reference period (24 min), and sticking – 29 min. Both disks and blocks were scratched, whereas the brass segments in the block pits had altered – they acquired copper (reddish) colour. While grinding microroughness, Ra 0.60 μm of the disk surface decreased to Ra 0.48 μm and waviness appeared on the surface.

50/50 blocks had been working the whole test period of 30 minutes without any vibration. After 18…20 min the temperature of the samples got settled at about 333 K. The first 10 min the changes in the lubricant state were being observed – microparticles of brass colour sprang up. The lubricant acquired yellowish brown colour. After 10…15 minutes a reddish discontinuous trace used to appear on the disk friction track (Fig. 4).

After the tests the entire block surface used to acquire light reddish colour, it looked as if covered by a very thin transparent film. The test period with 50/50 blocks was prolonged to 90 min and during it the wear conditions remained the same. The temperature and vibration proved it.

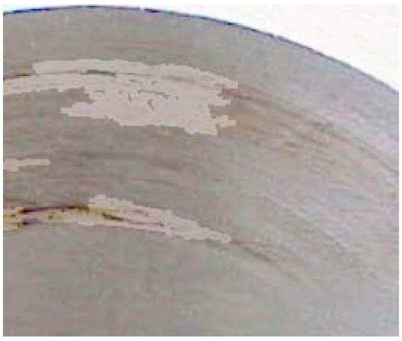


Fig. 4. Disk surface after the friction test with 50/50 block: light segments – copper coating (2:1)

The tests with 50/50 blocks were repeated applying different lubricating liquid (50 % glycerin and 50 % oil). In this case the color of the friction track was more intense. It was noticed, however, that having poured some drops of lubricating mixture in the first seconds the sample was vibrating. After 2…5 seconds vibration stopped and the reddish track got paler. After about 5 s the wear conditions got settled down and the track acquired the former reddish colour.

When the brass coating was sliding over the disk surface (0/100 block) the friction couple was working smoothly, the blocks surface was being coated by the brass layer which after 5…10 min got reddish – the disk friction surface got coated by a thin copper layer (Fig. 5).

Fig. 5. Disk surface after wear test with 0/100 samples: light segments – copper coating (2:1)

In order to investigate additionally the efficiency of the coating created on the block during the friction period, the blocks were manufactured whose one half of the working area was covered by the entire brass coating, while the other – by steel. During the testing a copper film formed on the disk from the brass coating and that copper film formed the film segments even on the part of the block never covered by brass (Fig. 6, zone b).

The tests of the glycerin – oil mixture haven been repeated, the analogous situation of 50/50 blocks recurred. The track colour on the disk was of a deeper copper shade. These glycerin – oil mixture tests suggest the conclusion that the greater quantity of an activating material in the lubricant accelerates the process of the surface treatment stage. When the surfaces had been treated, conventional oil can perfectly maintain the tribological environment.

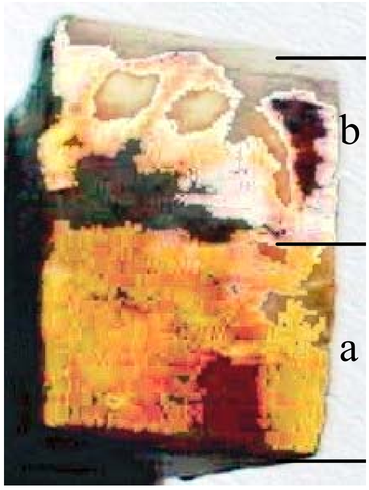


Fig. 6. Block whose one half of the functioning surface was covered by the entire (100 %) brass Л63 coating (zone a), the other half is not coated i.e. steel (zone b) after friction tests. In zone b the segments of copper colour film are seen (5:1)

To our mind, the created copper colour coating is a servovite film covering the surfaces at the presence of the non-wear effect.

The measurements of block temperatures indicated that at the initial stage of work the temperature was intensively rising to 320…325 K. Later the temperature got settled and its further change depended on the version of a friction couple. When the block was working with a minimal quantity of brass (95/5) the rise of the temperature was the fastest about 0.55 K/s speed (Fig. 7), later it fell down to 0.029 K/s and when 350 K was reached sticking commenced.

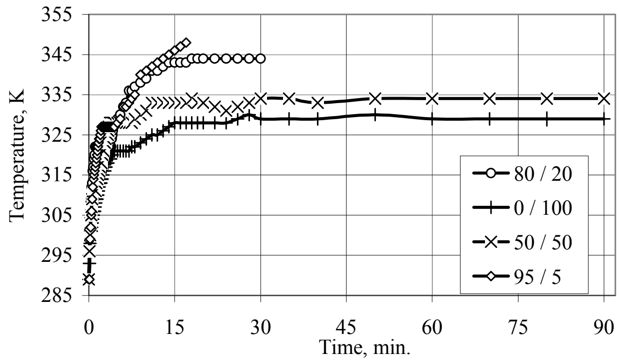


Fig. 7. The temperature change of a sample (2 mm depth from the sample rubbing surface) during friction

The microscopic analysis of friction surfaces and roughness measurements indicated that the created copper colour film is considerably smoother than the initial surface of both the disk and the block (Fig. 8).

Heating of 80/20 couples was intensive in the first minute of work – 0.55 K/s, soon it slowed down to 0.036 K/s and settled at 344 K. After 30 min sticking appeared and the tests were stopped.

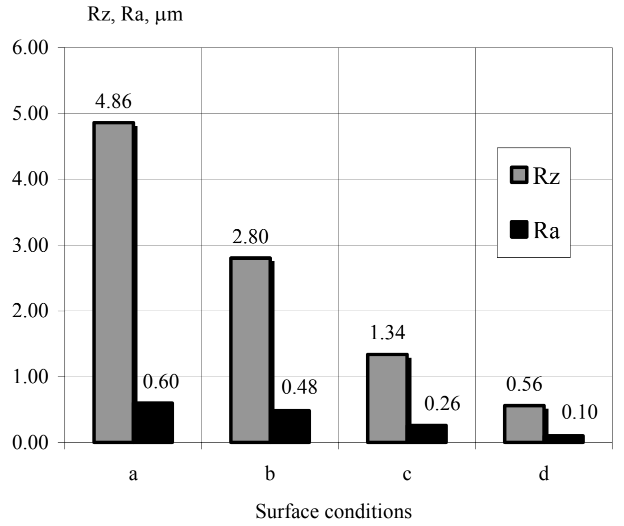


Fig. 8. Disk surface roughness dependence on block surface conditions: a – disk before experiment; b – friction couple with block 80/20; c – with block 0/100; d – servovite copper film

The temperature of 50/50 and 0/100 friction couples was considerably rising in the first minute of work. In 4…15 minutes of work there was only 0.018 K/s. In the 15th minute of work 50/50 block was heated to 333 K. When the testing was prolonged to 90 min, the slight fall of the temperature was observed. This fact and the results of both surfaces microscopic analysis and roughness measurements allow to state that the brass coating in a block composite surface occupies no less than 50 % of the area, there is a possibility to realize a "non-wear effect" in a friction couple and that a servovite film is created on the friction surfaces.

CONCLUSIONS

The investigation has indicated that:

1. "Non-wear effect" can be realized in sliding friction couples with composite surfaces when the sprayed brass coating covers no less than 50 % of the nominal area.
2. Roughness of the disk surface after tests is inversely proportional to the quantity of the brass coating on the block.

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