ISSN 1392-1134/ eISSN 2345-0371
Agricultural Engineering, Research Papers, 2015, Vol. 47, 1-5 p.

THE WEAR RESISTANCE OF ELECTROSPARK COATINGS ON STEEL C45 WHEN OPERATING WITH COUNTERBODIES OF DIFFERENT STEELS

V. Agafii*, J. Padgurskas**, V. Mihailov*, A. Andriušis**, R. Kreivaitis**, N. Kazak*
*Institute of Applied Physics, Moldova Academy of Sciences, Chisinau, Republic of Moldova
**Aleksandras Stulginskis University, Academy, Kaunas, Lithuania

In this work the tribological properties of coatings molybdenum, chromium, and stellite B3K obtained by electrospark alloying method on 45steel were studied. Tests data with rollers made of steel C45 HRC 50-52 and steel 30CrMnSiA HRC 38-42 showed, that molybdenum coatings were the most wear resistant. Tests with rollers made of steel 30Cr13 HRC 43-45 showed that wear resistant of chromium coatings was highest. During the work with rollers made of steel C45 and steel 30CrMnSiA, the molybdenum coatings were the most antifriction ones - at the beginning friction coefficient was f = 0.12-0.11, and at the end f = 0.04-0.034. The friction couple that was determined to be the most wear resistant was a block of steel C45 with a chromium coating and roller made of steel 30Cr13 (wear was U_{block} = 0.4 mg and U_{roller} = 10.8 mg).
Keywords: wear, electrospark coating, coefficient of friction, roughness, microhardness

Received 2015-10-23, accepted 2015-12-16

INTRODUCTION

One promising technique that is used for the surface strengthening of metals is the electrospark alloying (ESA). It has a number of advantages compared to such traditional methods of strengthening as metallic coating, deposition welding, plasma sputtering, etc. These advantages include high adhesion of the coated material to the substrate, the absence of heating of the workpieces during their treatment, as well as the simplicity of the equipment used to realize the process [1-3].

In papers [4, 5] to enhance the tribological properties of ESA molybdenum coatings and the coatings obtained using electrodes of Cu-Mo and Cu-Ti was further processed by laser after. To increase the mechanical properties of the steel, surface was ligated with the alloy WC-0.8Co [6], with materials WC-Co-Al_2O_3 [7], with WC-Cu [8] and the alloy Ti_6Al_4V [9]. The wear resistance of the steel was modified using electrodes made of molybdenum, chromium, hard alloy 15TiC6Co and of bronze [10-11]. In this paper the further reinforcement of the tribological properties of the C45 steel is presented. For this purpose as electrodes (anodes) were used sticks of pure molybdenum, chromium, and cobalt alloy - B3K Stellite (GOST, Cobalt based hard alloy). Three types of rollers made from three different steels were used as counter body. Aim of research was, find a pair of friction with optimal tribological properties.

EXPERIMENTAL

Steel C45 samples (blocks) were tested for friction and wear resistance with molybdenum, chromium and B3K-Stellite coatings deposited applying the regular electrospark method. The samples were coated with 3 layers of one and the same material in the modes of 3-4-3 using an EFI-10M device. All coatings were tested for friction and wear resistance using the rollers shape counter body (35-mm in diameter) of three types: steel C45 (HRC 50-52), steel 30CrMnSiA (HRC 38-42) and steel 30Cr13 HRC (43-45) in order to determine the optimal friction and wear couples. The principal schema of tribotests presented in picture 1.

Steel C45 rollers were quenched in water after being heated in the electric furnace at 850^0C. Then, a low-temperature tempering (at 190^0C) and cooling in air for 1 hour was performed. The counterbodies (rollers) made of steel 30CrMnSiA were quenched in an industrial I-20A oil after being heated at 880^0C. Then the rollers were exposed to a medium-tempering by heating for 1 h at 300^0C followed by water cooling. Steel 30Cr13 rollers were heated in the electrical furnace for 14 min at 850^0C followed by cooling in the industrial oil. The low-temperature tempering was carried out by heating for 1 h at 200^0C accompanied by a relevant air cooling.

The friction and wear tests of all coatings were performed at a load of 900 N in a transmission gear oil 80W-90. Rotating speed was 600 rpm. Basic distance of rubbing was taken to be 30000 m. Testing start load was 100 N, being increased by 100 N each minute, for reaching the working load of 900 N.

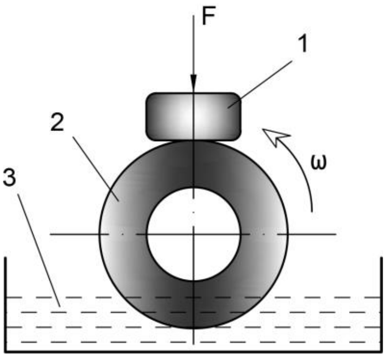

Fig. 1. Principal schema of tribotests: 1 – block with ESA coating; 2 – roller; 3 – lubricating oil; F- loading force.

The wear of the test samples was measured by weighing with an electronic balance with the accuracy of 0.1 mg. During the friction and wear testing, the friction coefficient and the distance covered by the friction couple were registered in a computer all the time. After the wear tests, the friction surfaces of the blocks and rollers were profilographed using a Mahr GmbH·Gottigen profilometer with MarSurf GD 25 roughness drive unit. Microstructure images were made using a NICON ECLIPSE MA-100 optical microscope, and microhardness was measured by a Vickers microhardness tester PMT-3.

RESULTS AND DISCUSSION

Figure 2 shows the average results of the wear of the blocks alloyed with different materials and that of steel C45 counter body rollers, which worked with those blocks. It is seen that the wear of the blocks surfaces alloyed with molybdenum (U_{Mo} = 0.65 mg) was the least of all, and the wear of the samples alloyed with stellite B3K (U_{B3K} = 1.5 mg) was the highest. The wear of chromium coatings was less by 23% than that of B3K Stellite coatings. The wear of the coatless steel C45 samples was three times as high (U_{st45} = 2 mg) as that of molybdenum alloyed samples.

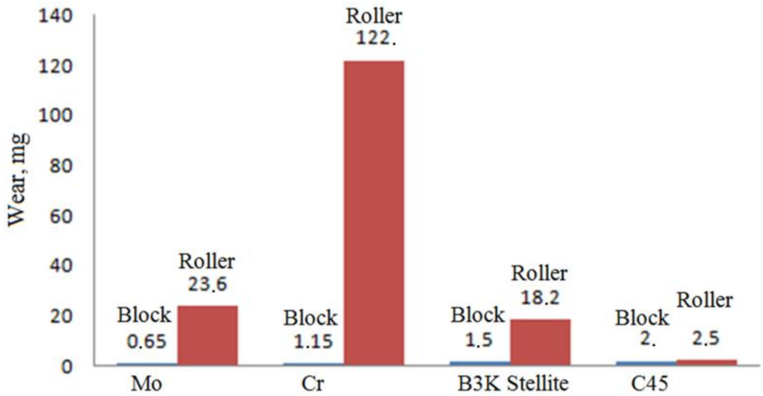

Fig. 2. The wear of steel C45 blocks alloyed with different materials and steel C45 rollers without a coating.

The wear resistance results of C45 steel rollers that worked with the blocks alloyed with various materials showed that the rollers that worked with the B3K Stellite coatings exceed by more than 6 times the wear resistance of the rollers that worked with chromium coatings, and by 22.5% the rollers that worked with molybdenum coatings. In order to see the effect of the coatings' microhardness on the wear of the rollers it is necessary to see the data of Table 1, which shows the microhardness values of all coatings.

Table 1. Microhardness of the electrospark coatings (the initial state, H_{50}, MPa)

Type of microhardness	Molybdenum coating	Stellite B3K coating	Chromium coating	Steel 45 without a coating

The average microhardness	8722	5272	5596	2597
The minimum microhardness	7468	2901	4145	-
The maximum microhardness	10849	8007	8477	-

Table 1 shows that the molybdenum coatings had the highest microhardness with respect to all types of microhardness, i.e., average, minimal, and maximal and, therefore, the wear of those coatings was the least of all.

Table 2 lists the average data on the roughness of the coatings and rollers prior to and after the tribological tests. After a thorough study of Table 2, it can be seen that molybdenum coatings had the lowest roughness (R_a = 1.66 μm) of all the coatings, and chromium coatings had by 1.84 times higher roughness than the molybdenum coatings. That is obviously why the chromium coatings were so much worn by the hardened steel 45 rollers (U_{roller} = 122 mg).

Table 2. Variation in the roughness parameters (R_a, R_z, and R_{max}) of the electrospark coatings and rollers prior to and after the tribological tests.

№ п/п	The material of the coatings and of rollers	The initial roughness of the coatings and of rollers, μm			The roughness of the coatings and of rollers after tribological tests, μm		
		R_a	R_z	R_{max}	R_a	R_z	R_{max}
1.	Molybdenum coating	1.66	9.16	12.04	0.72	4.6	6.22
2.	Steel 45 roller	0.093	0.74	0.81	0.48	2.84	4.02
3.	Stellite B3K coating	3.11	16.12	26.39	0.26	2.23	4.61
4.	Steel 45 roller	0.093	0.74	0.81	0.22	1.34	1.81
5.	Chromium coating	3.05	14.89	21.38	1.51	8.44	9.78
6.	Steel 45 roller	0.093	0.74	0.81	0.55	3.14	5.27
7.	Steel 45 without a coating	0.25	3.19	5.63	0.09	1.27	1.7
8.	Steel 45 roller	0.093	0.74	0.81	0.15	1.51	3.18
9.	Molybdenum coating	1.65	8.91	10.68	0.46	3.62	5.54
10.	Steel 30CrMnSiA roller	0.15	1.26	1.55	0.50	3.2	4.07
11.	Stellite B3K coating	3.42	18.29	26.36	1.79	10.35	15.61
12.	Steel 30CrMnSiA roller	0.15	1.26	1.55	0.68	4.7	6.0
13.	Chromium coating	3.97	17.99	27.97	0.72	6.21	7.72
14.	Steel 30CrMnSiA roller	0.15	1.26	1.55	0.85	6.0	8.84
15.	Steel 45 without a coating	0.16	1.36	3.19	0.19	2.39	4.25
16.	Steel 30CrMnSiA roller	0.15	1.26	1.55	0.12	1.22	2.03
17.	Molybdenum coating	1.94	9.3	10.97	0.63	4.34	5.83
18.	Steel 30Cr13 roller	0.11	0.90	1.06	0.49	2.73	3.36
19.	Stellite B3K coating	3.54	18.22	26.32	1.72	9.16	15.55
20.	Steel 30Cr13 roller	0.11	0.90	1.06	0.61	3.12	5.26
21.	Chromium coating	3.18	16.07	20.63	1.43	8.78	11.91
22.	Steel 30Cr13 roller	0.11	0.90	1.06	0.63	3.17	4.41
23.	Steel 45 without a coating	0.13	1.15	1.35	0.1	1.63	2.54
24.	Steel 30Cr13 roller	0.11	0.90	1.06	0.16	1.19	1.37

Figure 3 shows a diagram that is based on the average results of the wear of the blocks alloyed with various materials and 30CrMnSiA steel rollers that worked with those samples. It is noteworthy that the molybdenum coatings again turned out to be the most highly wear resistant (U_{Mo} = 0.6 mg), and the worst results were shown by the chromium coatings (U_{Cr} = 1.2 mg). B3K Stellite coatings worked almost twice as better with 30CrMnSiA steel rollers than with steel C45 rollers. We suppose that the hardness of 30CrMnSiA steel rollers is by 10-12 units lower than that of steel C45 rollers.

Comparing the average wear of 30CrMnSiA steel rollers which worked with various coatings, it is seen that chromium coatings as well were wearing the rollers more than all the rest of the coatings did. Still, the wear of 30CrMnSiA steel rollers against chromium coatings was two times less than the wear of steel C45 rollers. This shows that chromium coatings are more compatible with 30XGCA steel during their rubbing in oil, than with steel C45. However, even though B3K Stellite coatings were worn by 43% less than during the work with steel C45 rollers, they heavily wore out 30CrMnSiA steel rollers, which can again be attributed to the lesser hardness of 30CrMnSiA steel rollers compared to steel C45 rollers.

Studying the diagram (Fig. 4) of the average results of the wear of coatings and rollers from steel 30Cr13, we can note that all the three coatings worked fairly well with these rollers. However, chromium coatings worked best of all (U_{Cr} = 0.4 mg). The wear of the electrospark coatings increases in the direction of Cr → Mo → B3K.

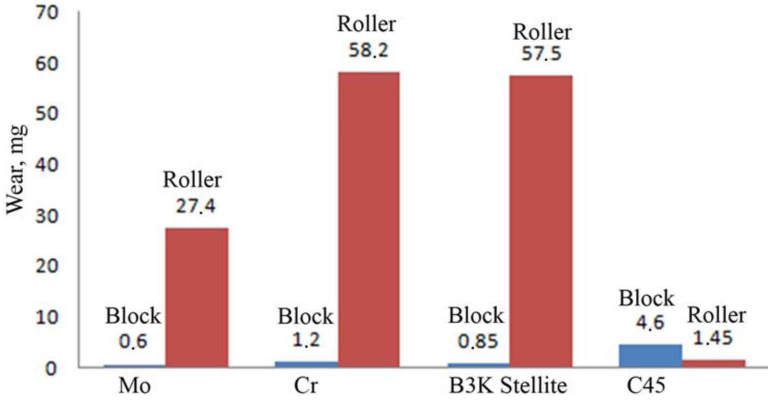

Fig. 3. The wear of steel C45 blocks alloyed with different materials, and 30CrMnSiA steel rollers without coatings.

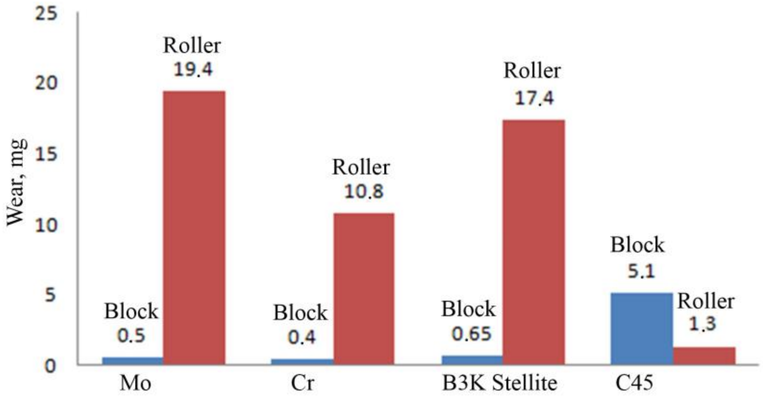

Fig. 4. The wear of steel C45 blocks alloyed with different materials, and 30Cr13 steel rollers without coatings

All friction couples that were formed of alloyed blocks and rollers from steel 30Cr13 exhibited a higher wear resistance compared to that at friction of electrospark coatings with rollers from steel C45 and steel 30CrMnSiA. The wear of the rollers decreased substantially. Particularly, the wear of steel 30Cr13 rollers was reduced in comparison with that of steel 30CrMnSiA rollers during the work with chromium coatings, more than by 5 times, and with B3K Stellite coatings by 3.3 times. It was only during the work with molybdenum coatings that the wear of the rollers decreased insignificantly, just by 21%. The wear of the rollers increases in the direction of steel C45 → Cr → B3K → Mo. It is also noteworthy that chromium coatings displayed the highest wear resistance of all coatings explicitly during the work in couples with steel 30Cr13 rollers. Generally in this work, the most optimal friction couple of all tested ones (with electrospark coatings applied) is that consisting of the blocks coated with chromium and the roller made of steel 30Cr13 (see Figs. 2, 3, 4).

Thus, the results presented in Fig. 3 prove that the coatings under consideration work best of all with steel 30Cr13 rollers, i.e. they form the most appropriate friction couples for the work in a transmission gear oil 80W-90 at a load of 900 N. Obviously, this is because these coatings are more compatible at friction with the rollers of steel 30Ch13 [12].

CONCLUSIONS

1. During the work with rollers made of steel C45 HRC 50-52 and steel 30CrMnSiA HRC 38-42, the molybdenum coating was the most wear resistant.

2. Tests of the coatings with rollers made of steel 30Cr13 HRC 43-45 showed that the chromium coatings were more wear resistant.

3. During the work with rollers made of steel C45 and steel 30CrMnSiA, the molybdenum coating was the most antifriction ones (at the beginning friction coefficient was f = 0.12-0.11 and at the end (f = 0.04-0.034).

4. The friction couple that was determined to be the most wear resistant was a block (steel C45) with a chromium coating and roller made of steel 30Cr13 (wear U_{block} = 0.4 mg and U_{roller} = 10.8 mg).

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Acknowlwgement

This work was supported in part of the Academy of Sciences of Moldova (Pr. No 11.817.05.05A) and FP7 program IRSES Project **—** “Oil and Sugar” (GA -2011-295202).

Author for contacts:
Dr. Vasile Agafii, Institute of Applied Physics, ASM, Chisinau, MD-2028, Academiei 5, Moldova,
Phone: +373 60071055, E-mail: vasile.agafii@mail.ru
Prof. Juozas Padgurskas
Aleksandras Stulginskis University, Akademija, Kauno r., Lithuania.
Phone: +370 37 752263, E-mail: juozas.padgurskas@asu.lt