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INCREASE OF WEAR RESISTANCE OF Cr18Ni10Ti STAINLESS STEEL BY METHOD OF ELECTRIC-SPARK ALLOYING WITH ELECTRODES OF REFRACTORY METALS AND GRAPHITE

V. Agafii, V. Mihailov[1], N. Kazak, G. Volodina, C. Cracan
Laboratory of Electrophysical and Electrochemical Methods of Material Treatment,
Laboratory of Physical Methods of Solid State Investigation,
Institute of Applied Physics, Academy of Sciences of Moldova, Chisinau, Moldova

Abstract. The article presents the results of wear testing of stainless steel Cr18Ni10Ti treated with electrodes made of refractory metals and graphite by the method of electric-spark alloying. It was established that all electrospark coatings had a higher wear resistance than the Cr18Ni10Ti uncoated steel. Wear resistance of coatings was increased in the direction→ Mo + Graphite→Ti + Ni→ W + Graphite →Ti + Al + Graphite. X-ray diffraction analysis showed that molybdenum, tungsten, titanium carbides and other solid materials such as titanium nitride and nickel-titanium intermetallide are formed on the doped steel surfaces, which increased microhardness from 4.9 to 8 times and wear resistance from 1.63 to 29 times.

Keywords: electric-spark alloying, stainless steel Cr18Ni10Ti, coatings, wear, wear resistance, microhardness.

1. INTRODUCTION

At the enterprises of food, medical, chemical and other industries, the parts of machines and mechanisms operating in corrosive environments are made of stainless steels, in particular, from austenitic steels Cr18Ni10Ti, 12Cr18Ni10Ti, which have high corrosion resistance. At the same time, these steel works poorly under friction [1] and for this reason can not be used in friction nodes without their additional surface hardening. In connection with this, the formation of surface layers with high tribological characteristics on these steels is an urgent task.

One of the promising methods of surface hardening of metals is electric-spark alloying (ESA) [2], which has a number of advantages in comparison with traditional methods of hardening by metallization, surfacing, plasma spraying, etc. Among these advantages, we note the high adhesion of the applied material to the substrate, no heating of parts during processing, as well as the simplicity of the equipment and process technology.

Literature search showed that in a number of works [3–6], authors used chromium carbides, titanium nitride, amorphous materials to increase the wear resistance of stainless steels, but the maximum coating thickness barely reached 30 μm, which did not provide sufficient service life of parts hardened in this way.

Taking into account the above, the task was set to develop, based on ESA, the technology of applying wear-resistant coatings on friction units made of stainless steels Cr18Ni10Ti and 12Cr18Ni10Ti, which ensure a high service life.

[1]Author for contacts: Valentin Mihailov.
E–mail: valentin.mihailov@gmail.com

2. EXPERIMENTAL

Investigation of the process of formation of wear-resistant coatings on stainless steels was carried out at industrial plants EFI-10M, ELITRON-22V and a number of experimental ones with the possibility of variation by power parameters in a wide range of energy values of electric pulses. Several types of newest applicators with vibrating and rotating electrodes were used to realize the hardening process.

As electrodes for ESA, rods of 40 mm in length and 4 mm in diameter made of molybdenum, titanium, tungsten, nickel, aluminum and graphite were used, and as a substrate, square-shaped samples of stainless steels of 20×20×4 mm were used, which were processed in processing regimes. To study the tribological characteristics, samples of a special shape were used from the same materials as for the testing of the ESA process.

The process was carried out according to the scheme: W + Graphite, Ti + Graphite, Mo + Graphite, Ti + Al + Graphite, Ti + Ni, i.e. by successively applying first the transition metal from those chosen, and then the graphite electrode. Such a treatment scheme allowed us, in our opinion, to provide a much more effective interaction of the previously deposited metal with the carbon of the graphite electrode under the influence of the plasma of a pulsed discharge.

Preliminary results showed that layers of good quality with a thickness of ~ 0.04–0.055 mm and a continuity of ~ 98% were obtained at an energy of electrical pulses in the range 0.3–1.0 J and pulse repetition frequency 250 Hz with complex motion of the processing electrode: rotation + vibration.

To assess the wear resistance of coatings obtained on steel Cr18Ni10Ti at ESA, the specified materials were tested on a friction machine of reciprocating type with an average sliding speed of the mobile sample 0.0675 m/s [7]. Lubricating oil was Vaseline oil. The counterbody was rectangular 3×25×30 mm samples from hardened steel 45 (HRC 58). The contact of the counterbody with the test surface was carried out with an area of nine mm^2 so that the counterbody was perpendicular to this surface. The testing was carried out in two stages. In the first stage, the counterbody and the test surface of the coating were run-in. It was conducted for ten hours of testing with a varying load of 19.6 to 88.2 N. In this case, run-in at the initial and final loads was carried out for two hours, and for intermediate loads - for an hour. At the second stage, test tests were performed at a load of 88.2 H for 20 hours.

The wear was determined on analytical scales with an accuracy of 0.1 mg. This article presents the results of wear measurements of five types of friction contacts: 45 steel / Cr18Ni10Ti, 45 steel / Cr18Ni10Ti + Mo + Graphite, 45 steel / Cr18Ni10Ti + W + Graphite, 45 steel / Cr18Ni10Ti +Ti + Ni and 45 steel / Cr18Ni10Ti + Ti + Al + Graphite.

The microhardness was determined on a PMT–3 microhardnesser with an indentor load of 0.49 N. The diffraction spectra of the surfaces of stainless steel samples after ESA were obtained on an X-ray diffractometer DRON-UM1-Fek_α radiation, Mn filter, $\theta/2\theta$ method. X-ray phase analysis was performed using the ASTM card file.

3. RESULTS AND DISCUSSION

Measurement of microhardness of surface layers of stainless steel Cr18Ni10Ti, subjected ESA by the mentioned materials showed its significant increase. The highest value of microhardness was achieved with a sequential ESA first with titanium, then with aluminum and graphite (Table 1). From a comparison of the microhardness values of all coatings, it can be seen that the minimum microhardness increases from 1.1 times to 3.36 times, and the average microhardness is 2.6 times to 4.94 times and the maximum microhardness is from 4.45 times to 7.56 times.

Analysis of the results of microhardness measurements of coatings also showed that their values are not the same over the entire length of the sample (Table 1), i.e. there is a wide spread between the maximum and minimum microhardness. It can be seen from Table 1 that the microhardness of coatings grows in the direction from (Mo + Graphite)→ (Ni + Ti)→ (W + Graphite) → (Ti + Al + Graphite).

Table 1. Initial microhardness of H_{μ} electrospark coatings obtained on steel Cr18Ni10Ti.

Nr/or	Coating material	Microhardness at a load of 0.49 N, MPa		
		Minimum microhardness	Average microhardness	Maximum microhardness
1.	Ti + Al + Graphite	10643	15641	23941
2.	W + Graphite	7664	9780	14896
3.	Ti + Ni	4430	9290	14092
4.	Mo + Graphite	3940	8222	14092
5.	Cr18Ni10Ti	3165	3165	3165

The figure shows the wear of the coatings after 30 hours of tribological testing, which consists of the amount of wear after 10 hours of run-in and wear after 20 hours of testing at a load of 88.2 N. As can be seen from the figure, all coatings improved the wear resistance of stainless steel from 1.63 to 29 times. It should be noted that the coating of Ti + Al + Graphite possessed the highest wear resistance in comparison with other coatings, and the lowest wear resistance is a coating of molybdenum. Wear of coatings correlates with the average microhardness of coatings, the greater the average microhardness, the less wear and vice versa, the smaller the average microhardness, the greater the wear.

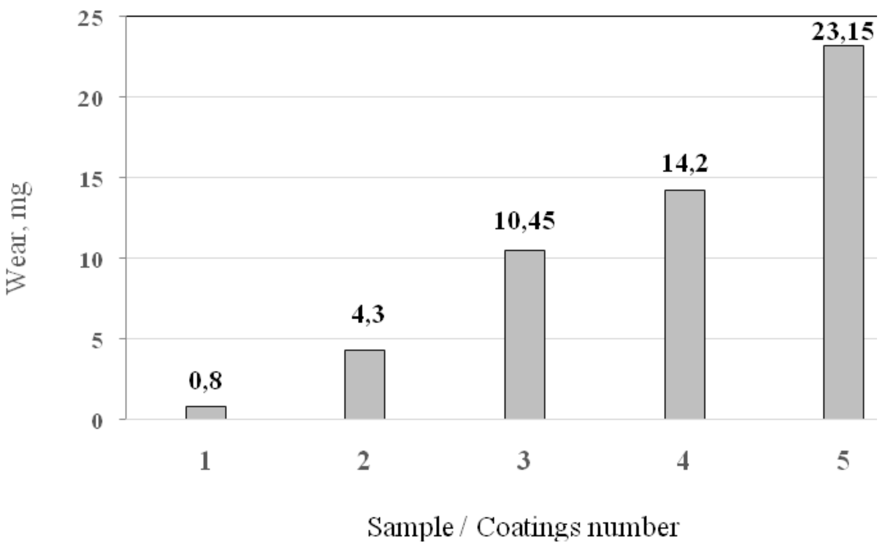

Figure 1. The total wear of the coatings after run-in (10 hours) and twenty hours of tribological testing of coatings at a load of 88.2 N (Coatings: 1 – Ti + Al + Graphite; 2 – W + Graphite; 3 – Ti + Ni; 4 – Mo + Graphite; 5 – Cr18Ni10Ti).

Table 2 shows the possible phases that can be formed during electric-spark alloying of surfaces made of Cr18Ni10Ti steel. It can be seen from Table 2 that the most solid structures such as titanium nitride (TiN) and titanium carbide (TiC) are formed when alloying Ti, Al and graphite stainless steel, which gives the surface layers after ESA the largest microhardness of the surface to 15641 MPa.

In our opinion, this contributed to the greatest increase in wear resistance of Cr18Ni10Ti steel. When alloying with other materials (Mo + Graphite) and (W + Graphite), molybdenum and tungsten carbides are formed on the surface, respectively. Moreover, when the surface is treated sequentially with nickel and titanium, solid intermetallides TiNi and NiTi are formed, which contribute to the increase of hardness.

Table 2. The phases that formed during the electric-spark alloying of Cr18Ni10Ti steel.

Nr/or	Coatings composition	Phases composition
1.	Mo, Graphite	α-Fe; γ-Fe; Graphite, χ-Fe_2C; (Fe_2MoC).
2.	W, Graphite	α-Fe; γ-Fe; Fe_3N; Fe_4N; $(Fe, Cr, W)_2C_6 \approx$ [Cr,-Fe-(W, Mo)]-C.
3.	Ti + Ni	α-Fe; γ-Fe; $\cong$ (FeNi); TiNi; FeTi; (Ni,Ti).
4.	Ti, Al, Graphite	α-Fe; γ-Fe; TiN; Fe_5C_2 or χ-Fe_2C; Fe_3Al or AlFe; (Ni_3(Al, Ti) C); FeTi.
5.	Stainless steel Cr18Ni10Ti	α-Fe; γ-Fe.

It should be noted one interesting point that X-rays appear nitride phase TiN, although there is no nitrogen in the processing electrodes. This is explained by the fact that ESA is produced in air, in which, as is known 78% of nitrogen is contained. Thus, in the process of the formation between the electrodes of electric impulse discharges, in the channel of which high temperatures of ~ 10^4 degree Celsius and pressure develop. Under these conditions, favorable conditions are created for the interaction of electrode materials with the cathode material and environmental elements [2].

CONCLUSIONS

1. The process of synthesis of carbide phases in the surface layers of austenitic steel Cr18Ni10Ti in the course of electric-spark alloying with graphite and transition metal electrodes: Ti, Mo, Ni and W has been developed.

2. Electrospark hardening with carbide phases allows increasing the wear resistance of stainless steel more than 20 times.

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