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DEVELOPMENT OF TECHNOLOGIES AND MATERIALS FOR ELECTROSPARK COATING WITH THE AIM OF INCREASING THE SERVICE LIFE AND RELIABILITY OF PARTS OF TECHNOLOGICAL AND POWER EQUIPMENT AND TOOLS

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It was established that the technology of electrospark alloying is a promising method of strengthening and restoration of parts of technological and power equipment: shafts of pumps and electric motors, impellers, pump casings, centrifuges, etc. To increase the efficiency of the proposed technology, a number of electrode materials were created, such as FeNiSi–Cr_3C_5, WC–TiC–Mo_2C–Co–Cr and WC–TiC–Co–Cr–Ni–Al, TiC–(Fe–Cr–Si–Al), NiCrBCuC–WC, FeNiCrBSiC–TiB_2 and FeNiCrBSiC–CrB_2, which were tested at industrial enterprises of Ukraine. It was revealed that application of the developed electrodes provides a simultaneous increase in the manufacturability of the process of electrospark alloying with an extension of the life of parts of technological equipment by 2.0–2.5 times. 10 Ref., 4 Figures.

Keywords: *electrospark hardening, coating, wear resistance, self-fluxing alloy, titanium diboride*

Wearing of friction unit parts is one of the main reasons of reduction of operating life of machines and mechanisms. Up to 85 % of defects and damage of machines and production equipment are caused by intensive wear of the surface layer of parts, which is the most exposed to the environment and contact loads at friction [1]. Premature failure of machines and mechanisms as a result of wear can lead to major man-made disasters in a number of cases. For instance, erosion-corrosion wear of technological equipment of the main pipelines and enterprises of petroleum-processing industry results in large-scale leakages of petroleum products that pose a threat to human life and health [2]. Therefore, increase of the reliability and fatigue life of parts of machines and mechanisms is an urgent scientific task, whose solution is inextricably linked with increase of wear resistance of working surfaces of critical parts of machines and mechanisms.

Project P8.1 «Development of technologies and materials for electrospark coating deposition with the aim of increasing the service life and reliability of parts of technological and power equipment and tools» that was fulfilled during 2016–2020 within the target integrated research program «Reliability and fatigue life of materials, structures, equipment and constructions» (Resurs-2) of the NAS of Ukraine, aimed at extending the operating life of parts of production equipment and tools by restoration/improvement of wear resistance of their working surfaces by the method of electrospark alloying (ESA). The method has the following main advantages: possibility of local application of coatings from any current-conducting materials; high strength of adhesion of the alloyed layer with the base material; simplicity of conducting the process; its low power consumption and low equipment cost. The disadvantages of this method are its relatively low productivity, which can be increased by applying new electrode materials and modern technological equipment.

Pure metals (Mo, Cr), metal alloys (Fe–Cr, Fe–C, Ni–Cr, Ni–Mo), graphite (EG-2, EG-4) and hard alloys (WC–Co and WC–TiC–Co) are traditionally used for ESA [3]. When using electrodes from pure metals and metal alloys, it is not possible to produce coatings with the required high service properties. Therefore, electrospark coatings from hard alloys based on tungsten carbide are the most widely used for wear-resistant coating deposition in the industrial enterprises. They, however, do not always meet the requirements of manufacturability of ESA coatings in view of their high erosion resistance and low mass-transfer coefficient, respectively, and because of tungsten deficit it becomes necessary to develop tungsten-free ESA coatings. Therefore, at present development of the technology of electrospark coating deposition is related to development of tungsten-free composite electrode materials of «refractory compound–metal alloy system» [4].

Frantsevich Institute for Problems of Material Science (IPMS) developed a number of electrode

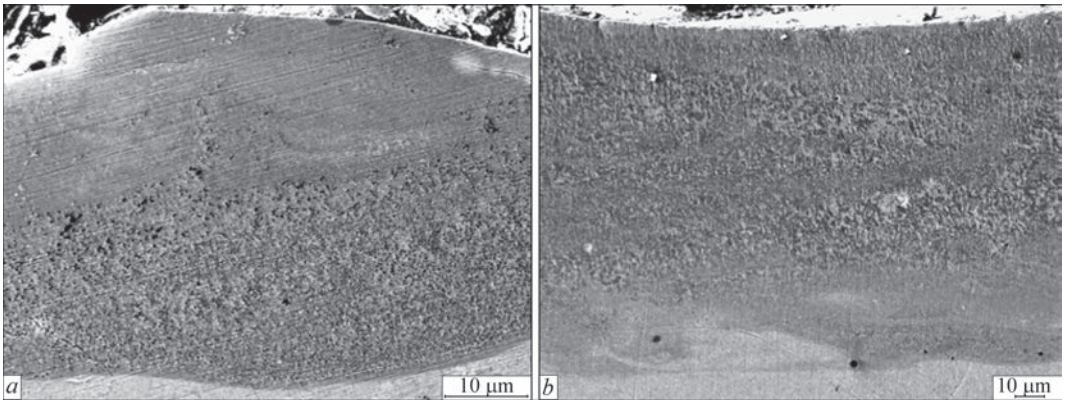

Figure 1. Structure of ESA coatings from developed FTB20 (*a*) and FCB20 (*b*) electrodes

composite materials based on carbides/borides of titanium, molybdenum, chromium and tungsten and batch-produced self-fluxing alloys: FeNiSi–Cr_3C_2, WC–TiC–Mo_2C–Co–Cr and WC–TiC–Co–Cr–Ni–Al, TiC–(Fe–Cr–Si–Al), NiCrBCuC–WC, FeNiCrSiC–TiB_2 and Fe–NiCrBSiC–CrB_2 [5–10]. Within the framework of project P8.1 investigations of mass transfer kinetics at electrospark alloying of steel 45 were conducted to reveal the optimum compositions of the developed electrodes from the view point of ensuring the adaptability-to-manufacture of the processes of electrospark strengthening/restoration of working surfaces of parts. Features of formation of the structure and relief of the surface of ESA coatings from the developed electrode materials were studied, depending on the ratio of the refractory and metal components of the electrodes, and their wear resistance was determined under the conditions of dry sliding friction and abrasive wear.

It was established, in particular, that ESA coatings based on batch-produced self-fluxing FeNiCrBSiC alloy with additives of 20 % TiB_2 (FTB20) and 20 % CrB_2 (FCB20) are formed by melting the electrode metal component with simultaneous breaking and fragmentation of inclusions of borides and carboborides of chromium with subsequent precipitation of electrode particles and their transfer to the surface of the cathode (steel), where they are welded to the surface as a result of micrometallurgical processes. Here, there is no mixing of the material of the electrode and the steel substrate. Nanostructured ESA coatings form on the steel surface as a result of refinement of titanium/chromium borides and carboborides from 20–30 µm to dimensions smaller than 1 µm (Figure 1). Surface of ESA coatings from FeNiCrBSiC–20 % TiB_2 and FeNiCrBSiC–20 % CrB_2 has a uniform relief over the entire surface of the samples. Under the conditions unlubricated sliding friction, ESA-coatings from developed electrode materials FTB20 and FCB20 have 2–3 times higher wear resistance, compared to coatings from batch-produced WC–6 % Co electrodes (Figure 2) [10].

Results of the work were used to develop TUU 25.9-05416930-049-014:2019 specification «FeNiCrSiC–TiB_2 electrodes for electrospark strengthening of parts for tribotechnical applications». Experimental production trials at UC «Kyiv Metropoliten» showed that deposition of electrospark coatings from the developed electrospark material FTB20 on working surfaces of gear–shaft L-20877A of LT-2 type escalator provides 2.0–2.5 times extension of its operating life (150–160 thou km) (Test report of 12.04.2019).

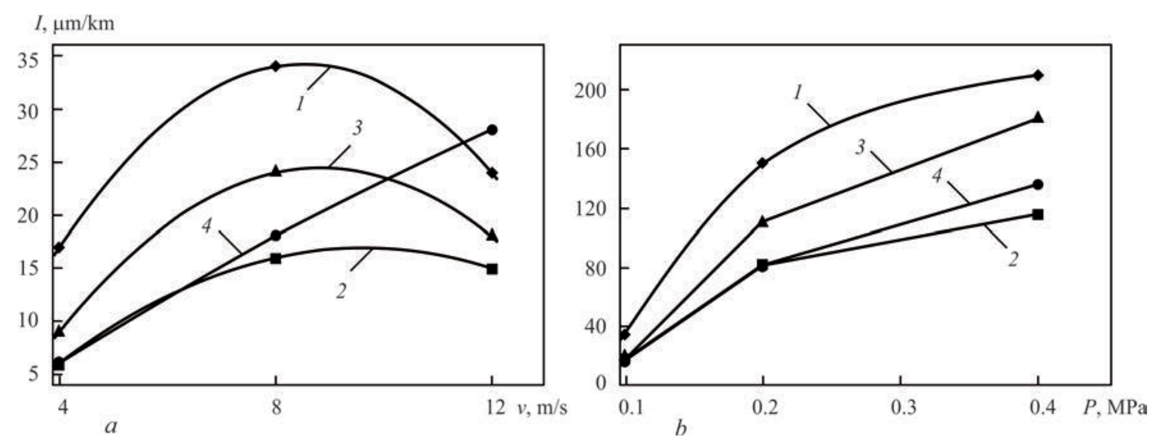

Figure 2. Dependence of wearing intensity of ESA coatings: FeNiCrBSiC (*1*), FRB20 (*2*), FCB20 (*3*) and WC–6 % Co (*4*) on speed (*a*) and load (*b*)

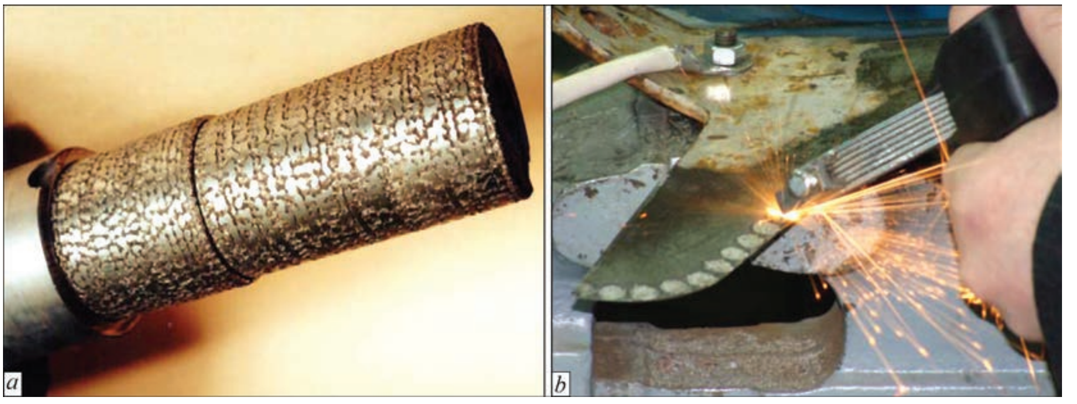

Figure 3. Part strengthening by ESA method with application of the developed electrodes: journal of electric motor rotor from half-coupling side (*a*) and plough share (*b*)

Experimental production trials at «TRIZ» enterprise showed that deposition of ESA-coatings from the developed FKhTB20 composite material on working surfaces of end seals of TsBS-30.50.01.200 grade for STsL-20-24 fuel pumps by electrodes from FTB20 composite material of FeNiCrBSiC–TiB system (ALIER52 unit: pulse duration of 170 μs; amplitude value of pulse current of 200 A; pulse energy of 0.6 J) ensures 2.0–2.5 times extension of seal assembly operating life.

Process of electrospark hardening and restoration of parts of technological equipment and tools using developed electrode materials NiBCuSi–WC, FeNiSi–Cr_3C_5, WC–TiC–Mo_2C–Co–Cr and WC–TiC–Co–Cr–Ni–Al, TiC– (Fe–Cr–Si–Al) was applied in the enterprises of «TRIZ» (Sumy) and JSC «SPC Elektromash» (Sumy). Analysis of damaged parts in these enterprises showed that the most widely spread kinds of wear include cavities on the surface of blades of centrifugal compressor impellers, corrosive-abrasive wear of bearing journals of the rotor shaft of TsNS-180 pump and electric motor rotors. Parts of these units are made from high-strength steels, their working surfaces are strengthened by different kinds of chemicothermal treatment. However, these parts operate under the conditions of dry friction at specific loads of up to 20 MPa that leads to their intensive wear. Electrospark hardening of large-sized parts (electric motors, impellers, casing pumps, centrifuges) using the developed electrodes allowed increasing their wear resistance and operating life 2.0–2.5 times. In particular, electrospark treatment of shaft working surfaces (Figure 3, *a*) by FeNiSi–Cr_3C electrodes in EIL-8A unit allowed increasing the maximum thickness of ESA coatings compared to application of WC–6 % Co (VK6) electrodes from 0.2 to 1.6 mm. NiBCuSi-WC electrode material was used at SPE «Elektromash» (Sumy) for local hardening and restoration in «Elitron-22A» and «Elitron-52A» units the plough shares (Figure 3, *b*) and seats of industrial fans with considerable local damage and wear of the surface.

In addition, «TRIZ» enterprise developed a number of technological processes for strengthening compressor parts using graphite as ESA electrode. Sealing assembly is one of the most critical components ensuring the compressor unit tightness, its safe and no-failure operation. Two thirds of all the compressor failures are the result of violation of the seal performance. Therefore, a technology was developed within the framework of project P8.1 for strengthening the heat-treated collars from 38Kh2MYuA steel by electrospark treatment by graphite, after their fitting on

Figure 4. Appearance of the protective collar of the seal assembly after ESA (*a*) and floating seal ring of a centrifugal compressor (*b*)

the shaft. Contact end surfaces of floating ring seals and respective parts of the casing and cover (Figure 4) were hardened in a similar way. The process of electrospark treatment was conducted in «Elitron-22A» unit at discharge energy of 0.5 J; the depth of the strengthened layer was 30–50 μm, microhardness was *HV* 900–1100. After that, alloying of the contact surfaces by silver at discharge energy of 0.05 J was conducted, in order to lower the roughness and coefficient of friction.

EILV-8 unit was used to make a mock-up of a mechanized unit (EILV-8M) for strengthening the rotation parts. In keeping with the recommendations of the staff of IPMS «TRIZ» enterprise manufactured the fixture for mechanization of ESA process of small-sized cylindrical parts (parts of fuel pumps, compressor impellers and shaft journals of electric motor rotor), that resulted in a significant increase of productivity.

Thus, application of the proposed under the project technological solutions and developed electrodes allows increasing the adaptability-to-manufacture of the process of electrospark alloying, lowering the labour consumption and increasing the operating life of parts of power and technological equipment by 2.0–2.5 times. Developed electrospark coatings have passed trials at industrial enterprises of Ukraine (OJSC «TRIZ» (Sumy), SPE «Elektromash» (Sumy), CE Kyiv Metropoliten) that is confirmed by positive reports of experimental-production trials.

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