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OBTAINING WEAR-RESISTANT COATINGS BY SURFACING WITH POWDER CORE WELDING WIRE

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ABSTRACT

A modification of hard and wear-resistant coatings fabricating technology by substrates surfacing with powder core welding wire is proposed. Nichrome or steel tapes are used as welding wire shells, while the specially produced CrB_2–Al_2O_3 and $(TiCr)B_2$–Al_2O_3 composite powders, as well as commercially available Cr_3C_2 powder, serve for cores. The microstructure of one-, two- and three-layer surface welds reveals the presence of carbide–boride and aluminum oxide phases, which improve their tribological properties.

KEYWORDS: arc surfacing, hard powder, powder core wire, wear resistance

INTRODUCTION

Surfacing with powder core welding wire is known [1, 2] as one of the most effective technologies of coating various substrates. A special attention has been paid [3–6] to the production of powder core wires of new compositions intended for providing wear and corrosion-resistant coatings.

In the present work, for the first time nichrome tape (GOST 12766.2–90, 15×0.5 mm) is used as a powder welding wire shell instead of low-carbon steel-08KP (C 0.05–0.11, Mn 0.25–0.50, Si <0.03, and S and P together <0.04 %) one serving for shell material in standard welding wires with iron-based powder core (GOST 26101–84). Moreover, in order to increase the fabricated coatings hardness and wear resistance, for core there are utilized specially produced CrB_2–Al_2O_3 and $(TiCr)B_2$–Al_2O_3 composite powders, in addition to commercial Cr_3C_2 powder.

OBTAINING COMPOSITE POWDERS FOR WELDING WIRE CORE

This technology, which is based on the aluminothermal reduction of a chloride–oxide charge, includes the following stages:

- Mixing the charge in a rotating mixer;
- Briquetting the charge;
- Reduction in argon atmosphere in a shaft-type furnace;
- Wet grinding the sinter in a ball mill; and
- Drying, sieving and packaging of powders.

During the full cycle, the loss of usable powder did not exceed 5 %. By comparing the main kinetic characteristics of the reduction process of metal chloride–oxide charge with aluminum and the results of thermographic and X-ray phase-analysis of the products obtained in this way, the optimal technological parameters for producing refractory compounds reinforced with aluminum oxide are developed and composite powders CrB_2–Al_2O_3 and $(TiCr)B_2$–Al_2O_3 useful for welding wire powder core are obtained.

The size of the particles constituting the maximum fraction in these powders ranges from 125 to 100 μm. And its share does not exceed 5 %. Other relatively important fraction contents are: 100–55, 50–20 and 20–5 μm — 15–20, 35–40 and 30–35 %, respectively. In addition, the particles of reinforcing oxide and carbide phases are practically evenly distributed in the powder sample volume.

By investigating some technological characteristics of powders, it is determined that their true, free bulk and rolling densities range within the intervals of 4.60–4.95, 1.05–1.20 and 1.50–1.65 g/cm^3, respectively, while fluidity is of 39–42 s.

In order to prevent the cracks formation and improve the welding layer structure, the following powder mixture is added to the charge: rutile 30, calcium fluoride 20–21, ferrovanadium 0.35–0.50, ferrotitanium 0.8–1.0, boron carbide 1.0–1.5, sodium silicide–fluoride 1.5–2.0, marble 11–12, nitrided ferromanganese 0.3–0.5, copper 1.0–1.5, cobalt 1.0–1.5, graphite 1.0–1.5 and of Ce-group rare earth metals fluorides (CeF_3, LaF_3, NdF_3, PrF_3 and YF_3) together 0.5–1.0 %.

The proportion of refractory compounds in the charge was constant, around 30–32 wt.%.

FABRICATING POWDER WELDING WIRES

Powder core wires are made from above listed powder materials. The scheme of this technology is presented in Figure 1. A general view of the laboratory equipment used for this purpose and coil of a powder welding wire made in this way is shown in Figure 2.

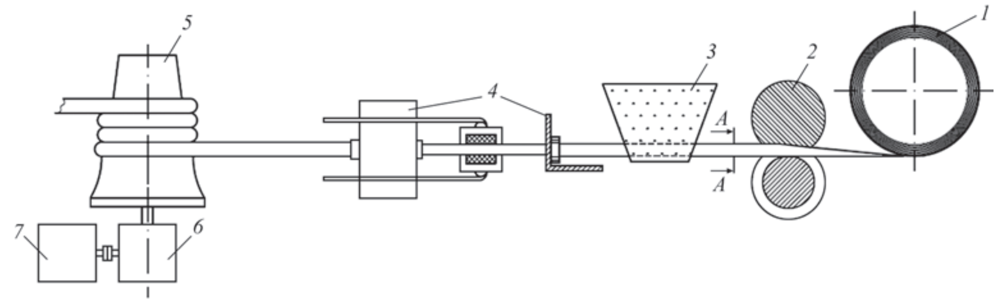

Figure 1. Schematic of powder core wire fabrication: *1* — tape coil; *2* — bending rollers; *3* — powder hopper; *4* — dies; *5* — coiler drum; *6* — reducer; *7* — electric motor

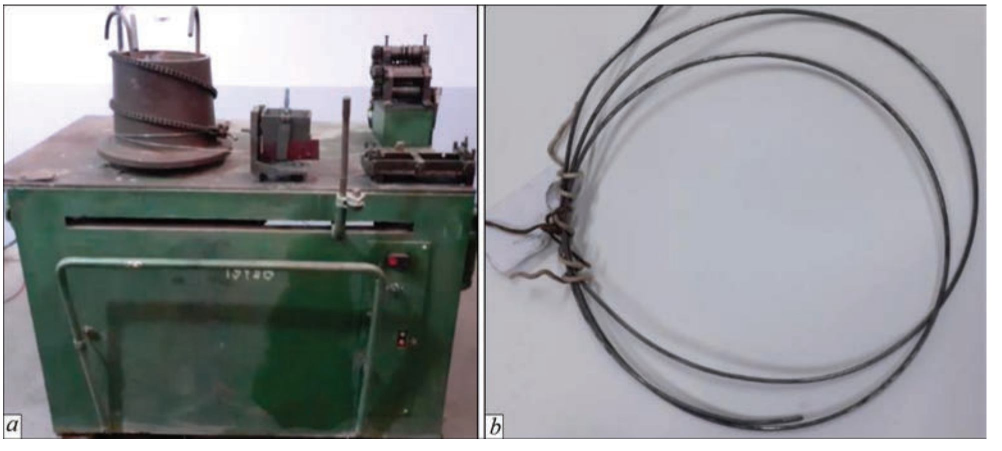

Figure 2. Powder core wire fabrication laboratory setup (*a*) and fabricated powder core wire (*b*)

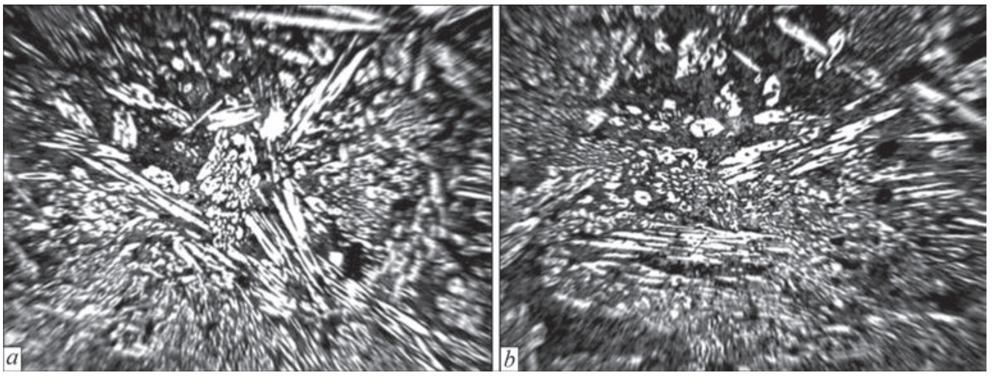

Figure 3. Microstructure of samples (*a*) and (*b*) with one-layer weld at ×100 magnification

Powder core wire welds are obtained in argon atmosphere on the steel-20 surface in one, two and three layers. The thickness of each layer is of 1.0–1.3 mm. By measuring the hardness and microhardness of the welding layer (Table 1), it was determined that the best result of the tested samples is given by the powder core wire with nichrome shell. When using steel-08KP as shell, formation of microcracks is noticed.

By metallographic study (Figures 3–5) it is determined that high hardness might be caused by carbide, boride and aluminum oxide inclusions, which has a positive effect on the coatings tribological properties. The hardness and microhardness values analyzes shows that the three-layer weld characteristics are higher than those of one- or two-layer welds.

Based on the microstructural analysis of one-layer weld, the different regions of the welded zone are significantly different from each other. Carbide inclusions are fixed in all weld layers, however, in different shapes, sizes and relative positions. Carbide inclusions are large and elongated in shape and vary in size. Along with large carbide inclusions, relatively finer randomly oriented inclusions can be seen.

Hardness of one-, two- and three-layer welds are estimated as: 3.33, 5.64 and 6.38 GPa, respectively. In this way, the increase in the number of layers leads to a significant increase in microhardness, which in turn significantly changes tribological properties of the material.

Table 1. Typical values of hardness and microhardness measured at one-, two- and three-layer welds

Number of welded layers	1	2	3
Hardness, *HRC*	44.5	48.5	59.0
Microhardness, GPa	7.43	8.53	11.26

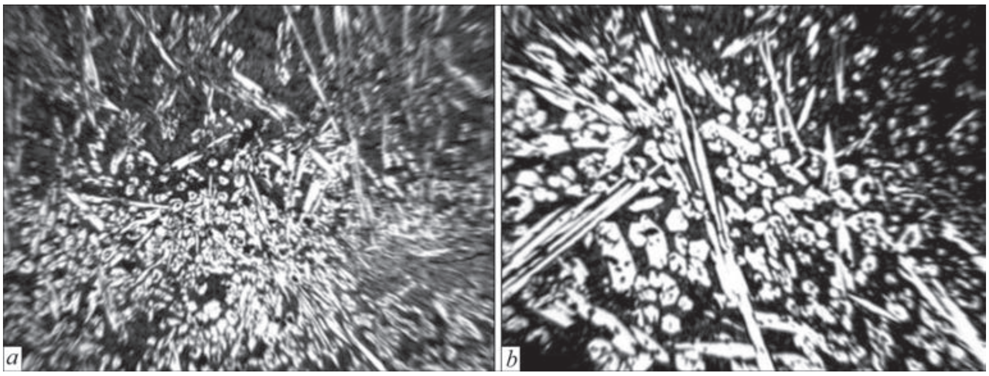

Figure 4. Microstructure of samples (*a*) and (*b*) with two-layer weld at ×100 magnification

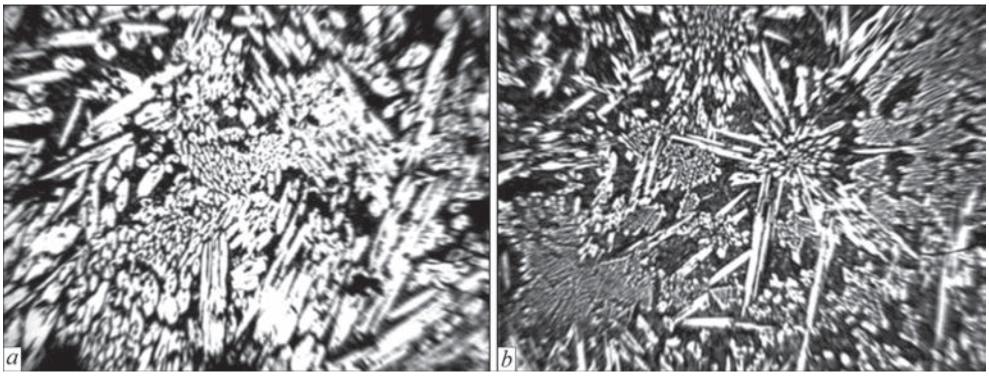

Figure 5. Microstructure of samples (*a*) and (*b*) with three-layer weld at ×100 magnification

Figure 6. Inverter welding machine TIG/MMA-320 (*a*) and argon-arc welding process on universal welding rectifier VDU-506 (*b*)

The described structures were obtained by welding using powder core wires with shells made of nichrome.

TRIBOLOGICAL CHARACTERIZATION OF OBTAINED COATINGS

To evaluate the tribological properties of coatings fabricated by powder core wire welding, there are selected samples obtained with:

- Nichrome tape shell and Cr_3C_2 core;
- Steel-08KP tape and Cr_3C_2 core;
- Steel-08KP tape and CrB_2 core; and
- Steel-08KP tape and $(TiCr)B_2$ core.

The surface of steel-20 samples were welded with powder core wires by argon-arc method (Figure 6) on the TIG/MMA-320 inventory welding machine (Georgian Technical University).

The powder core wires, shell of which is steel-08KP, and the powder core is made of CrB_2–Al_2O_3 or $(TiCr)B_2$–Al_2O_3, practically do not differ from each other in the technological parameters of welding. At relatively low currents, up to 120 A, the quality of welding is poor, and above 140 A, the quality of welding is of average quality or sharply worsens, which is caused by overheating of the weld metal and an increase in the depth of welding.

The microstructure of the three-layer welded sample is characterized by carbide liquefaction zones. The white areas with microhardness of 7.28 GPa shown in Figure 5 belong to the carbide phase. The dark areas correspond to the structure of the base metal, which initially is in the ferritopearlite state, but in the welding zone it is not excluded that it is alloyed. Its microhardness is of 5.12 GPa. One thing is worth noting: when approaching the border of the base metal from the center of the carbide inclusions, the value of microhardness decreases from 11.08 to 7.28 GPa.

The wear-resistant test of the steel-20 surface coated with powder core electrodes is conducted under dry friction conditions on the friction machine SMC-2 and at constant number of rotations: 1000 rpm. The loading force is of 25, 50 or 100 N. A roller made of tempered steel-U8 with diameter of 40 mm and hardness of 64 *HRC* is taken as a counterbody. The friction coefficient f and the wear mass loss of the samples are determined. During the tests to find the coefficient of friction, the values of loading force F acting on sample, moment of friction M and counterbody diameter d are recorded. The coefficient of friction is calculated by the formula: $f = 2M/Fd$. The wear resistance of the samples is assessed by the weight loss of the samples under dry friction conditions.

The wear resistance of welds made with powder core wires is studied on samples with one-, two- and three-layer coatings, when the used powder core wire is made of steel-08KP tape and powders CrB_2–Al_2O_3 or $(TiCr)B_2$–Al_2O_3. For these coatings, there are studied the relationship between the sliding distance and the friction coefficient. For layers welded with powder core wires (steel-08KP shell and Cr_3C_2 or CrB_2–Al_2O_3 and $(TiCr)B_2$–Al_2O_3 core) on steel-20 under Ar pressure, it is determined that the friction coefficient is almost equal after passing different distance of 1200 to 1400 m. The surface of the welded sample is stable and therefore does not significantly affect the wear resistance. However, after passing a distance from 1200 to 1350 m, it experiences a slight fall in a certain section, which affects the mass weight loss, however does not significantly affect the wear resistance.

As mentioned above, metallographic studies and hardness measurements revealed that high hardness is caused by inclusions of carbide, boride and aluminum oxides, which positively affects the tribological properties of coatings obtained in this way.

Compared with samples welded with nichrome tape wires, in structures obtained using powder core wires with 08KP steel shells, the corrosion resistance of the coating decreases, but its wear resistance increases by 20 %.

CONCLUSIONS

In the present work, nichrome tape was used for the first time as a shell of powder core wire. In order to increase the formed coatings hardness and wear resistance, specially produced CrB_2–Al_2O_3 or $(TiCr)B_2$–Al_2O_3 or commercial Cr_3C_2 powders, whose mass fraction was about 30 %, were used as cores of powder welding wire. In these powders, particles of reinforcing and strengthening oxide (aluminum oxide) and boride (chromium and titanium-chromium diborides) phases are evenly distributed in the volume. The microstructure of one-, two- and three-layer welds indicates the presence of inclusions of carbide–boride and aluminum oxide phases, which positively affects their tribological properties.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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