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Investigation of Properties of Electro-metallized Coatings Deposited by Supersonic Air Stream with Aerosol Fluxing

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Abstract. The article presents the results of studies of the effect of flux components on the adhesive strength, porosity and oil absorption of coatings obtained by supersonic arc metallization (EM) using aerosol fluxing (AF) deposited on 45G2 steel with a speed v = 400-410 m / s. Due to the use of AF in EM, the adhesion strength of electrometallization coatings (EM coatings) increases. The highest value of adhesive strength is 66 MPa. Porosity due to the use of AF decreases by 1.5 - 1.6 times, in comparison with EM coatings without AF. At the same time, the oil absorption of EM coatings using AF decreases 1.6–1.7 times. It is advisable to use EM coatings with AF when restoring worn-out parts for various purpose equipment, as well as for eliminating defects at the production stage.

1. Introduction

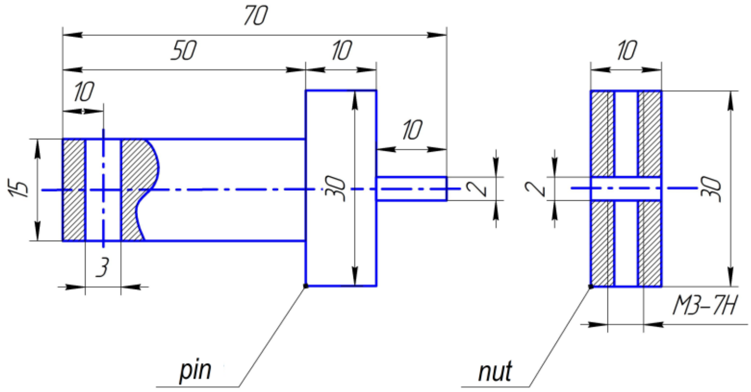
One of the common ways to restore worn surfaces of parts is EM. However, wires that provide high physicomechanical properties of applied EM coatings (50HFA, 40X13, PP-PN-100H15, PP-TP-1) have a high cost. In this regard, it is proposed to use an inexpensive welding wire Sv08G2S (with a hardness of the obtained coatings of 300 HV) and to alloy it with EM flux components [1-3].

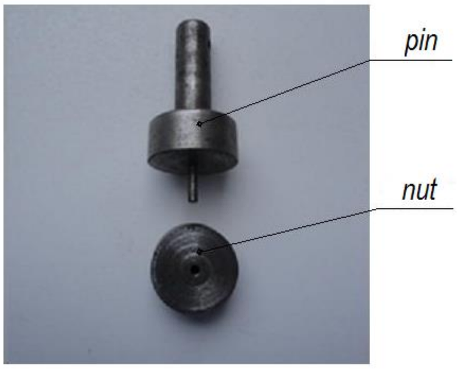
When conducting research, 45G2 GOST 4543 steel, which is widely used for the manufacture of shaft-type parts, was used as a material for manufacturing samples [4].

In EM it is most expedient to use a flux consisting of the components Na_2CO_3, Na_3AlF_6, $Na_2B_4O_7$ [5 - 7]. Microhardness studies of EM coatings obtained using this flux with various contents of the above components in it were carried out. During the studies, fluxes were established that showed the best results: flux No. 1 (665 HV) CNa_2CO_3 = 42 g / l, CNa_3AlF_6=6 g/l, $CNa_2B_4O_7$=12 g/l and flux No. 2 (771 HV) CNa_2CO_3=42 g/l, CNa_3AlF_6=6 g/l, $CNa_2B_4O_7$=16 g/l [8]. In this regard, further studies of the physicomechanical properties of EM coatings considered in this work were performed using these two fluxes.

2. Materials and research methods

It is known that one of the most important characteristics determining working properties of various coatings notably determining durability of the parts working areas, is adhesive strength between coating and base (adhesive strength) [6 – 8]. Adhesive strength of the deposited electro-metallized coating (EM-coating) was determined with the pin method according to GOST 15140. The method essence is in destructive force evaluation at pin extension in the direction normally to its end surface with the deposited electro-metallized coating (EM-coating). The sample (fig. 1) consists of a pin and a nut with a gripping device in the shape of an opening.

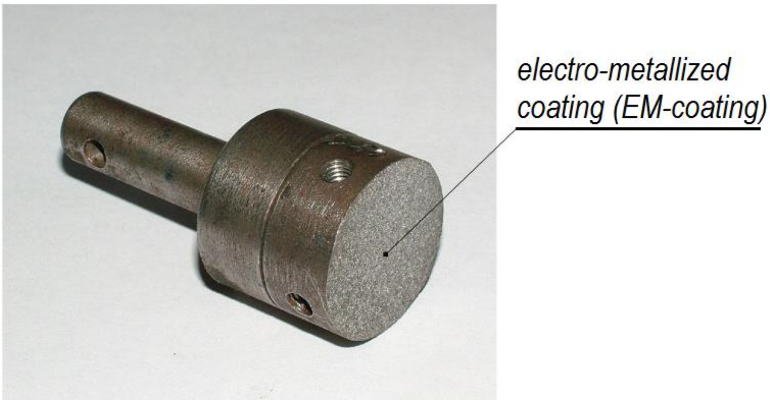




a) b)

Figure 1. Sample for investigation of adhesive strength of electro-metallized coatings (EM-coatings): a) scheme; b) general view

The pin assembled with the nut was set in the sample fixer and preliminary jet-oriental treatment was carried out. The electro-metallized coating (EM-coating) was deposited on the working surface of the sample at its even movement around its radial axis (fig. 2). The investigations on determination of the adhesive strength were carried out on the versatile tensile machine PM-1000.



Fugure 2. Sample (in the assembled condition) for determining the value of the adhesion strength of the EM-coating

3. Results and discussion

The comparative analysis of the obtained adhesion strength depending on the applied fluxes and the components contained in them (fig. 3) displayed that the electro-metallized coatings (EM-coatings), deposited with application of aerosol fluxing (AF) (60…66 MPa), it is in 2.1 – 2.2 times higher in comparison with analogous coatings, obtained without aerosol fluxing (AF) (30 MPa).

The increase of adhesive strength of the EM-coatings obtained with aerosol fluxing (AF) application, is explained with deoxidate carbon effect. Under the effect of high temperature of the electric arc thermal dissociation with emission of active elements with C, CO and subsequent carbothermal process take place, i.e. ferrum deoxidation at steel fusion wire in the arc of metal spraying gun occurs. As a result the purer dispersed metal contacts with base, thereby increasing strength of its cohesion with base material [8].

Porousness is one of the main characteristics of the electro-metallized coatings (EM-coatings) [9, 10]. It characterizes density and homogeneity of the deposited metal layer [11]. Porousness of the electro-metallized coatings (EM-coatings) was determined with the method of dye penetrant testing according to GOST 9.302. After electro-metallization and grinding of the external surface R_a = 0.63…0.64 µm the samples (fig. 4) were cooled up to ambient temperature and ungreased with spirit. Then they were washed with distilled water and dried with filter paper.

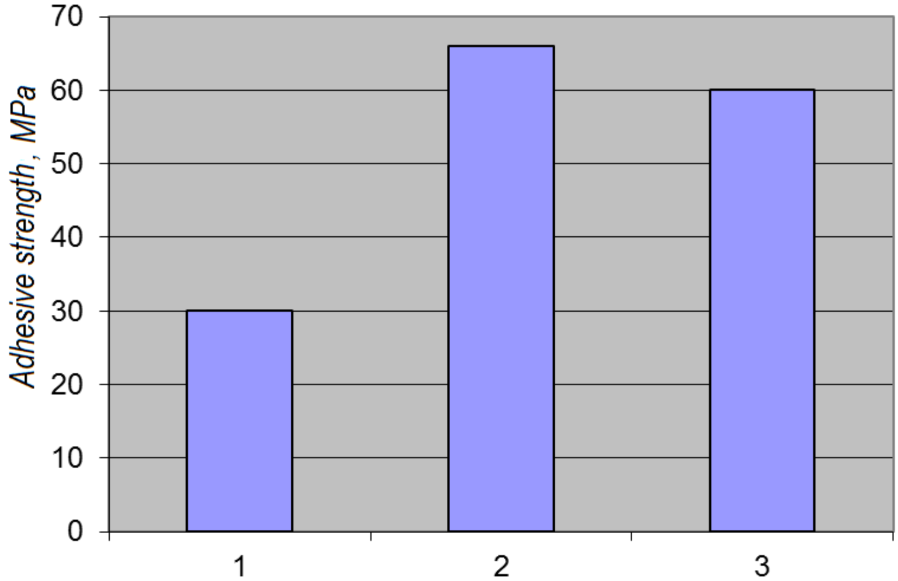
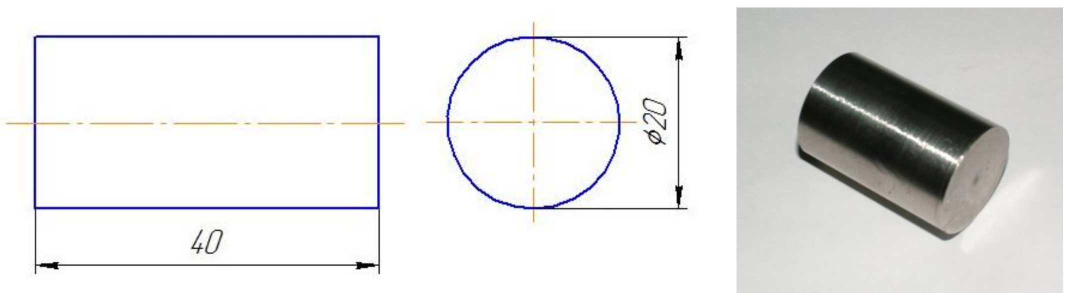


Figure 3. Values of adhesion strength of EM coatings: 1 - Sv-08G2S (without AF); 2 - Sv-08G2S + AF (flux No. 1); 3 - Sv-08G2S + AF (flux number 2)

For pores coloring the samples were put into the solution containing ferricyanide potassium 3 g/l and sodium chloride – 10 g/l, and were held in it for 5 minutes at the temperature of 18…30°C [12, 13]. Washed and dried samples with blue spots areas appeared on the surface were studied under the microscope, 20^x. Porousness of the electro-metallized coatings (EM-coatings) was determined as percentage ratio of the areas of the colored spots to the area of the examined region. The porousness value change at the electro-metallization depending on aerosol fluxing (AF) application and the flux content in it is presented in figure 5.



a) b)

Figure 4. Sample for study of porousness and oil absorption of the electro-metallized coatings (EM-coatings): a) scheme; b) general view

The investigations displayed that the application of aerosol fluxing (AF) allows decreasing porousness of the electro-metallized coatings (EM-coatings) in 1.5 – 1.6 times. Tis is explained by the fact that because of ferrum deoxidation its oxide content decreases. This provides increase of density and quality of the applied metal layer [15, 16]. Besides, low porousness is connected with high speed of the deposited particles (400 – 410 m/s) and thus, with their higher kinetic energy, which makes it possible to obtain denser and semi-porous electro-metallized coating (EM-coating).

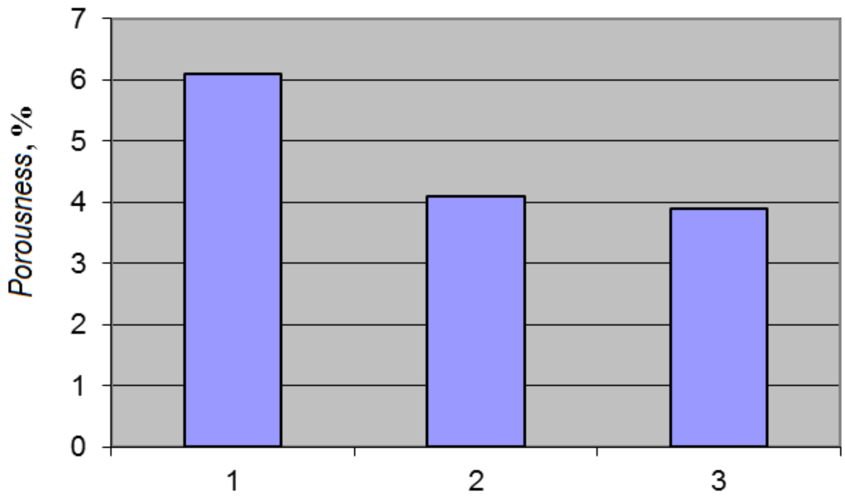


Figure 5. Porosity of EM coatings: 1 - Sv-08G2S (without AF); 2 - Sv-08G2S + AF (flux No. 1); 3 - Sv-08G2S + AF (flux number 2)

Determination of oil absorption of the deposited metal layer was done according to GOST 9.302. The method is based on determining the quality of the oil absorbed with the electro-metallized coating (EM-coating). During the investigation we applied the oil with kinematic viscosity (2.5 – 3.5) 10^{-5} m^2/s at the temperature of 25°C.

To determine oil absorption we used the cylindrical samples with the electro-metallized coating (EM-coating) (fig. 4). They were plunged into the oil heated up to the temperature of 130°C and were kept in it up to the temperature of (20±5)°C. Then they were withdrawn, the oil excess was removed with filter paper and they were weighted. Oil absorption (M) in grams per square meter was calculated using the formula (1):

$$M = \frac{m - m_1}{S}, \tag{1}$$

where m – mass of the sample after its plunging into oil, g; m_1 – mass of the sample before plunging into oil, g; S – area of the sample surface, m^2.

Oil absorption of the electro-metallized coatings (EM-coatings) is connected with porousness, which is formed during the deposition process [17, 18]. For the parts operating in the conditions of the greasing variation from liquid to boundary, the coatings oil absorption is one of the most important properties that allows improving self-lubrication of the co-working surfaces and decreasing friction coefficient in sliding joint [19]. That way, the wear decreases and the component life in assembly unit increases.

The investigations showed that the oil absorption value of the electro-metallized coating (EM-coating), deposited without aerosol fluxing (AF) application (65 g/m^2), is higher than with aerosol fluxing (AF) application (36 – 39 g/m^2) in 1.7 – 1.8 times (fig. 6).

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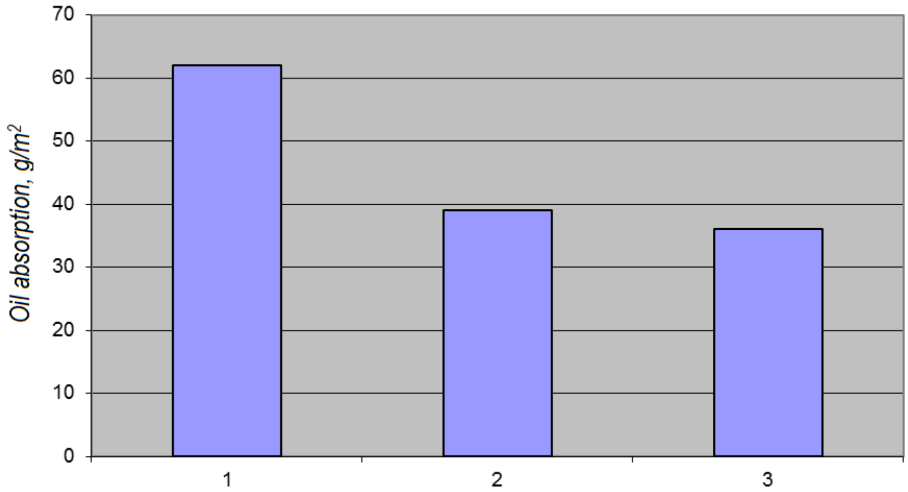

Figure 6. Oil coverage of EM coatings: 1 - Sv-08G2S (without AF); 2 - Sv-08G2S + AF (flux No. 1); 3 - Sv-08G2S + AF (flux number 2)

The decrease of oil absorption of the electro-metallized coatings (EM-coatings), obtained with equal speed v=400 – 410 m/s and with aerosol fluxing (AF) application, is explained with the decrease of their porousness, because of ferrum deoxidation its oxide content decreases and it provides the increase of the density and the quality of the deposited metal layer [20].

Conclusion

Due to the use of AF in EM adhesive strength of EM coatings increases. The highest value of adhesion strength (66 MPa) was obtained on the flux No. 2.

Porousness of the electro-metallized coatings (EM-coatings) at the account of the aerosol fluxing (AF) application decreases in 1.5 – 1.6 times in comparison with the analogous coatings, obtained without the aerosol fluxing (AF) application. Herewith the oil absorption of the coatings, obtained with the electro-metallization method, at the aerosol fluxing (AF) application decreases in 1.6 – 1.7 times. It should be taken into account at prediction of the sliding joints resource, where the parts reconditioned by the electro-metallized coatings (EM-coatings) are used. Divergence in the obtained test results according to porousness and oil absorption is connected with error at calculation of painted area spaces on the electro-metallized coatings (EM-coatings) surface, and with some porousness depth depending on many factors.

To increase physical and mechanical properties of electro-metallized coatings (EM-coatings), it is recommended to apply aerosol fluxing (AF) on the basis of distilled water of the following composition: CNa_2CO_3 = 42 g/l, CNa_3AlF_6 = 6 g/l, $CNa_2B_4O_7$ = 16 g/l.

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