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FORMATION OF NANODIMENSIONAL POLYGONIZATION SUBSTRUCTURE IN SPRAYED ELECTRIC ARC COATINGS

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In the work the possibility of forming a thermally stable nanodimensional polygonization substructure in the sprayed electric arc coatings of Sv-08G2S and 12Kh18N10T wires was studied applying the additional deformation and pre-recrystallization heat treatment. It was shown that carrying out additional deformation of coatings allows 15–40 % increasing the duration of holding at heat treatment of up to 90–180 min without a significant deterioration in hardness due to decrease in the mobility of polygonization subboundaries. It was established that the size of the coherent scattering regions (CSR) of both deformed coatings, as well as coatings without deformation after performing the heat treatment (which provides the maximum hardness) is 1.5–3.0 times smaller than that in the state after spraying. With an increase in duration of holding the deformed coatings up to 150 min, the size of their CSR due to reduced mobility of subboundaries increases slightly, that is correlated with the slight decrease in hardness. As a result, carrying out the additional deformation by 40 and 15% and the subsequent heat treatment of the sprayed electric arc coatings of Sv-08G2S and 12Kh18N10T allows forming a thermally stable nanodimensional polygonization substructure, which provides an increased hardness as compared to the sprayed state by 75 and 54 %, respectively. 8 Ref., 1 Table, 2 Figures.

Keywords: *deformation, polygonization substructure, pre-recrystallization heat treatment, electric arc coatings*

The modern tendency of development of technology of thermal spraying mostly consists in increase in physical and mechanical properties of coatings applying nanostructuring. The methods for formation of nanostructures, such as spraying of ultra-dispersed powders [1, 2] and the powders produced using mechanical alloying and mechanical synthesis [3], transformation of amorphous phase into nanocrystalline ones [4] requiring special preparation of powder, are rather complex and labor-intensive and, as a result, expensive. The challenging is the application of pre-recrystallization heat treatment (PHT) of sprayed coatings [5, 6], which allows increasing their physical and mechanical properties due to producing a refined and nanodimensional polygonization substructure.

However, the produced polygonization substructure has a low thermal resistance (not more than 10 min) due to running the processes of collective polygonizaiton during a long holding at the elevated temperature which restrains the application of PHT for massive products.

The aim of this work is investigation of opportunity of forming a thermally stable nanodimensional polygonization substructure in the sprayed electric arc coatings.

For investigations the electric arc coatings were selected, as they are characterized by a high effect of increasing hardness after PHT and producing the nanodimensional substructure [5]. The coating was produced using the installation KDM-2 which is equipped with electric arc spraying device EM-14M at the following mode: arc voltage is 30 V, current is 110 A, pressure of compressed air is 0.4–0.6 MPa, distance of spraying is 100 mm. As a spraying material the welding wires of the grade Sv-08G2S and high-alloyed wires of steel 12Kh18N10T of 1.2 mm diameters were used. The optimization of the PHT mode of coatings was carried out by the values of hardness. The hardness on Vickers HV was determined in the device TP at the load to indenter of 5 kg (DSTU ISO 6507-4:2008). The heat treatment of specimens was carried out in the laboratory electric furnace SNOL-1.6.2.0.08/9-M1 at the temperature of 500 and 600 ^{o}C, respectively [6]. The additional deformation of coatings was performed by pressing at different levels of deformation. The results of measurement of hardness of deformed and heat-treated coatings are given in Figure 1.

According to the data given in Figure 1, *a*, the use of the following deformation of coatings provides a lower reduction in hardness at the increase in duration of holding at PHT to 90–180 min. Thus, for the coating of Sv-08G2S wire without deformation at the increase in duration of holding to more than 2 min (maximum hardness) to 90 min, the hardness is reduced by 30 %. Using the deformation of coating by 20, 30 and 40 % and increase in duration of holding from 5 min (maximum) to 90 min, the hardness is de-

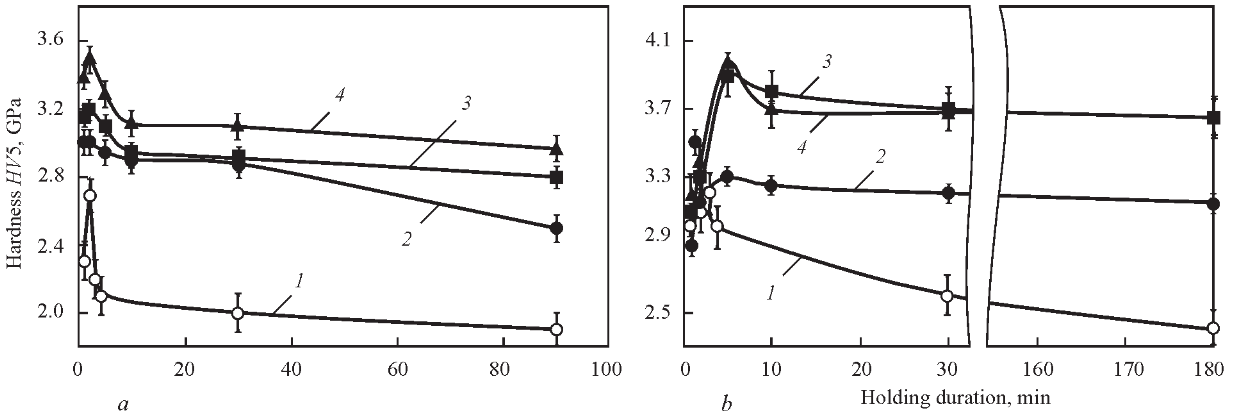

Figure 1. Dependence of hardness of electric arc coatings of the wires Sv-08G2S (*a*) and 12Kh18N10T (*b*) on the duration of holding at the heat treatment and the degree of additional deformation (curve *1* — without deformations); for a: *2* — 20; *3* — 30; *4* — 40 %; for *b*: *2* — 10; *3* — 15; *4* — 20 %

creased by 17, 12 and 16 %, respectively. The sufficient stability and high hardness of the polygonization substructure are provided by 40 % deformation.

The similar dependence is also observed for the coatings, produced of 12Kh18N10T wire (Figure 2, *b*). For the coating without deformation, at the increase in duration of holding time from 3 to 180 min, the hardness is reduced by 25 %. Using the additional deformation by 10, 15, 20 % and at the increase in the duration of holding from 5 to 180 min, the hardness decreases by 7, 5 and 8 %, respectively. In this case, the highest stability of the polygonization substructure is provided by the 15 % deformation.

This is explained by the fact that in the course of repeated deformation the dislocation interaction is finished by the appearance of dislocation barriers from 50 to 75 % (Hirt, Lomer–Cottrell), the rest ones participate in the formation of dislocation tangles. These dislocation barriers, which arise along the direction perpendicular to the axis of deformation, restrain the movement of dislocations and, as a result, reduce the mobility of polygonization subboundaries, and thus, provide a stabilizing effect by reducing the speed of polygonization processes [7].

The maximum 90 min duration of holding for Sv-08G2S wire and 150 min duration for 12Kh18N10T are provided by increase in hardness as compared to

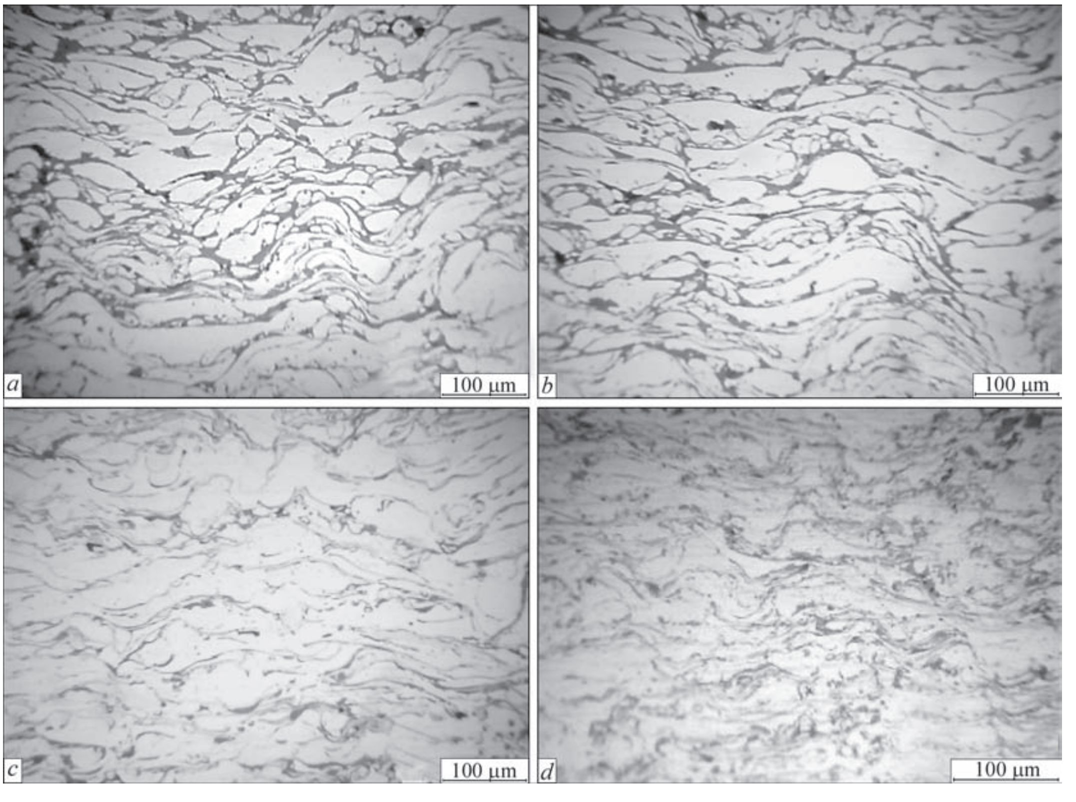

Figure 2. Microstructure of electric arc coatings of the wires Sv-08G2S (*a*, *b*) and 12Kh18N10T (*c*, *d*): *a*, *c* — after spraying; *b* — after PHT (3 min, 600 °C); *d* — after deformation at a load of 20 t

Dependence of CSR sizes of X-ray radiation of electric arc coatings on the type of treatment

Coating material	Type of treatment	CSR, nm
Св- Sv-08G2S	After spraying	200
	Spraying + PHT (2 min, 500 ^{o}C)	62
	Spraying + deformation by 30 %	163
	Spraying + deformation by 30 % + PHT (5 min, 500 ^{o}C)	82
	Spraying + deformation by 30 % + PHT (90 min, 500 ^{o}C)	111
12Kh18N10T	After spraying	200
	Spraying + PHT (3 min, 600 ^{o}C)	153
	Spraying + deformation by 15 %	164
	Spraying + deformation by 15 % + PHT (5 min, 600 ^{o}C)	87
	Spraying + deformation by 15 % + PHT (150 min, 600 ^{o}C)	138

the state after spraying by 75 % and 54 %, respectively due to increased thermal stability of the polygonization substructure as a result of deformation of coatings.

The microstructure of coatings was examined using the optical metallographic microscope MMU-3.

The investigation of microstructure of electric arc coatings of the wire 12Kh18N10T, given in Figure 2, showed that after PHT, as compared to the initial one, no changes were observed (Figure 2, *a*, *b*).

The coatings have a typical rippled microstructure. After spraying the average thickness of lamellas is about 14 μm (Figure 2, *c*), deformation using pressing to 15 % causes a decrease of this parameter to 11.9 μm (Figure 2, *d*).

The influence of deformation and PHT on the substructure of sprayed coatings was evaluated by changing the sizes of coherent scattering regions (CSR) of X-ray radiation applying the approximation method [8]. As the CSR corresponds to the internal ordering of the grain region and does not include the highly distorted boundaries, the size of CSR is identified with the average size of crystallites [8]. The X-ray diffraction analysis was carried out in the diffractometer DRON-3 in CuK_a-radiation (λ = 0.154 nm) using Ni of β filter. The rotation of specimens was carried out in the range of double angles from 30 to 100°, the scanning speed was 1 degree/min. The results of investigations are shown in Table.

According to the given data, the size of CSR subgrains of both deformed coatings, as well as coatings without deformation after performing PHT, which provides the maximum hardness, is 1.5–3.0 times smaller than in the state after spraying. With an increase in duration of holding to 90 and 150 min of the deformed coatings of Sv-08G2S and 12Kh18N10T due to decreased mobility of subboundaries the size of their CSR increases insignificantly, which correlates with a slight decrease in hardness (see Table). At somewhat shorter holding of 45 and 60 min, respectively, the CSR size for both coatings amounts to about 96 nm.

Thus, carrying out the additional deformation of 40 and 15 % and PHT of the sprayed electric arc coatings of Sv-08G2S and 12Kh18N10T allows forming a thermally stable nanodimensional polygonization substructure which provides an increased hardness as compared to the sprayed state by 75 and 54 %, respectively.

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