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ELECTRODES FOR ARC HARDFACING OF COMPOSITE ALLOYS

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This paper considers the peculiarities of formation of composite alloys based on tungsten carbides in arc hardfacing. It was found that application of spherical granules of tungsten carbides as a wear-resistant phase, which are to lower degree subjected to solution in process of hardfacing, is the most reasonable in development of electrode material. The optimum content of reinforcing phase in electrode metal was determined which should vary in 60–70 % limits of material weight in volume. Developed were gas-slag-forming and alloying systems and experimental compositions of the electrodes were manufactured. A series of technological peculiarities for providing coating homogeneity, consisting of components different in specific weight and granulometric composition, as well as its deposition on the electrode rod, were specified in experimental way. Determined were specifics of hardfacing process using developed electrodes, presented are the results of metallographic examinations of the deposited metal. Laboratory abrasive wear tests of composite alloys with experimental electrodes showed their high efficiency. 10 Ref., 1 Table, 2 Figures.

Keywords: *arc hardfacing, composite alloy, coated electrode, tungsten carbide, reinforcing particles, wear resistance*

The existing methods of producing composite alloys by the method of hardfacing are based on using the effect of reinforcement the deposited metal by particles of fused tungsten carbides WC + W_2C (relite), which have a high hardness (*HV* 1800–2200) and high specific weight. The most widespread method for producing composite alloys is a manual oxyacetylene surfacing with a filler metal. As a filler material, most often the strip or much rare the tubular-grain relite, developed at the E.O. Paton Electric Welding Institute, as well as rods or flexible cords of foreign companies, are applied [1–3]. In the recent years, plasma-powder and laser surfacing of composite alloys became widespread [4, 5]. At present, to a lesser extent, the induction or plasma surfacing is used with the addition of powder or strip electrode [6]. It is also known about the application of furnace method for production of composite alloys [1, 7]. However, a large volume of preparatory works, the use of low-temperature materials as a matrix and a high power consuming restrain the spreading of the mentioned method.

All the methods of surfacing mentioned above need stationary stations and specialized equipment. However, the problems with surfacing materials arise when it is necessary to strengthen the parts in field conditions and if disassembly of parts is difficult. In such cases, for arc semi-automatic or manual hardfacing of composite alloys only imported consumables are applied in Ukraine. As a rule, these are flux-cored wires, rods, electrodes, of well-known companies like DURUM, Castolin, Sulzer Metco Woka and others.

In this regard, the development of domestic electrode materials for arc hardfacing of composite alloys represents a hardfacing interest. The application of electric arc hardafing has a number of advantages over other methods: universality and simplicity of technological process; high efficiency as compared to gas surfacing; low energy consumption for hardfacing; wide range of control of basic parameters of hardfacing mode; opportunity for mechanization and automation of the hardfacing process. To realize the electric arc hardfacing method, it is necessary to develop the new domestic electrode materialss which provide the producing of composite alloys with preset high service characteristics. The maximum efficiency of such alloys is achieved due to the optimal concentration of a reinforcing phase, which determines the wear resistance of deposited metal and also serviceability of the matrix (wear resistance, crack resistance, porosity, etc.) to the highest extent. Moreover, the wear resistance of the produced alloys is also largely depends on chemical composition of matrix, which is determined by the degree of dissolution of tungsten carbide granules due to the diffusion of tungsten and carbon in welding pool during hardfacing. This also leads to decrease in the concentration of a reinforcing phase and increase in brittleness of matrix due to formation of secondary complex iron-tungsten carbides [8, 9]. This is particularly pronounced in using of tungsten carbide granules produced by crushing the ingots. As a rule, such granules are subjected to plenty of cracks, have irregular shape and sharp angles which facilitates their high dissolution in liquid matrix melt.

The works on creation of technology of spraying the refractory compounds, carried out at the E.O. Paton Electric Welding Institute, allowed starting the industrial production of granules of fused tungsten carbides of spherical shape of almost all fraction compositions from 0.05 to 0.8 mm. The strength of spherical particles is 1.5–1.7 times higher than the strength of crushed grains of similar composition, and the microhardness after spraying grew to *HV* 2800–3000 [10]. Moreover, the investigations showed, that due to the spherical shape of reinforcing particles, it was possible to significantly decrease their dissolution in hardfacing and to reduce the transition of tungsten and carbon from reinforcing particles to the matrix. Thus, in gas hardfacing using strip relite with crushed reinforcing grains of 0.45–0.63 mm size, the average content of tungsten in the matrix of the composite alloy reaches 18–20 %, and with spherical reinforcing grains of the same size it reaches 11–12 % [10]. Thus, when developing a new electrode material, it was advisable to use spherical granules of tungsten carbide $WC + W_2C$ as a reinforcing phase and, thus, to provide their minimal dissolution in welding pool.

It is known that the ratio between the content of reinforcing particles and binder alloy of the composite alloy is one of the determinating conditions for wear resistance of the alloy as a whole. This ratio depends on the type and structure of filler material, granulometric composition of reinforcing particles and should be in the range of 60–70 %, which provides the content of wear resistant phase in the deposited layer to about 40 % as to the volume and its high wear resistance. This ratio became a basis for the development of a new hardfacing electrode material.

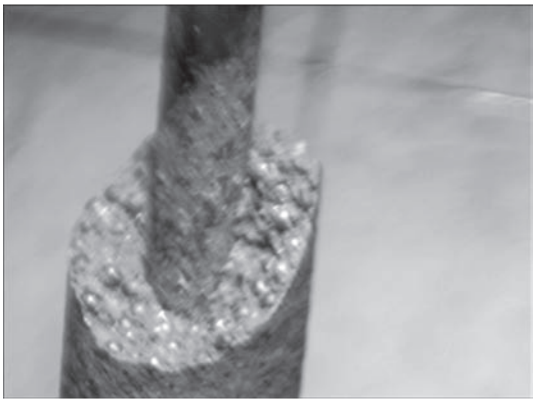

Figure 1. Electrode for electric arc hardfacing of composite alloys

The main feature of the designed electrodes is the fact that reinforcing granules are introduced to the composition of electrode coating, which, as a result, consists of the components considerably different between each other in size and specific weight of particles. This required the certain technological procedures in manufacture of electrodes of such composition in future. As a wear resistant component, the granulometric particles of tungsten carbides of spherical shape of 0.45–0.63 mm and 0.63–0.80 mm are applied. The selection of such particles is predetermined by design peculiarities of the equipment for manufacture of electrodes and the required coefficient of the coating mass.

The gas-slag-forming and alloying system is represented by traditional charge components applied for production of welding and surfacing materials. The granulometric composition of charge materials was in the range of 0.28–0.40 mm. As a gas-slag-forming system, the system based on marble and fluorspar concentrate was adopted. The deoxidation of welding pool was carried out by introducing ferromanganese and ferrosilicon into the electrodes coating composition. For a partial limitation of formation of brittle iron-tungsten structures in the matrix of deposited composite alloy, the doping ferroalloys, containing titanium and vanadium, are introduced into the coating composition.

These elements have a greater affinity to carbon than iron and tungsten, and, in the first turn, they form their carbides, thus reducing the amount of secondary iron-tungsten carbide phases. Taking into account the abovementioned difference in components as to their specific weight and granulometric composition, their mixing was carried out with keeping the necessary technological measures providing homogeneity of coating composition. At the same time, taking into account the high weight ratio of the coating, the electrodes shaping was carried out at the speeds considerably lower than the usual ones established for manufacture of typical electrodes. The ratio of weight of spherical particles of tungsten carbides in the coating to the weight of metallic rod was in the range of 60–65 %.

In the course of experiments, the modes of drying and calcination of electrodes after shaping were established, at which the corresponding quality of coat-

Results of tests of specimens on abrasive wear

Marking of specimen	Weight of specimen, g		Wear, g	Relative wear resistance
	Initial	After tests		
Steel 45-1	11.6157	10.9912	0.6245	1.0
OP-1	12.9226	12.8474	0.0752	8.3
OP-2	12.7251	12.6587	0.0664	9.4
OP-3	12.6434	12.5663	0.0771	8.1
Steel 45-2	11.8264	11.0612	0.7652	1.0
OP-4	13.0876	12.9895	0.0981	7.8
OP-5	13.3317	13.2485	0.0832	9.2
OP-6	12.9581	12.8659	0.0922	8.3
Steel 45-3	11.7361	11.0518	0.6843	1.0
S-1	12.6769	12.5869	0.0900	7.6
S-2	12.4935	12.3985	0.0950	7.2
S-3	13.1079	13.0058	0.1021	6.7

ing is provided. The calcination of electrodes should be carried out in vertical position using special yokes, as far as application of racks for drying in the horizontal position leads to a probable distortion in the uniformity of the electrode coating due to its high specific weight. The drying and calcination of electrodes is carried out according to the following cycle:

- drying of electrodes in the vertical position at a room temperature for 24 h;
- preliminary calcination of electrodes in the furnace at $T = 200$ °C for 1 h;
- calcination of electrodes in the furnace at $T = 400$ °C for 2 h.

For comparative investigations, more than ten experimental compositions of filler materials were produced. The appearance of electrodes with particles of spherical tungsten carbides is shown in Figure 1.

To evaluate the technological features of hardfacing process by designed electrodes and metallographic examinations, the specimens were manufactured, deposited by these electrodes. Figure 2 presents macrostructure of the deposited composite layer. The concentration of reinforcing particles in the plane of the section amounts to higher than 45 %.

It should be noted that the process of hardfacing by new electrodes has its own technological features. The direct effect of arc on reinforcing particles can lead to their partial fracture, appearance of small particles of tungsten carbides and increase in the degree of saturation of matrix melt by tungsten and carbon.

In this regard, during hardfacing the application of technological procedures is required providing transition of tungsten carbides from coating to welding pool at a minimal effect of arc on the reinforcing particles. The hardfacing was carried out in flat position with a forward inclination of electrode at small oscillations, providing some delays in melting of coating and, thus, facilitating the transition of a significant part of reinforcing particles to welding pool, avoiding the region of high temperatures. However, the keeping of the mentioned procedures does not exclude the diffusion of tungsten and carbon into the binder alloy. Therefore, the complete exclusion of forming the undesired structures in the alloy matrix, which embrittle the matrix in the form of secondary iron-tungsten carbides and eutectics, is impossible. The results of investigations of microstructure of composite alloys produced by electric arc hardfacing will be covered in a separate work.

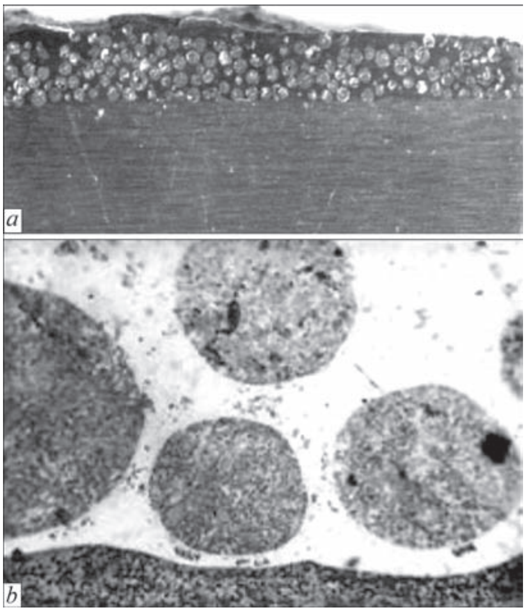

Figure 2. Macrostructure of composite alloy: *a* — ×80; *b* — ×200

To evaluate the wear resistance of composite layers deposited by experimental electrodes, the method of tests on abrasive wear in the machine NK-M was applied, which consisted in abrasion of specimens MI-90 moving along the copper path at the speed of 0.5 m/s under the load of 30 N. The friction path is 800 m, quartz sand serves as an abrasive. As a reference, the specimen of steel 45 is applied. The wear resistance is evaluated with respect to the weight loss of the reference specimen to the weight loss of the specimen tested. The test results are presented in Table. The data given in table show that the composite alloys deposited using experimental electrodes (OP-1–OP-6) are not inferior, and in some cases are 1.2–1.4 times superior to the serial ones (S-1–S-3) and can be successfully applied for wear-resistant hardfacing of different parts.

Conclusions

1. The electrodes for arc hardfacing of composite alloys were designed on the base of granular tungsten carbides of spherical shape, the feature of which is

the introduction of reinforcing granules into the coatings of electrodes. The designed electrodes provide concentration of reinforcing particles in the deposited composite layer of at least 40–50 %.

2. The technology for electrodes manufacture was developed, providing homogeneity of coating consisting of components different in specific weight and granulometric composition. The features of modes of drying and calcination of electrodes were determined.

3. The results of laboratory tests on abrasive wear allow predicting the high service characteristics of the developed electrodes.

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