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WELDING AND TECHNOLOGICAL PROPERTIES OF FLUX-CORED WIRE WITH THE CHARGE IN THE FORM OF GRANULATED POWDER

I.O. Ryabtsev[1], **A.A. Babinets**[1], **I.P. Lentyugov**[1], **J. Niagaj**[2], **A. Czuprynski**[3]

[1] E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine
[2]Upper Silesian Institute of Technology, Poland
[3]Silesian Polytechnic Institute, Poland

ABSTRACT

Comparative experimental studies have been carried out on the influence of the type and particle size distribution of the original metal granulated materials, which were used as a flux-cored wire charge, on its welding and technological properties during submerged arc surfacing. High-speed steel powder PG-R6M5 with 50–300 μm and 200–250 μm granulation, obtained by spraying of a melt metal, was used as a charge for experimental wires. The standard was flux-cored wire, the charge of which consists of ferroalloys with 50–300 μm granulation, calculated to ensure a similar chemical composition of the deposited metal and manufactured using standard technology. It has been experimentally determined that the welding and technological properties of three types of wires are at a high level, while the surfacing process with flux-cored wires, the charge of which contains granulated powder PG-R6M5, is characterized by greater stability, which results in an increase in melting and surfacing coefficients, and a decrease in the loss coefficient, compared to analogue wire with a charge of ferroalloy powders. It was also determined that the content of harmful impurities in the sample deposited with experimental wires with a charge of granulated powders is lower than in the standard sample. The patterns noted above indicate that the use of granulated powder in a flux-cored wire charge is not only technically feasible, but also leads to an increase in flux-cored wire homogeneity, which has a positive effect on their welding and technological properties.

KEYWORDS: arc surfacing, flux-cored wire, flux-cored wire charge, particle size distribution of powders, ferroalloys, welding and technological properties, deposited metal, surfacing stability, metallurgical heredity

INTRODUCTION

It is widely known that service properties of surfaced parts are determined, primarily by the chemical composition and structure of the deposited layer metal, so that the method of complex alloying of the latter is usually used for their improvement [1–7]. At present, however, the technical and economic capabilities of such an approach have practically been exhausted. In addition, deposited metal alloying for the majority of surfacing processes, is performed through electrode and filler materials, in the charge of which mostly ferroalloys are mainly used, which are rather considerably contaminated by unwanted impurities.

The content of undesirable and even harmful impurities in the ferroalloys can be 2–5 times higher than in pure metal powders. For instance, the volume fraction of impurities in ferromanganese can be up to 0.4 %, in ferrotitanium — 0.6 %, in ferrosilicon ––1.0 %. One of the main contaminants in ferroalloys is sulphur, the content of which in high-carbon ferrochrome is equal to 0.08 %; in ferrotitanium it is up to 0.1%; in ferromolybdenum and ferrotungsten — up to 0.2 %. Here, the content of impurities is much lower in the powders of pure metals and alloys, manufactured by metal melt spraying. In particular, in the granulated powder of PG-R6M5 grade sulphur content is not higher than 0.03 % [8–10].

The majority of unwanted impurities in arc spraying pass into the deposited metal, thus causing certain negative metallurgical heredity, and they can impair the mechanical and service properties of the deposited metal. In this connection, at surfacing or welding there exist many chemical and technological methods of dealing with the impurities to improve the welding and technological properties of flux-cored wires and service properties of metal deposited using them [11–13].

In works [14–16] it is shown that application of granulated materials of certain types, produced by metal melt spraying, as flux-cored wire charge allows obtaining more uniform filling of the flux-cored wire and improving the arc process stability and, consequently, improving the quality of deposited metal formation and lowering the impurity content, which has a positive effect on its service properties.

THE OBJECTIVE

of the work consists in a comparative study of the influence of the type and particle size distribution of granulated powders from high-speed steel R5M5 which were used as charge of flux-cored electrode wires instead of a composition from ferroalloys, on its welding and technological properties and quality of deposited metal formation at electric arc surfacing.

INVESTIGATION MATERIALS AND PROCEDURES

Three batches of experimental flux-cored electrode wires were produced with charge composition of three different types, which provide deposited metal of the same chemical composition of tool low-alloyed steel 30V2KhMF. For this purpose, the composition of the respective wires was calculated, in which the fill coefficient was ~ 30 %, and diameter was ~ 2.0 mm. Wire design is tubular with edge overlapping.

Granulated powder of PG-R6M5 grade was selected as charge for wire No. 1, with standard granulation of 50–300 μm. The same powder was used in the charge of wire No. 2. However, its particle size distribution was limited to narrower boundaries of 200–250 μm. Also the composition of wire No. 3 was calculated and it was manufactured. This wire could ensure production of deposited metal of chemical composition similar to that of wires Nos 1 and 2, but its charge consisted of ferroalloys of a standard granulation of 50–300 μm [11]. Determination and limitation of particle size distribution of the powders was performed using sieve analysis.

Deposition was performed by the automatic arc method under a layer of AN-26 flux in the same modes: wire feed rate of 120 m/h; that corresponded to current of ~200 A, voltage of 30 V, deposition rate of 18 m/h. The samples were first preheated up to the temperature of 280–300 °C to avoid hot cracks.

In order to avoid the influence of deposited metal mixing with the base metal (S235 to EN 10025-2) deposition of each sample was performed in five layers. Determination of the chemical composition, performed by the spectral method, and of hardness of the metal was conducted in the fifth deposited layer of each sample after its grinding.

Welding and technological properties of experimental wires were assessed by the following parameters:

- arc excitation pattern (easy, medium, complicated);
- stable arc burning (stable, satisfactory, unstable);
- deposited bead formation quality (sound, satisfactory, unsound);
- quality of slag crust detachment (easy, satisfactory, complicated);
- type and availability of defects in the deposited metal (absent, isolated, considerable number);
- melting characteristics (coefficients of melting, surfacing, and loss).

In order to calculate the coefficients of melting (α_m), surfacing (α_d) and losses for burnout and spatter (ψ), the weight of the plates and wires was determined before deposition and after it, and the deposition time was recorded. The respective coefficients were determined, using well-known expressions:

$$\alpha_m = G_m/(It); \qquad (1)$$

$$\alpha_d = G_d/(It); \qquad (2)$$

$$\psi = ((\alpha_m - \alpha_d)/\alpha_m)\cdot 100~\%, \qquad (3)$$

where G_m is the molten metal weight, g; G_d is the deposited metal weight, g; I is the welding current, A; t is the deposition time, h.

In addition to visual assessment, evaluation of arc process stability was performed by analyzing the integral values, which determine its energy state, such as for instance, arc voltage and current at their multiple recording [17]. In keeping with the procedure, the deviations of the values of arc current and voltage from average current value were analyzed by the calculated coefficients of variation. During the deposition process the mode parameters were analyzed using digital recoding multimeter ANENG AN9002, fitted with high-velocity analog-digital converter.

INVESTIGATION RESULTS AND THEIR DISCUSSION

Visually, the metal deposited with all the types of experimental wires, has equally high quality of formation, no defects, and the quality of the slag crust detachment is satisfactory (Figure 1). The results of spectral analysis and measurement of the deposited metal hardness showed (Table 1) that the metal deposited with experimental wires of the three types, practically the same chemical composition and hard-

Table 1. Chemical composition and hardness of metal, deposited with experimental wires

Number	Chemical composition of elements in the deposited metal, %									Hardness, *HRC*
	C	Cr	Mo	W	V	Mn	Si	S	P	
1	0.19	1.2	1.64	1.70	0.50	0.3	0.56	0.020	0.022	30–32
2	0.19	1.2	1.71	1.74	0.51	0.3	0.56	0.021	0.024	29–31
3	0.25	1.38	1.27	1.63	0.35	0.38	0.73	0.027	0.037	28–32
*	0.2–0.3	1.0–1.4	1.0–1.7	1.5–2.0	0.3–0.5	0.3–0.5	0.3–0.5	≤0.04	≤0.04	30–35

*Calculated composition and deposited metal hardness.

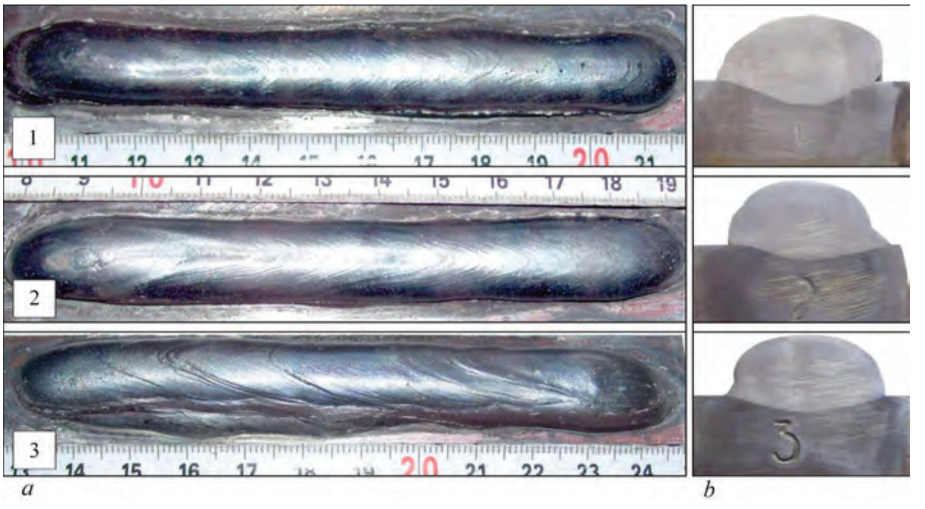

Figure 1. Appearance of samples deposited with wires Nos 1–3 in five layers (*a*), and their transverse macrosections (*b*)

Table 2. Comparative evaluation of welding-technological properties of experimental wires

Parameter	Wire type		
	No. 1	No. 2	No. 3
Arc excitation pattern	Light		
Arc burning stability	Stable		
Quality of deposited bead formation	Sound		
Quality of slag crust separation	Satisfactory		
Presence of visible defects (pores, cracks, lacks-of-penetration, etc.)	None		
Coefficients of, %:			
• melting α_m	17.1	16.2	13.6
• deposition α_d	16.8	15.8	12.6
• losses ψ	1.75	2.47	7.35

Table 3. Comparative evaluation of the stability of the process of arc surfacing with experimental wires

Parameter	Wire grade		
	No. 1	No. 2	No. 3
Set voltage, V	28.0		
Minimal voltage, V	26.03	25.91	25.27
Maximal voltage V	32.39	32.72	36.41
Average voltage, V	29.45	29.19	29.46
Range of deviation by voltage, V	–1.97/+1.45	–2.09/+4.72	–2.73/+8.41
Coefficient of arc voltage variation,	4.72	4.99	6.07
Set current, A	200.0		
Minimal current, A	136.4	127.8	128.6
Maximal current, A	252.0	266.0	312.0
Average current, A	194.8	194.9	214.6
Range of current deviation, A	–63.6/+52.0	–72.2/+66.0	–71.4/+112.0
Coefficient of voltage variation K_I, %	14.12	14.71	16.18

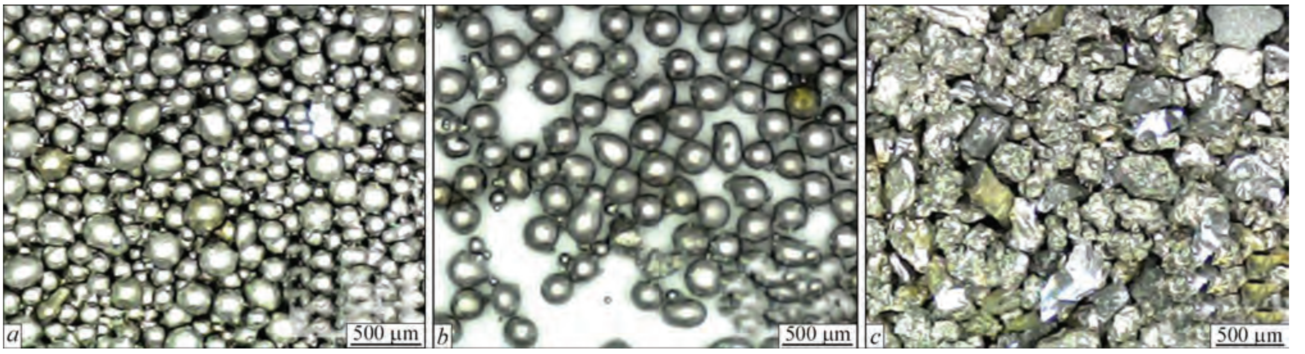

Figure 2. Appearance of samples of charge from powder R6M5 of 50 μm (*a*) and 200–250 (*b*) granulation, as well as from ferroalloys of 50–300 μm granulation (*c*)

ness, thus ensuring production of deposited metal of the type of low-alloyed tool steel 30V2KhMD. Note, the somewhat smaller, compared to the charge from ferroalloys, contamination by sulphur and phosphorus of the metal deposited using wires with charge from pure metal powders. This is attributable to lower content of these elements in the powders of high-speed steel R6M5.

Comparative evaluation of welding and technological properties of experimental wires (Table 2) showed that they are at approximately same level. However, wires Nos 1 and 2 with the charge, consisting of granulated powder of PG-R6M5 grade, have 1.2–1.3 higher coefficients of melting and surfacing, compared to the analogue wire with the charge from ferroalloys. In the same way, wires Nos 1 and 2 have 2.9–4.2 times lower coefficient of losses at deposition, compared to analogue wire.

Analysis of the data on current and voltage, obtained during surfacing with experimental wires showed (Table 3) that the most stable is the process of surfacing with wire No. 1: it is characterized by the smallest range of value deviation from average current and voltage. The process of surfacing with analogue wire No. 3 with a ferroalloy charge, is characterized by the lowest stability, which, apparently, is attributable to the fact that the kinetics of the process of melting of flux-cored wire, which contains components of the same composition and type (PG-R6M5 granulated powder), and also having identical physical properties (density, melting temperature, electric conductivity, etc.) will be characterized by higher stability, compared to melting kinetics of the wire, the charge of which contains ferroalloys and other components, for which these characteristics are different [18].

Somewhat higher welding-technological properties of wire No. 1, compared to wire No. 2 (both having charge from R6M5 granulated powder) can be accounted for, in our opinion, by the difference in the particle size distribution of the used powders. In wire No. 1 powders, consisting of globular particles of 50–300 μm size were used, and wire No. 2 had the same particles, but of 200–250 μm (Figure 2).

It is obvious that at application of components of the same, rather large size (200–250 μm) for the wire charge, voids form between the components during manufacture, which may affect the kinetics of flux-cored electrode wire melting. At application of powders with a wide range of particle size distribution from 50 to 300 μm in the charge, a much smaller number of such voids form in the charge, that is related to a higher density and homogeneity of the flux-cored wire, which melts in a more stable manner.

CONCLUSIONS

1. A comprehensive comparative study of welding and technological properties of flux-cored wires for arc surfacing, in the charge of which materials of two different types — granulated powders and ferroalloys — were used, demonstrated that application of granulated materials in the flux-cored wire charge provides higher welding and technological properties, improvement of stability of arc surfacing process, quality of deposited metal formation and lowering of the content of sulphur and phosphorus impurities in them.

2. It was experimentally determined that the type of the initial charge components and their particle size distribution have a significant influence on the stability of arc surfacing process running, and, hence, they can affect the structure and service properties of the deposited metal.

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ORCID

I.O. Ryabtsev: 0000-0001-7180-7782
A.A. Babinets: 0000-0003-4432-8879,
I.P. Lentyugov: 0000-0001-8474-6819,
J. Niagaj: 0009-0001-6831-1548,
A. Czuprynski: 0000-0001-9337-8325

CONFLICT OF INTEREST

The Authors declare no conflict of interest

CORRESPONDING AUTHOR

A.A. Babinets
E.O. Paton Electric Welding Institute of the NASU
11 Kazymyr Malevych Str., 03150, Kyiv, Ukraine.
E-mail: a_babinets@ukr.net

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