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STABILITY OF MMA WELDING WITH PROTECTIVE COATINGS

STABILNOST RUČNOG ELEKTROLUČNOG ZAVARIVANJA NA ZAŠTITNIM PREVLAKAMA

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Keywords
- manual arc welding
- protective coating
- arc stability welding
- heat content
- weld pool
- microstructure

Ključne reči
- ručno elektrolučno zavarivanje (E postupak)
- zaštitna prevlaka
- zavarivanje stabilnim lukom
- toplota
- zavarivačko kupatilo
- mikrostruktura

Abstract

The paper presents outcomes of comprehensive research that examines the relevance of protective surface coatings on a product to be welded for such parameters as MMA welding stability, width of temperature fields on the surface of a welded structure, as well as structure and phase composition of the deposited metal. The experimental study has associated the use of a protective coating in MMA with an increase in certain characteristics - shortcut period of arc gap (5-11 %); bridging time (10-12 %); mass of transferred electrode metal droplets (up to 50 %); amplitude value of the welding current (25 %); size of a deposited metal grain; and a heat affected zone (15-25%).

Izvod

U radu su prikazani ishodi sveobuhvatnog istraživanja od značaja kod zaštitnih površinskih prevlaka na proizvodima koji su predviđeni za zavarivanje, s obzirom na parametre kao što su stabilnost pri zavarivanju E postupkom, širina temperaturskih polja na površini zavarene konstrukcije, kao i strukturni i fazni sastav metala šava. Eksperimentalno ispitivanje je obuhvatilo zavarivanje E postupkom na zaštitnoj prevlaki sa povećanjem karakteristika – perioda kratkog spoja električnog luka (5-11 %); perioda popunjavanja (10-12 %); mase unetih kapljica dodatnog metala (do 50 %); amplitude jačine struje (25 %); dimenzija zrna metala šava, kao i uvećanje zone uticaja toplote za (15-25 %).

INTRODUCTION

Splashing of the electrode metal represents one of the weaknesses of consumable electrode arc welding. As a result of this process, a great number of molten metal splashes (droplets) with a variety of sizes are ejected from an arc zone and initiate physical and chemical reactions with surface layers of a metal to be welded, which change its structure and phase state. When welding high-strength alloying steels under a droplet there is an annealed structure, seen as a stress riser, worsening operation properties of a construction. For instance, a protective surface coating is deposited to prevent splashing of molten metal when carrying out assembly and welding operations, /1/. Fig. 1 demonstrates the effect of a protective coating used in MMA.

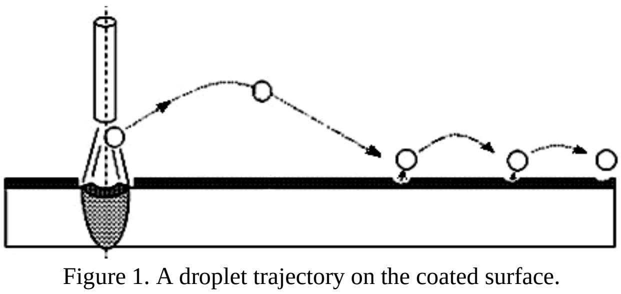


Figure 1. A droplet trajectory on the coated surface.

Previous research /2-4/ is focused on the effect of protective surface coatings on chemical composition of a weld and operational parameters of a welded structure in MMA. While other conditions are kept the same, protective surface coatings make a difference for these characteristics if deposited on the surface to be welded. At the same time there is little published data on the physical nature of structural formation, phase and chemical composition in welded joints, a lot of researchers explain this limited attention to this issue by stability of the welding and metal content in a weld pool. Criteria of stability parameters developed in /5/ can be useful for qualitative and quantitative assessment of welding stability.

Therefore, this study aims to identify the effect of protective coatings in welded structures on MMA stability.

METHODS OF EXPERIMENTAL RESEARCH

To eliminate the shortcoming described above we have developed a method of quantitative assessment of the welding working properties, /6/. For the purpose of research, we selected coated electrodes LB-52U, broadly applied in oil-refining and gas industries, and a specially developed protective coating /7/ and spray /8/.

Heat content of the weld pool metal can be determined according to patterns of heat field distribution (as stated in /9/). When fusion welding with protective coatings, a bead is formed manually by arc welding with coated electrodes LB 52U on 6 mm thick St37-2 steel plate of 100×150 mm. A power supply made according to the classic circuit of welding rectifier – VD-306E type (diode rectifier) was selected as a power supply for welding. Fields are registered by a thermal imaging camera. Filming is carried out at a speed of 5 frames per second.

Microstructure is analysed with the help of optical metallography on cross sections according to the plan (Fig. 2). A microscope Altami tooled with a digital camera is used. Cross sections are made by mechanical grinding, mechanical polishing with diamond paste AFM 10/7 NBL and chemical etching in aqua regia (40 % HCl + 40 % HNO_3 + 10 % C_2H_5OH).

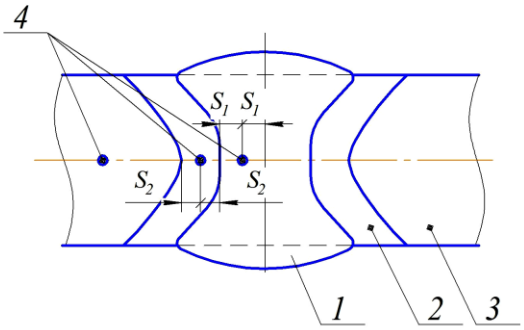
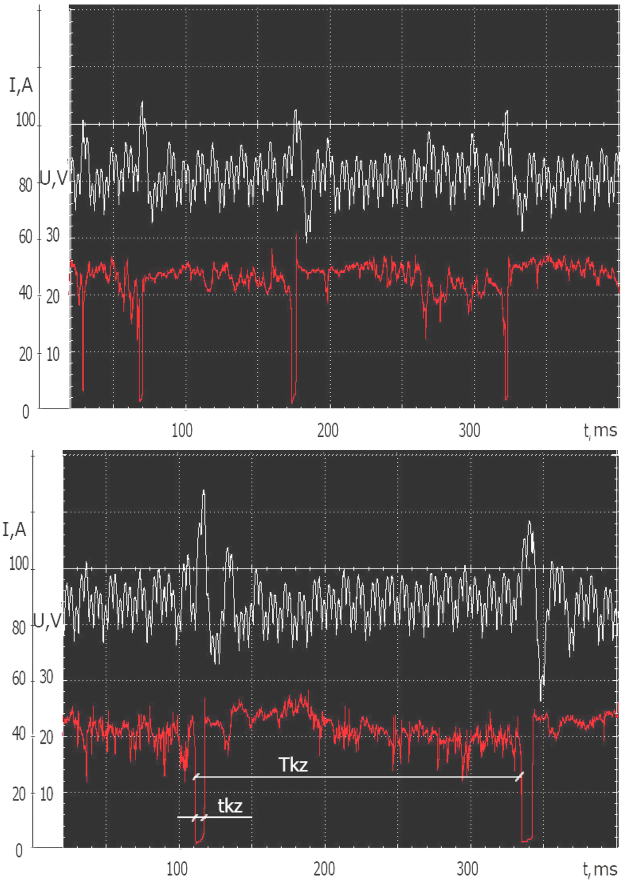


Figure 2. Plan of microstructural analysis: 1-weld metal; 2-heat affected zone; 3-base metal; 4-spots to be examined.

(a)

(b)



(c)

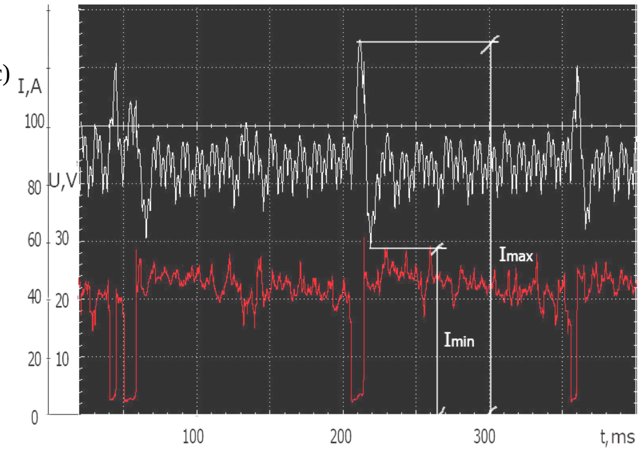


Figure 3. Oscillograms of current (89+2.7 A) and voltage (20.8+0.6 V) in MMA (estimated welding speed 0.25 m/min): (a) no coating; (b) developed protective coating, /7/; (c) spray, /8/.

RESULTS OF RESEARCH

Oscillograms of the welding current and voltage between electrode and work piece are recorded at MMA welding with protective coatings (Fig. 3), processed statistically and presented in Table 1.

Table 1. Statistically processed data on transfer parameters of electrode metal droplets.

Parameters	No coating	Protective coating	
		Developed coating /7/	Spray /8/
Short-circuit of arc gap τ_{kz} (ms) ± mean square root deviation of short-circuit duration $\sigma_{\tau kz}$ (ms)	6±1.9	6.3±2.54	8.7±1.85
Cycle duration T_{kz} (ms) ± mean root deviation of cycle duration, σ_{Tkz} (ms)	150±39.9	166±56.2	205±52.2
$I_{min,kz}$ (A)	58.5±3	57.1±5	61.4±4
$I_{max,kz}$ (A)	105±2	119±2	124±3
Droplet mass /10/, m (g)	0.0083 ±0.0002	0.0087 ±0.0005	0.0217 ±0.0005
Active droplet surface /10/, S (mm^2)	0.79±0.24	0.81±0.31	1.1±0.23

We analysed the obtained oscillograph charts for the current in the welding circuit and for the voltage between the electrode and the work piece (Fig. 3, Table 1) when applying power supplies with different type of energy conversion with consideration to:

- parameters of electrode metal drop transfer from the electrode surface: the longest time of bridging is ensured without coating (τ_{kz} = 6±1.9 ms) and the shortest - spray (τ_{kz} = 8.7±1.85 ms). Reduction of drop transfer time and increase of short circuits number when applying inverters proves that electrode metal is transferred by smaller electrode metal drops /6, 10/: the largest active droplet surface with a coating - spray (S = 1.1±0.23 mm^2), a minimum when welding without a protective coating (S = 0.79± 0.24 mm^2);
- maximal and minimal values of the welding current: the smallest value is ensured by welding without the coating

(46.5 A), and the largest – with developed coating (62 A). High peak values increase the rate of the power supply response to the natural disturbing influences of the short circuits of the arc space, which improves the stability of the welding process.

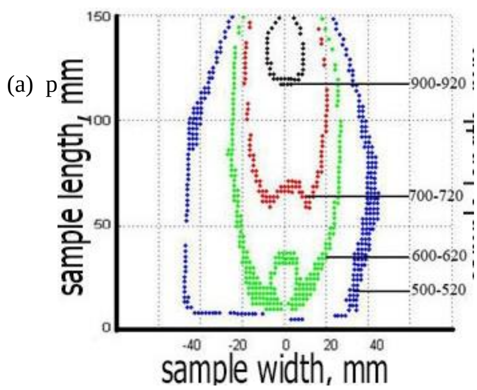
As seen in Table 1, there is 5-11 % increase in time of a droplet transfer and 10-12 % increase of cycle duration (period of formation and transfer). It suggests that electrode metal is transferred in larger drops, /11-14/. This regularity is possible since protective coatings deposited on edges to be welded form a film, which is a layer between an electrode and the work piece, being important for welding stability. The difference in mass-transfer parameters of the molten metal is to have an effect on the heat content of transmitted droplets of electrode metal, i.e. heat input onto the work piece to be welded.

Figure 4 demonstrates the heat distribution patterns of the welding, processed in MATLAB, presented as a set of m-files, /9/.

The difference in heat field distribution in welding with protective coatings (Fig. 4) is caused by large-drop transfer of electrode metal (Table 1). Studies /6, 9, 15/ suggest that the sizes of transferred electrode metal drops are relevant for the grain size in the welded structure. Furthermore, while drying up of a protective coating, a film is formed on the surface of the work-piece to be welded – acting as a 'heat cover', thus preventing heat dissipation from the work-piece surface and extending heat spreading along the entire surface.

The structure of welded metal, heat impact zone and base metal are given in Fig. 5.

The MMA weld metal (Fig. 5 a, b, c) tends to have a heterogeneous structure of columnar dendrites, typical for the as-cast state. Lengths of ferritic plates are: 50 μm (Fig. 5a); 1 mm (Fig. 5b) and 1.2 mm (Fig. 5c), and their width is 20 ± 0.5 μm (Fig. 5 a, b, c). A gap between plates is filled with smaller dendrites. Zooming it slightly, the ferritic plates consist of polyhedral grains of sizes: 12 ± 0.64 μm (Fig. 5a); 14.5 ± 0.28 μm (Fig. 5b); and 15.2 ± 0.28 μm (Fig. 5c). No other phases and structural components except ferrite are detected, being in line with the electrode LB 52U.



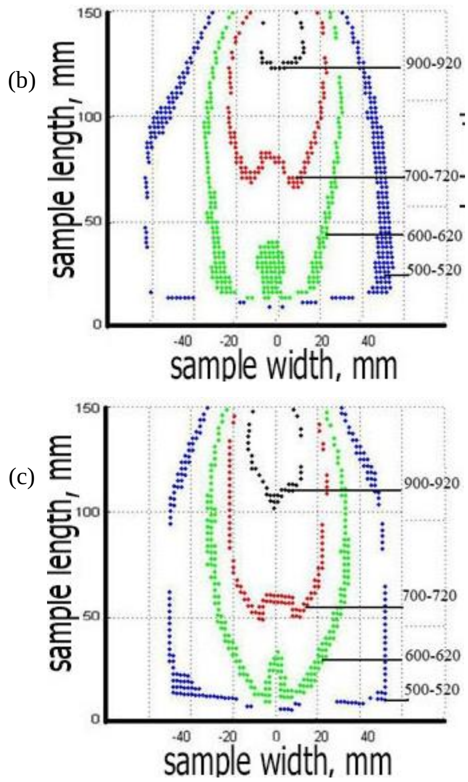
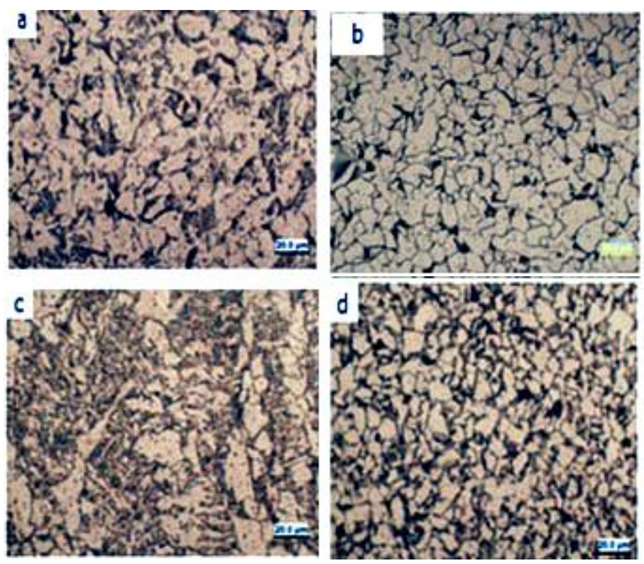


Figure 4. Processed heat fields: diode rectifier power source (current 89+2.7 A; voltage 20.8+0.6 V; estimated welding speed 0.25 m/min): (a) no coating; (b) developed protective coating /7/; (c) spray /8/.

In the heat affected zone of the weld (Fig. 5 d, e, f) the sizes of the ferritic grain are: 8.5 ± 0.32 μm (Fig. 5d); 10.3 ± 0.32 μm (Fig. 5e); 11.2 ± 0.4 μm (Fig. 5f). Pearlite is detected in the structure, and its amount is similar to that in the base metal (steel St37-2). Generally, the heat affected zone is 2 mm wide.

The base metal has a ferrite-pearlite structure (Fig. 5 g). The percentage of pearlite averages to 10-12 %, being in line with the chemical composition of St37-2 steel. Ferritic grains are polyhedral with well-formed sharp boundaries.



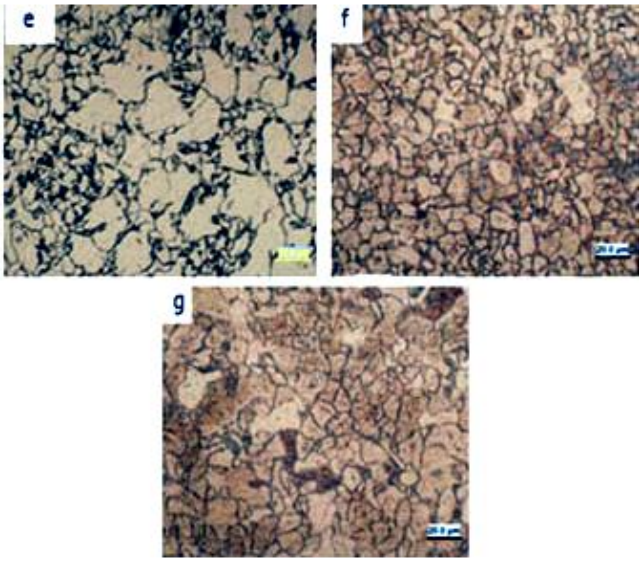


Figure 5. Microstructure photos of steel St37-2: a, b, c - weld; d, e, f - heat affected zone; g - base metal (a, d, g - no coating; b, e, g - developed coating, /7/; c, f, g - spray, /8/).

CONCLUSIONS

The study on the effect of a protective coating deposited onto edges to be welded in MMA has revealed an increase in:

- shortcut period of arc gap (5-11 %), bridging time (10-12 %); mass of transferred electrode metal droplets (up to 50 %); and amplitude value of the welding current (25 %) due to a film on the surface to be welded. This surface prevents electric contact between an electrode and a product to be welded;
- width of temperature fields on the surface (7 %), size of weld metal grain (15 %), and heat affected zone (25 %). Welds cool down more slowly because of a heat layer drying up on the surface of a protective coating when welding and prevent heat removal from the weld surface. Thus, structure components of the deposited metal tend to form differently.

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