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Method for predicting the composition of the protective coating in MMA

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Abstract. This article presents the results of experimental studies to determine the optimal coating composition for MMA. The optimization is based on the idea of multi-factor planning, which allows us to disseminate the obtained results not only on welding processes, but also related technologies.

1. 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/. Figure 1 demonstrates the effect of a protective coating used in MMA [1, 2, 9].

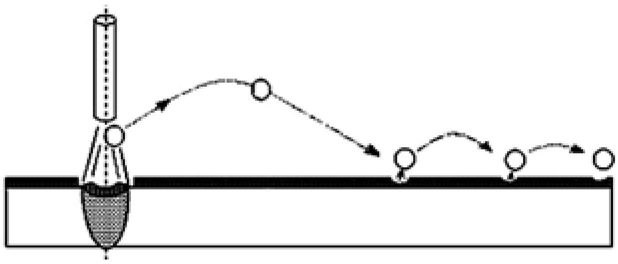

Figure 1. A droplet trajectory on the coated surface.

Research and analysis of the coatings used showed [3, 4] that there is no methodology for predicting the composition of the coating taking into account technological and rheological properties. The technique is especially relevant when developing coatings containing more than two components, since each component has its own functional purpose.

2. The main part

When developing and testing the methodology for predicting the composition of the coating, the known coating was taken as an analogue [5], having the following composition:

1) a binder – sulphite-alcohol stillage (LWC);
3) functional additive (to increase the viscosity of the composition) – Glycerin;
2) stabilizing substance (preventing the spread of putrefactive bacteria) – Furacilin.

The first and second components are introduced into the coating composition in the form of a solution, the third – in the form of a powder.

Optimization of the composition of the coating was carried out according to the following technological and rheological indicators:

1) a criterion indicator of protective properties (the number of hard-to-remove sprays) – β (%);
2) conditional viscosity – η_y (c).

Before starting the optimization of the coating composition, it was found that the parameters of the MMA mode affect the amount of hard to remove spatter. The research results showed that the maximum adhesion of the spray to the surface of the product is observed at a current strength of I_{CB}=100–120A and arc voltage Ud = 25V (coated electrodes with a diameter of 3 mm) [6], which were taken as the basis for optimizing the composition protective coating.

Each component was assigned the designation: binder (LWC) – X; furatsilin – Y; glycyrin – Z.

At the initial stage, the boundaries of changes in the X, Y, and Z components, as well as the change step (the results are shown in table 1) were experimentally determined. The number of components is given in grams per liter of water. The decisive factor in choosing the boundaries of the change in components was the correspondence of the behavior during shear of the coating, similar to the Shvedov – Bingham body [7]. The shear tests of the coatings were carried out using the setup described in [7].

Table 1. Determining the boundaries of component changes.

Component Change Boundaries	Parameter Change Step
$60<X<120$	ΔX=30
$0<Y<6$	ΔY=1
$60<Z<160$	ΔZ=20

When planning studies, the idea of factor planning was used [8]. The main condition for factor planning is to ensure the orthogonality of the used “Latin (magic) square” (factor experiment).

As a result, three values were considered for component X, six values for components Y and Z. Variants of factors are indicated with indices 1, 2, 3, ... (X_1, X_2, X_3, Y_1, Y_2, …, Y_6, Z_1, Z_2, …, Z_6). Variation of factors is given in table 2.

Table 2. Variation of factors.

	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6
Z_1	X_1	X_2	X_3	X_1	X_2	X_3
Z_2	X_3	X_1	X_2	X_3	X_1	X_2
Z_3	X_2	X_3	X_1	X_2	X_3	X_1
Z_4	X_1	X_2	X_3	X_1	X_2	X_3
Z_5	X_3	X_1	X_2	X_3	X_1	X_2
Z_6	X_2	X_3	X_1	X_2	X_3	X_1

In order to exclude the influence of systematic errors caused with external conditions, using a table of evenly distributed random numbers, the experiments were randomized. Next, experiments were conducted on the effect of components on the protective and viscous characteristics of the protective coating.

To find the optimal composition of the protective coating, the dimensionless function Φ was determined from the expression:

$$\Phi=\beta_D\cdot\eta_D, \tag{1}$$

where β_D is the dimensionless value of the protective property (difficult to remove spray); η_D – dimensionless value of conditional viscosity.

The dimensionless quantity for hard to remove sprays is found from the expression:

$$\beta_D = \frac{\beta_i}{\beta_c} \ , \tag{2}$$

where β_i is the actual value of the number of hard-to-remove sprays in the *i*-th experiment; β_C is the systemic value of the amount of hard to remove spatter (taken for welding without coating equal to 2.1% [4]).

Dimensionless value for conditional viscosity of protective coatings:

$$\eta_D = \frac{\eta_i}{\eta_c} \ , \tag{3}$$

where η_i is the actual value of the conditional viscosity of the protective coating during the *i*-th experiment; η_C is the systemic value of the conditional viscosity (we take for water equal to 10 by [7]).

To ensure reliable protection of the surface from splashes of molten metal during welding, parameter β should tend to a minimum. The ease of application of the protective coating is due to its low viscosity; therefore, the parameter η should also tend to a minimum.

Therefore, the optimal composition of the protective coating will correspond to the minimum value of the dimensionless function Φ (figure 2):

$$\Phi=\beta_D\cdot\eta_D\rightarrow\min$$

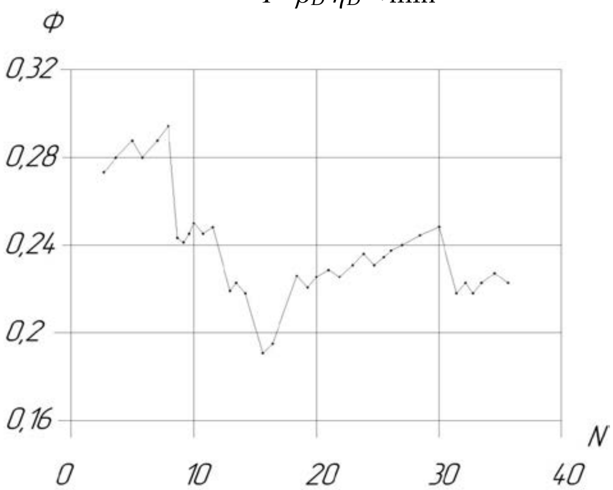

Figure 2. Determination of the optimal composition of the protective coating: Φ – dimensionless function, N – experiment number.

Based on a multivariate experiment on the influence of various components on the technological and rheological properties of the coating, the coating composition was obtained with combining factors X_2,

Y_4 and Z_3. The minimum value of the dimensionless function Φ was obtained at $N = 16$ (figure 2) (according to the order of implementation, the thirty-third experiment).

As a result, we obtained coating compositions that take into account technological and rheological properties (in grams per liter of water): coating 1 (optimized) – binder (LWC) – 80–100; Furacilin – 1–3; Glycerin – 90–110; coating 2 (corresponds to experiment number 5, figure 1) – binder (CBF) – 60–70; Furacilin – 1–3; Glycerin – 70–80.

Based on the results of further studies, it was established that the nature of the flow curve of coating 1 corresponds to the curve of the flow of the Shvedov – Bingham body, and the protective properties of the coating are necessary and sufficient, that cannot be said about coating 2.

For the obtained coating compositions, a study was carried out to determine the amount of spraying according to the method [4], the coating scheme for the parts to be welded is presented in figure 3.

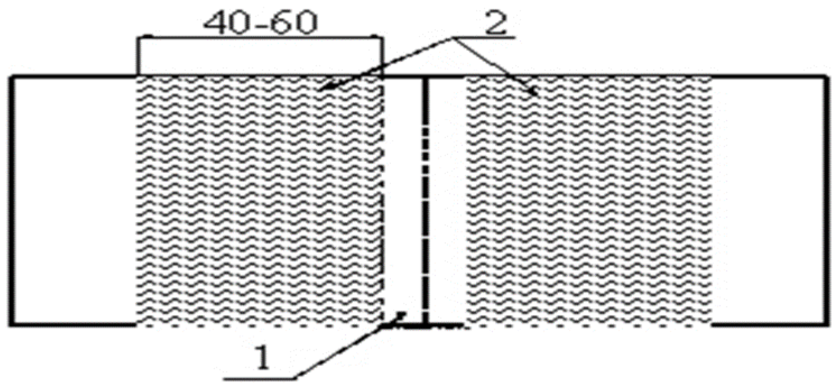

Figure 3. The scheme of applying a protective coating for MMA: 1 – weld; 2 – protective coating.

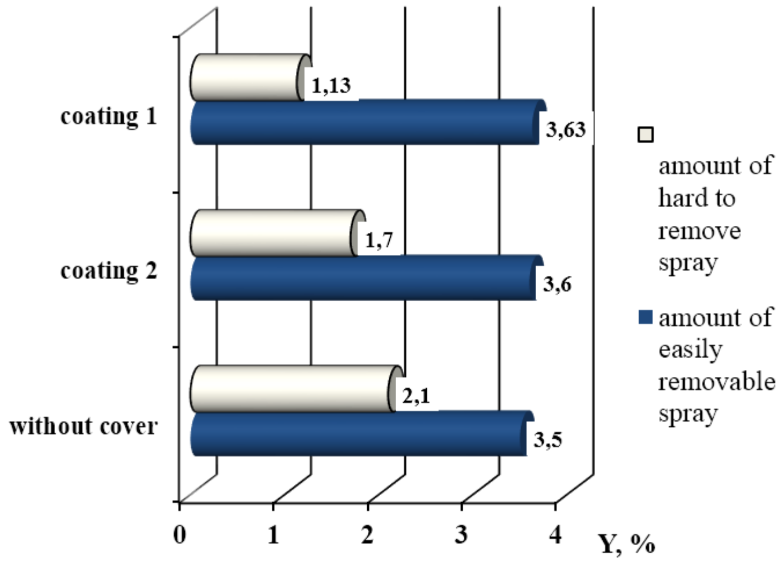

Figure 4. The effectiveness of the use of a protective coating with MMA coated electrodes UONI 13/55 (diameter 3 mm; I_{CB}=110 ± 4A; Ud = 25 ± 2V).

Analysis of the data presented in figure 4 shows a 47% reduction in the number of hard-to-remove droplets on the surface to be welded when using coating 1, in comparison with welding without coating.

3. Conclusion

The developed approach to predicting the coating composition for MMA is the foundation when creating a mathematical model for designing multifunctional coatings for various technological purposes: not only for welding production, but also for metallurgy (non-stick coatings) and other related technologies.

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