OPTIMISATION OF PARAMETERS OF ADDITIONAL GAS SHIELDING IN SUBMERGED ARC WELDING AND SURFACING OF COPPER AND ITS ALLOYS

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The paper presents the results of evaluation of influence of a combined shielding on gas saturation of metal at the stage of a drop and a pool in welding and surfacing of copper and its alloys. Parameters of the process of submerged arc welding and surfacing using an additional gas shielding were optimized. A new method of a pulsed supply of shielding gas into the arc zone in submerged arc welding and surfacing was developed.

Keywords: *arc welding, submerged arc surfacing, copper and copper alloys, gas shielding, hydrogen, porosity prevention*

Automatic submerged arc welding and surfacing of copper and its alloys is one of the prospective methods of manufacturing both elements of metallurgy equipment as well as producing of bimetallic products from copper–bronze and steel–bronze [1–4].

Nowadays, for welding and surfacing of copper and copper alloys the fused fluxes AN-60, AN-20P, AN-26P, AN-348-A, OSTs-45 and other, developed for welding of steels, are used. However, even keeping all technological recommendations (calcination of fluxes, mechanical cleaning, degreasing of wire and base metal) they do not always provide the required density of metal. It is known that efficient measure of preventing porosity is the decrease of a partial pressure of hydrogen in the arc atmosphere. It can be achieved due to both its binding into compounds and also adding of other gases into the arc atmosphere [5, 6].

This wok evaluates the influence of additional gas shielding on gas saturation of metal at the stage of a drop and a pool, quality of welds of copper, copper with steel and surfacing of copper alloys on steel and copper.

To select the optimal scheme of gas supply to the arc zone, two methods were tested: through the copper nozzle and through a copper tube located horizontally. As an additional shielding the nitrogen was used (300–700 l/h consumption), which was supplied in a continuous mode. During supply of shielding gas using the first method the diameter of a nozzle (from 10 to 20 mm) and distance from its end to the base metal (from 10 to 30 mm) were changed, while at the second method the diameter of tube (from 3 to 10 mm), inclination angle (from 0 to 30°) to the horizon, distance from the outlet hole to the electrode (from 10 to 30 mm), to the base metal (from 5 to 15 mm) were changed. The external pores were determined visually. The presence and character of location of inner defects were studied on macro- and microsections. Tendency of deposited metal to the porosity was estimated according to the quantity of dense beads.

As the carried out experiments showed, during supply of shielding gas through the nozzle the positive effect was achieved only when the lower edge of nozzle was in a molten slag and favorable conditions were created for shielding gas to get into the zone of arc. However it leads to shunting of welding current, violation of the process stability and deterioration of bead formation.

During supply of shielding gas through the gas-supplying copper tube the best results were obtained when it was positioned ahead the arc or on the side at the angle of not more than 5–10° to the horizon, its end was located in the molten slag. The optimal diameter of the tube was 4–6 mm. While selecting the most effective shielding environment the nitrogen, argon and carbon dioxide were tested.

To study mechanism of influence of additional gas shielding on the porosity, the gas saturation of metal at the stages of a drop and a pool was determined. For this purpose the content of hydrogen was determined in drops of electrode metal, remaining at the ends of electrode after interruption of welding, and in «pencil samples» after sampling by drain of a pool metal through a hole in the specimen. The liquid metal entered the dismountable copper mould of 10 mm inner hole diameter. Fixation of gases dissolved in liquid metal occurs as a result of high rate of samples crystallization. Specimens manufactured of «pencil samples» and drops of electrode metal were analyzed in the LECO unit RH-2 to determine the content of residual hydrogen in them. The surfacing was performed using wire of the BrAMts9-2 grade under flux AN-26P on 10 mm thick plates of bronze of the BrAMts9-2 grade. During welding of copper of 10 mm thickness the wire of the BrKh07 grade and flux AN-348-A were used, in welding of copper with steel of 10 mm thickness the wire of the MNZhKT5-1-0.2-0.2

grade and AN-60 flux were used. The consumption of argon, nitrogen and carbon dioxide was 500 l/h. Gas was supplied in a continuous mode through the 5 mm diameter copper tube, positioned ahead the arc at the angle of 10° to the horizon. The distance from the outlet hole to the electrode was 12 mm, and to the surface of specimens — 7 mm.

It was established that application of additional gas shielding allows reduction of saturation of liquid metal with hydrogen at the stage of a drop and a pool (Figure 1) that stipulates the decrease of porosity in welds and deposits.

In welds and deposits performed with additional gas shielding the porosity was absent in all cases. Without application of additional gas shielding in welding copper and copper with steel the single pores were observed in welds, and in surfacing of bronze the noticeable porosity was observed.

Figure 1 shows that the content of hydrogen in a molten pool is much lower than in electrode metal drops that is probably due to a partial degassing of the pool.

To study the effect of additional gas shielding on the porosity of deposited metal, the method of multilayer deposition was applied, when in each next bead the tendency of deposited metal to porosity is increased. The deposits were made with wire of the BRAMts9-2 grade under the flux AN-26P on copper and steel specimens of 15 mm thickness. A copper tube of 5 mm diameter was set at the distance of 10 mm from the electrode ahead the arc. The angle of inclination to the horizon was 5°, and distance from outlet hole to the surface of specimens was 5 mm. As an additional shielding, the argon, nitrogen and carbon dioxide were used which were supplied in a continuous mode, changing the consumption from 100 to 900 l/h. The data about the effect of additional gas shielding on the porosity of deposited metal are given in Figure 2.

As the carried out experiments showed, with increase of gas consumption the resistance of deposited metal against pores formation was increased. However, at consumption of more than 800 l/h the breaks of slag bubble are observed, that leads to the violation of stability of arc burning process, increased spattering of metal and deterioration of beads formation. During consumptions of less than 200 l/h the uniform gas supply is not provided due to the tube sealing with a slag.

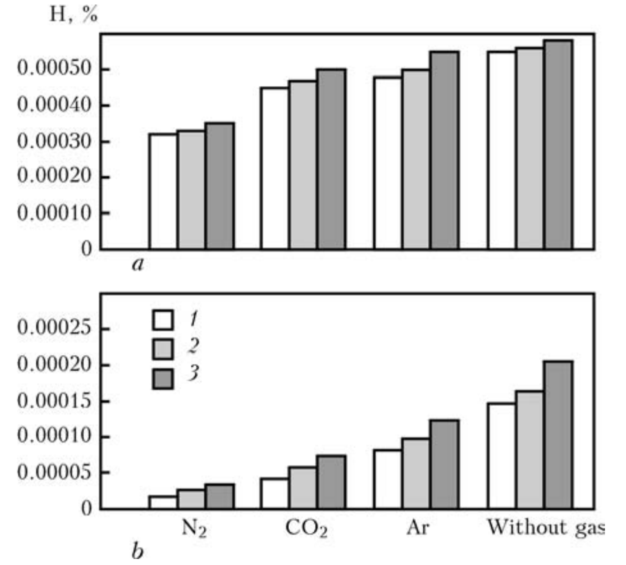

Figure 1. Influence of shielding gas on the hydrogen content in drops of electrode metal (*a*) and metal of weld pool (*b*): *1* — wire of the BrAMts9-2 grade; *2* — BrKh07; *3* — MNZhKT5-1-0.2-0.2

The best density of the deposited metal is achieved in use of carbon dioxide as an additional shielding, which does not only dilute the arc atmosphere, but also, having oxidation ability, it binds hydrogen additionally.

The high efficiency of nitrogen as a shielding gas, as compared to argon, is probably can be explained, on the one hand, by a content of admixtures of oxygen in commercial nitrogen (from 0.5 to 5 %), which binds hydrogen, and on the other hand — by the better conditions of degassing the weld pool. Here the evolution of nitrogen bubbles is possible which can serve as nuclei of pores and leads to porosity at lower hydrogen contents in liquid metal.

To decrease consumption of shielding gas the comparative tests on supply of shielding gas in pulsed and continuous modes were carried out. In experiments the inclination angle of gas pipeline was changed from 0 to 15°, the distance from outlet hole of gas pipeline to the base metal — from 3 to 9 mm, frequency of pulses — from 0 to 1.5 Hz, consumption of shielding gas — from 250 to 800 l/h.

The testing of method of shielding gas supply through the copper tube in a pulsed mode showed that

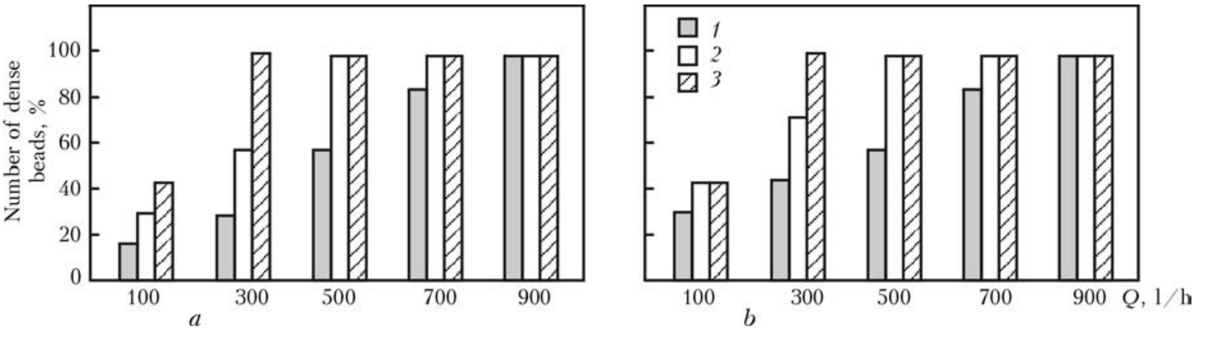

Figure 2. Influence of gases content and their consumption on the resistance to porosity in surfacing of bronze BrAMts9-2 under the flux AN-26P on the copper (*a*) and steel (*b*): *1* — Ar ; *2* — N_2; *3* — CO_2

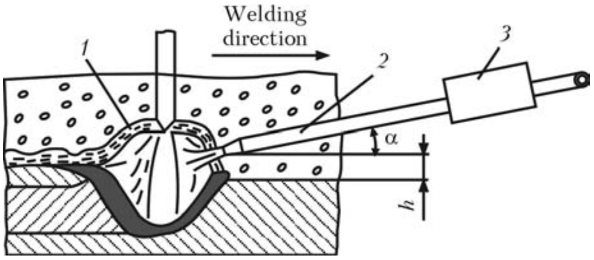

Figure 3. Scheme of the method of shielding gas supply (designations see in the text)

at certain parameters of a pulsed supply, a significant decrease in consumption of shielding gases, improvement of stability of welding and surfacing processes at a guaranteed absence of pores in welds and deposited metal can be reached.

On the basis of carried out experiments the method of shielding gas supply to the arc zone in a pulsed mode, schematically shown in Figure 3, was developed. A gas pipeline *2*, made in the form of a tube, is arranged on the boundary of flux fusion *1*. Gas can be supplied to the welding zone both in continuous and pulsed modes by means of device *3*.

The output diameter of gas pipeline is selected in the limits of one diameter of electrode and positioned at the distance of 5–7 mm from the surface of a part being welded, and gas pipeline is arranged at the angle of 5–1° to the horizontal plane. The duration of a pulse of gas supply is set in the volume of 40–60 % of duration of a selected period of gas supply. The increase or decrease of inclination angle of gas pipeline to the horizontal plane leads to deterioration of weld formation, spattering of metal in welding and surfacing, overlap formation, violation of stability of welding and surfacing process, and also appearing of porosity in welds and deposited metal. At setting the distance from outlet hole of a gas pipeline up to the surface of a part being welded of less than 5 mm the cases of its sticking to the metal surface are possible and with increase of this distance by more than 7 mm a jet of shielding gas can be spread in the flux above the molten film of a slag. Here, the partial pressure of hydrogen is not reduced, which results in appearance of porosity in deposited metal. The frequency of gas pulsation is set in the limits of 0.75–1.25 Hz. Decrease in pulses frequency leads to appearing of porosity in deposited metal, and increase in frequency leads practically to continuous gas supply and increase of its consumption. Decrease or increase in ratio of duration of a pulse to the duration of the whole period of pulsation from 40–60 % leads to porosity in the deposited metal of a weld.

The experimental data are generalized in the Table, where results of surfacing by the bronze wire BrAMts9-2 of 4 mm diameter on the specimens of copper of M1 grade under flux AN-26P at different consumptions of argon shielding gas are given.

At a pulsed shielding gas supply the periodical break of a film of molten flux is achieved and gas, directly getting into the arc zone, decreases the partial pressure of hydrogen in it with a dynamic effect on the molten metal and thus facilitating the evolution of hydrogen, dissolved in it.

As is seen from the Table, the keeping of the above-mentioned optimal parameters of a pulsed gas supply through the copper tube allows obtaining the stable process of surfacing, dense beads with a good formation at lower consumptions of shielding gas in comparison with its supply in a continuous mode.

Influence of parameters of shielding gas supply and technological factors on the quality of welds

Pulse frequency f, Hz	Angle of inclination of gas pipeline α, deg	Height of gas pipeline over base metal, mm	Shielding gas consumption Q, l/h	Quality		Presence of pores
				Stability of process	Bead formation	
0.50	5	5	250	Satisfactory	Satisfactory	Pores
0.75	7	5	250	Good	Good	No pores
1.00	5	6	250	Excellent	Excellent	Same
1.25	5	7	250	Same	Good	»
1.50	5	5	250	»	Same	Single pores
1.00	0	5	250	Satisfactory	Unsatisfactory	No pores
1.00	10	5	250	Good	Good	Same
1.00	15	5	250	Satisfactory	Satisfactory	Single pores
1.00	7	3	250	Unsatisfactory	Unsatisfactory	Pores
1.00	7	9	250	Good	Satisfactory	Same
–	5	5	250	Excellent	Excellent	»
–	5	5	300	Same	Same	»
–	5	5	400	»	»	»
–	5	5	500	»	»	»
–	5	5	600	»	»	Single pores
–	5	5	700	»	»	Same
–	5	5	800	»	»	No pores

Comprehensive testing of this method in welding of copper and copper with steel, multilayer surfacing on copper and steel, bronzes of the BrAMts9-2, BrKMts3-1 types under the fluxes of AN-26P, AN-20P, AN-60, AN-348-A, OSTs-45 grades showed that application of combined shielding provides dense welds and deposited metal in all cases.

The method of combined shielding has passed the industrial tests in welding of copper with steel under flux as applied to the manufacturing of blast furnace tuyeres with thickness of edges being welded of 5–10 mm, and also in deposition of bronze on steel under flux on circumferential surfaces with the purpose to increase the operability and service characteristics of bimetal products, that allows it to be recommended for the industrial implementation.

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HALF-CENTURY ANNIVERSARY OF THE FIRST EXHIBITION OF ACHIEVEMENTS OF WELDING PRODUCTION

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50 years ago (since 12 July till 3 October, 1960) the exhibition «Implementation of advanced welding technology into national economy of the USSR» took place in Moscow at the Exhibition of Achievements of National Economy in the pavilion «Machine building» at the area of above 6000 m^2, where more than a thousand of exhibits (full-scale specimens, mockups and posters) was shown. According to the scales of demonstration of development of welding production in the single country the exposition had no equals. By that time in the USSR not only world-famous methods of welding and related technologies were successfully applied, but also a number of principally new methods of joining were developed. Therefore, it can be considered that the exposition illustrated the world level of welding technology for the end of the first half of the XX century. It was namely the period when welding became the most widely applied in mak-