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EFFECTIVENESS OF COMBINED GAS-SLAG PROTECTION AT MIG DEPOSITION OF COPPER ALLOYS ON STEEL

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ABSTRACT

A complex of investigations was performed to study the technological capabilities for application of combined gas-slag protection in MIG-process of copper alloy deposition on steel. It is shown that at semi-submerged arc surfacing (by semi-open arc) it is possible to control the technological characteristics of the welding arc, namely: increase its spatial stability, improve the pattern of electrode metal transfer (essentially reducing its spattering fraction), as well as provide a high-quality protection of the deposits from oxidation. Application of such a combined protection is particularly rational at a highly efficient process of two-electrode MIG surfacing.

KEYWORDS: copper alloys, combined gas-slag protection, spatial stability of the arc, two-electrode surfacing, deposited metal quality

INTRODUCTION

Copper alloys are widely used in various fields of mechanical engineering. In order to increase the structural strength of products and save precious nonferrous metals, bimetal products steel + bronze are often used. The most common method to produce such parts is the mechanized and automated consumable electrode arc surfacing in shielding gases (MIG-process) [1, 2]. At the same time, to provide minimal penetration of steel and a slight transition of iron into the deposited metal, surfacing is performed on low current densities, which leads to a decrease in the process stability and a significant spattering of the electrode metal. Taken into account the high tendency of bronze (especially aluminium and silicon) to oxidation, a need arises to use more reliable protection of welding pool from air. It is typical that in surfacing of silicon bronzes even applying such an advanced process as CMT Brazing of the Fronius Company with the use of CuSi wire, on the metal surface, a film of a thin layer of silicates and oxides, that are poorly removed from the surface, is observed [3, 4].

The mentioned disadvantages are especially revealed in a high-efficiency two-electrode MIG-process of surfacing, in which the volume of molten metal increases and requires creating additional conditions for its protection from environmental impact. In connection with that, the problem of studying technological capabilities of using a combined gas-slag protection in automated arc processes when the process of melting and transfer of electrode metal occurs in a gas-protective environment and the weld pool metal is additionally protected by molten flux.

It should be noted that in the practice of welding production, the use of combined gas-slag protection is successfully realized in manual welding using coating electrodes and mechanized and automated welding using flux-cored wires [5–7].

RESEARCH MATERIALS AND EQUIPMENT

The studies were carried out using specimens of steel of grade St.20 of 200×300×14 mm. The welding wire is bronze BrKMts3-1 of 1.2 mm diameter. As a shielding gas, argon of the first grade was used. The molten glass-type fluxes of general purpose of grades AN-60SM, AN-20S, AN-26S, as well as the agglomerated flux UV420 TT of the Böhler Thyssen Company were evaluated.

The installation for surfacing is equipped with a mechanism for feeding two wires, which provided the process of surfacing with both one and two electrodes connected to a one power source (the so-

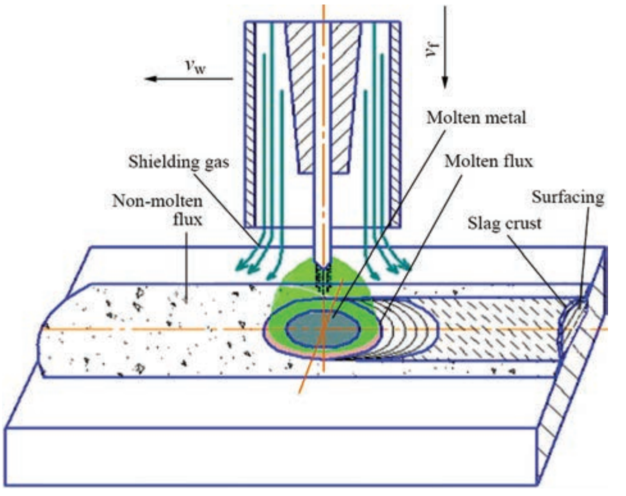


Figure 1. Scheme of surfacing process with a combined gas-slag protection

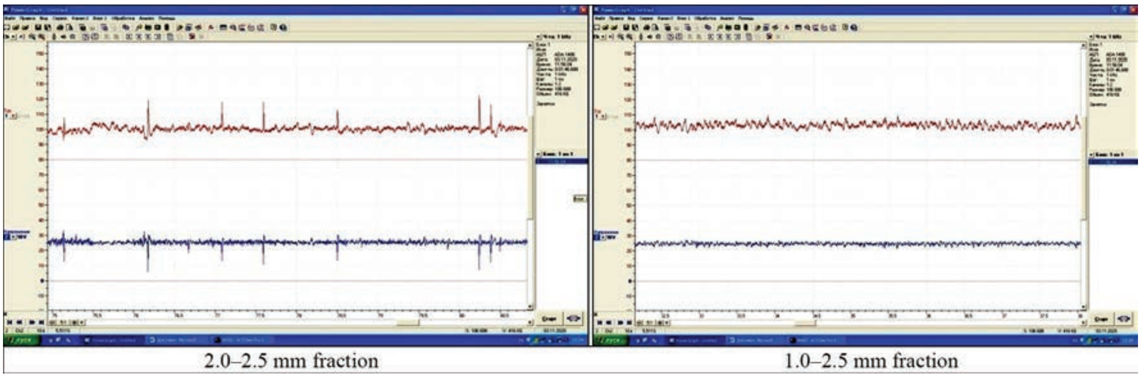


Figure 2. Osclograms of surfacing processes using flux AN-60SM of different granularity

called split electrode). The power source is rectifier VDU-506. The laboratory equipment is fitted with a registration and measuring complex on the base of an analogue-digital converter ADA-1406, which makes it possible to monitor the actual parameters of the surfacing process and to study the technological properties of welding arc.

The scheme of surfacing process with a combined gas-slag protection is shown in Figure 1.

EXPERIMENTAL STUDIES AND RESULTS

The principal possibility of MIG-process of surfacing bronze with a combined protection (over a flux layer) was evaluated during the one-electrode process. As the experiments showed, during traditional shielding gas consumptions, at the exit from the nozzle, its pressure can blow the flux away, which leads to a deterioration of the quality of deposits. It was determined that boundary argon consumptions should not exceed 15 l/min.

In order to choose the optimal grade of flux, the impact of different fluxes on the stability of MIG-process of surfacing, formation of deposited metal, separation of slag crust and metallurgical quality of deposits (presence of pores) were studied.

Table shows the appearance and geometric dimensions of deposited beads, produced using fluxes of grades AN-60SM, AN-20S, AN-26S and agglomerated flux UV420 TT.

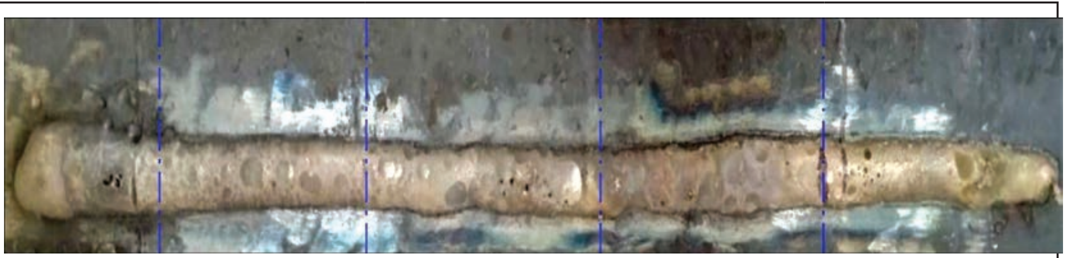
As the experiments showed, in surfacing bronze BrKMts3-1 on steel with additional slag protection, the best results as for deposited bead formation, separation of slag crust and quality of deposited metal were obtained when using manganese-silicate flux AN-60SM. It was found that the highest stability of the process is observed while using fine-grained flux with the grain size of 1.0–2.5 mm (Figure 2).

To determine the optimal amount of flux, the height of its layer was changed in the range 4–8 mm, the rest of the process parameters was not changed (I_w = 180–200 A, U_a = 24–25 V, v_w = 10 m/h, electrode stickout is 12 mm, Q_{Ar} = 15 l/min). The best results on the process stability were recorded when using a flux layer of 6.0 mm height, which is evidenced by the oscillograms of current and voltage (Figure 3).

In addition to increased stability of the surfacing process, at the height of the flux layer of 6.0 mm, spattering of electrode metal is also absent and a high quality of bead formation is observed. In this case, the arc is semi-open, a thin film of the slag covers the entire surface of the bead, as a result of which, it has a not oxidized "shiny" appearance, which is typical for bronze (Figure 4).

In addition, when using a combined protection at the same modes, the shape of beads changes: the height of beads increases and they are getting narrow in the cross-section. In our opinion, such effect of flux

Table 1. Appearance and geometric dimensions of beads depending on flux grade

Geometric dimensions of beads					
Protection	Ar	Ar + AN-60SM	Ar + AN-20S	Ar + AN-26S	Ar + UV420TT
Bead width, mm	16–17	14–15	13.5–14	13.5–14	12–13
Bead height, mm	3–3.5	3.5–3.8	4–4.5	4–4.5	4.2–4.6
Penetration depth, mm	0.3–0.6	0.4–0.45	0.4–0.6	0.35–0.45	0.35–0.45

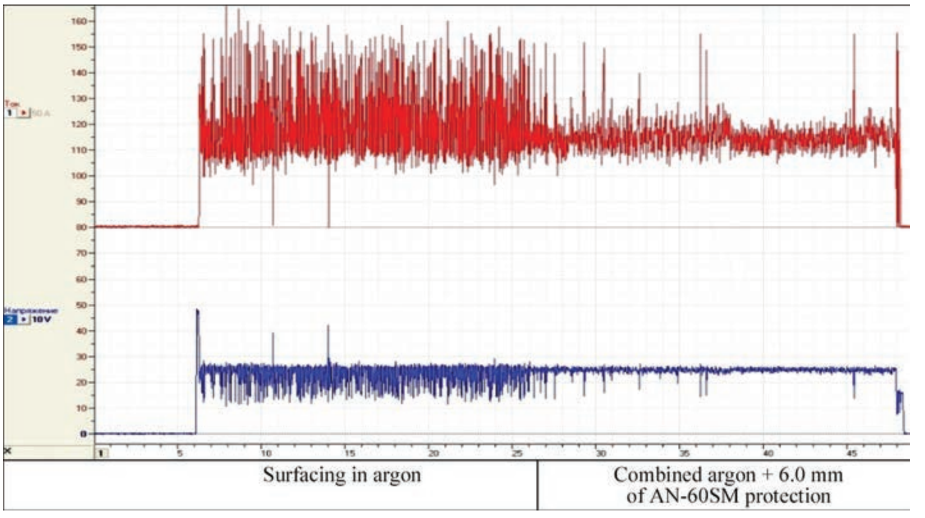


Figure 3. Oscillograms of current (*a*) and voltage (*b*) of the process of surfacing bronze BrKMts3-1 at a combined argon + flux AN-60SM protection

on the formation of deposited beads occurs due to the improvement of a spatial stability of the arc, predetermined by the presence of the film of molten flux on the edges of the pool and in its tail part, which stabilizes the position of the cathode spot on the surface of the welding pool. The quality of beads can also be affected by surface tension on the boundary molten slag–liquid metal–solid backup.

As was noted above, the need in additional protection of molten metal is especially relevant for the two-electrode MIG-process of surfacing bronze. The previously developed and mastered [2] technologies of surfacing bronze by a "split electrode" were focused on the processes with the wires of 2.0–3.0 mm diameter with the use of flux or argon as a welding pool protection.

A complex of studies on the influence of mode parameters on the process of two-electrode surfacing using a wire of 1.2 mm diameter with the use of a combined argon + flux protection was performed. Considering that along with the basic mode parameters (current, voltage on the arc, speed of surfacing), distance between the electrodes has a significant impact on the penetration of steel and the shape of the deposited bead. A number of experiments were performed in order to optimize this parameter for wires of 1.2 mm diameter.

In the proceedings [2], that present the results of argon-arc surfacing of aluminium bronze BrAMts9-2 of 2 mm diameter by a "split electrode", for the oriented choice of optimal value of the interelectrode distance, it is recommended to take the distance equal to three electrode diameters.

In our experiments, the distance between the electrodes varied from 3.6 to 8.0 mm. The experiments were performed by surfacing of individual beads and each subsequent bead was deposited after a complete cooling of the plate.

Surfacing mode: I_s = 200–240 A; U_a = 28–32 V; v_s = 12 m/h; Q_{Ar} = 15 l/min, height of the layer of flux AN-60SM is 6 mm.

Figure 5 shows macrosections of cross-sections of the beads, deposited at a different interelectrode distance. It is clearly seen that with an increase in the interelectrode distance, the shape and degree of penetration of the base metal change. This change is predetermined by the peculiarities of welding arc burning, melting and transfer of electrode metal in the two-electrode process.

At optimal values of an interelectrode distance, an alternate arc burning at each electrode is observed, which provides a scattered heat input across the width of the pool and, accordingly, the minimum penetration of the base metal.

Figure 4. Appearance of deposited beads: *a* — surfacing in argon; *b* — argon + 4.0 mm of flux AN-60SM; *c* — argon + 6.0 mm of flux AN-60SM

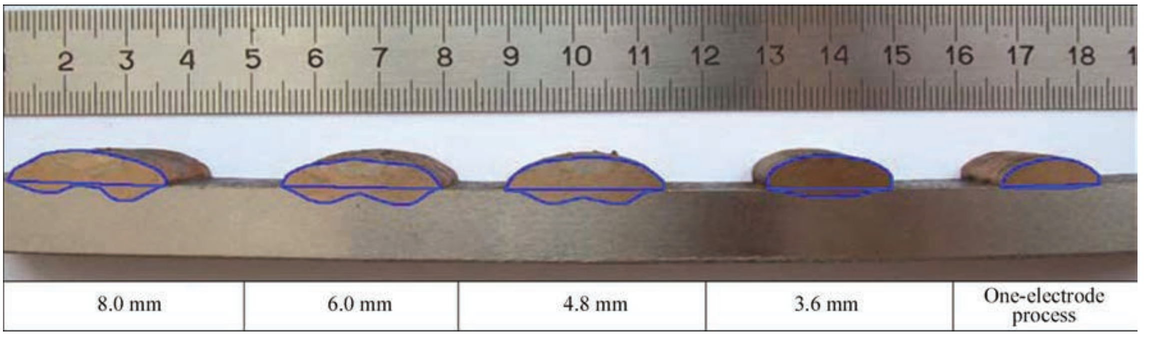


Figure 5. Cross-section of deposited beads at different interelectrode distance

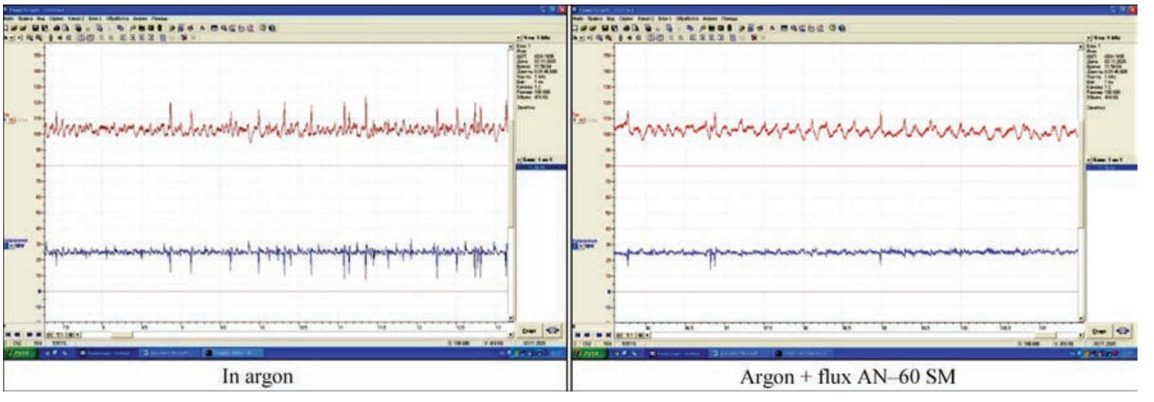


Figure 6. Oscillograms of two-electrode process of surfacing bronze BrKMts3-1 of 1.2 mm diameter on steel in argon and with a combined protection

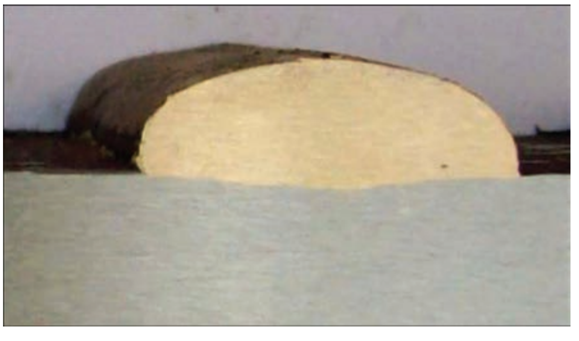


Figure 7. Transverse macrosection of deposited bead of bronze at optimal modes (×2)

It should be noted that at an interelectrode distance of up to 4.0 mm, the process of two-electrode surfacing with a combined gas-slag protection is also characterized by an increased stability (Figure 6), which guarantees producing of well-formed deposits.

Considering that the two-electrode process allows improving the efficiency of surfacing by 1.5–1.7 times (up to 3.0–3.2 kg/h for the wires of 1.2 mm diameter, additional slag protection of welding pool provides a high quality of deposited metal (Figure 7).

CONCLUSIONS

1. As a result of experimental studies, it was established that the use of a combined gas-slag protection improves technological properties of the welding arc, namely its spatial stability due to the presence of shielding molten slag, affects the pattern of the transfer and the degree of electrode metal spattering, provides a high-quality formation of deposited bronze with its typical “shining” surface.

2. The best results of MIG-process of surfacing bronze BrKMts 3-1 using a wire of 1.2 mm diameter with a combined gas-slag protection were obtained when as an additional slag protection, the flux of grade AN-60SM with 6 mm height of the layer was used.

3. The special rationality of using combined gas-slag protection in the two-electrode MIG-process of surfacing copper alloys in order to better protect the volumes of molten metal and welding pool against oxidation, which were increased as compared to the one-electrode process, was shown. The basic parameters of the two-electrode MIG-process of surfacing with a combined protection of the wire of 1.2 mm diameter are optimized. Also, the optimal interelectrode distance was determined, which provides a slight penetration of steel and minimal mixing of base and deposited metals at the selected values of current and speed of surfacing.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest

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