

Characteristics of droplet transfer of electrode metal during MMA depending on the chemical composition of the material of the rod of the coated electrode

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Abstract. This article presents the results of experimental studies of the effect of the coated electrode material for MMA welding on the droplet transfer parameters of electrode metal. It has been established that the use of coated electrodes based on copper (OZCH-4) and aluminum (Castolin EC 4001) alloys, compared to traditionally used metal rod based electrodes (Sabaros me20|10, LB-52U), affects the mass transfer characteristics of droplets electrode metal, in the form of an increase in the average duration of arc burning at intervals of melting of the electrode and the period of formation of drops of electrode metal up to 4 times.

1. Introduction

Over the past three years, a stable level of production and consumption of coated electrodes has been observed in Russia. In 2019, 99 296.7 tons of coated electrodes for MMA were produced in Russia, which is 3.4% more than the previous year's production volume [1].

It was established in [2–6, 9] that the grade of the coated electrode for MMA welding with coated electrodes intended for welding steels, namely the chemical composition of the metal rod and coating, have a significant effect on the parameters of the transferred droplets of the electrode metal during welding, and, accordingly, on received performance characteristics of welded joints. However, data on the influence of the chemical composition of the electrode rod, which includes non-ferrous metals, on the characteristics of droplet transfer during MMA are absent.

Objective: to determine the effect of the chemical composition of the coated electrode rod for MMA on the stability of melting and transfer of electrode metal into the weld pool, as the main indicators of heat and mass transfer of the welding process, affecting the operational and strength properties of the formed permanent joints.



It was established in [2, 7] that the main parameters for assessing the stability of heat and mass transfer during arc welding with a consumable electrode are:

- the duration of the short circuit of the arc gap, $\tau_{k.3.}$, ms;
- the duration of the cycle (the period of formation and transfer of the droplet), $T_{k.3.}$, ms;
- values of currents: maximum – I_{max} and minimum I_{min} , A;
- current slew rate: V increase I_{sb} , and V decrease I_{sb} , A / s.

2. Experimental part

A comparative assessment of the stability of the welding process and the droplet transfer parameters of the electrode metal was carried out with building up rollers on the surface of the plates of the material for welding which they are intended.

The following ones were selected as coated electrodes for the experiment: Castolin EC 4001, OZCh-4, Sabaros me20 | 10, LB-52U (table 1).

Surfacing was carried out using a classic power source for MMA welding – welding rectifier VD-306.

Oscillograms of the current in the welding circuit and the voltage between the electrode and the product recorded changes in the energy characteristics of the surfacing mode (figure 1) and are presented in table 1.

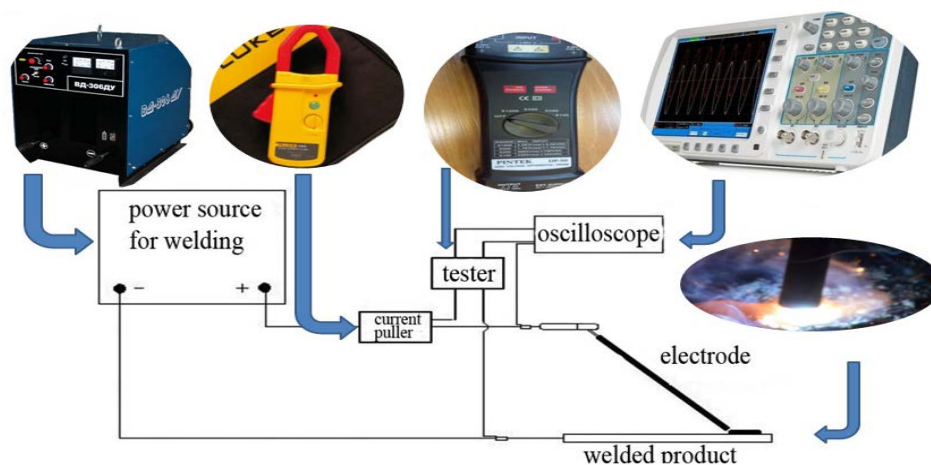


Figure 1. Experimental procedure to determine stability criteria for MMA welding [4].

Table 1. Welding conditions for different electrodes and power sources.

Electrode	Material to be welded	Average values of parameters (oscilloscope AKIP -4122/1V)
Castolin EC 4001	Aluminum	Current 90.7 ± 2.7 A; Voltage 20.7 ± 0.6 B
OZCh-4	Cast iron	Current 90 ± 2.7 A; Voltage 23.5 ± 0.6 B
Sabaros me20 10	Austenitic steel	Current 86.7 ± 2.5 A; Voltage 24.5 ± 0.6 B
LB-52U	Low alloy steel	Current 89 ± 2.7 A; Voltage 20.8 ± 0.6 B

Studying the stability of arc burning (figure 2) of the electrodes under consideration (table 1) was carried out according to the method described in [2, 4] based on a comparison of current and voltage waveforms (figure 3) obtained using: an AKIP-4122/22 digital storage oscilloscope; differential probe "Pintek Electronics" DP-50 "; "Fluke i1010" clamp meters and the "OWON_Oscilloscope" program.

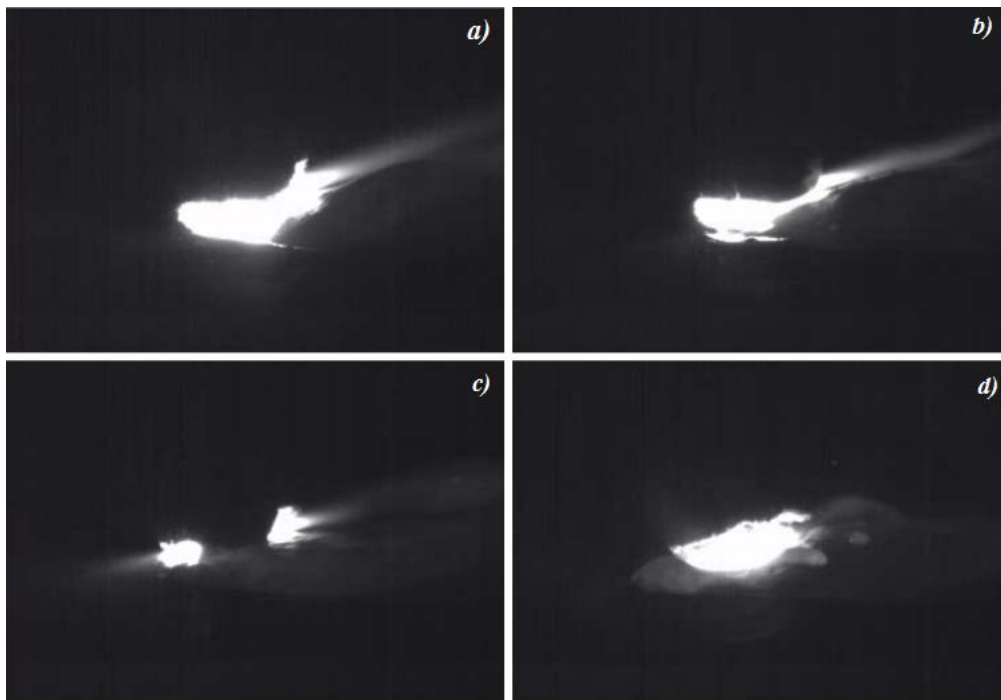


Figure 2. Kinograms of the process of transferring drops of electrode metal during manual arc welding: *a* – the beginning of the formation of a drop on the surface of the coated electrode; *b* – the growth of a drop of liquid metal on the surface of the electrode; *c* – drop transition from the electrode surface to the weld pool with the closure of the arc gap; *d* – the process of the onset of nucleation of the subsequent drop.

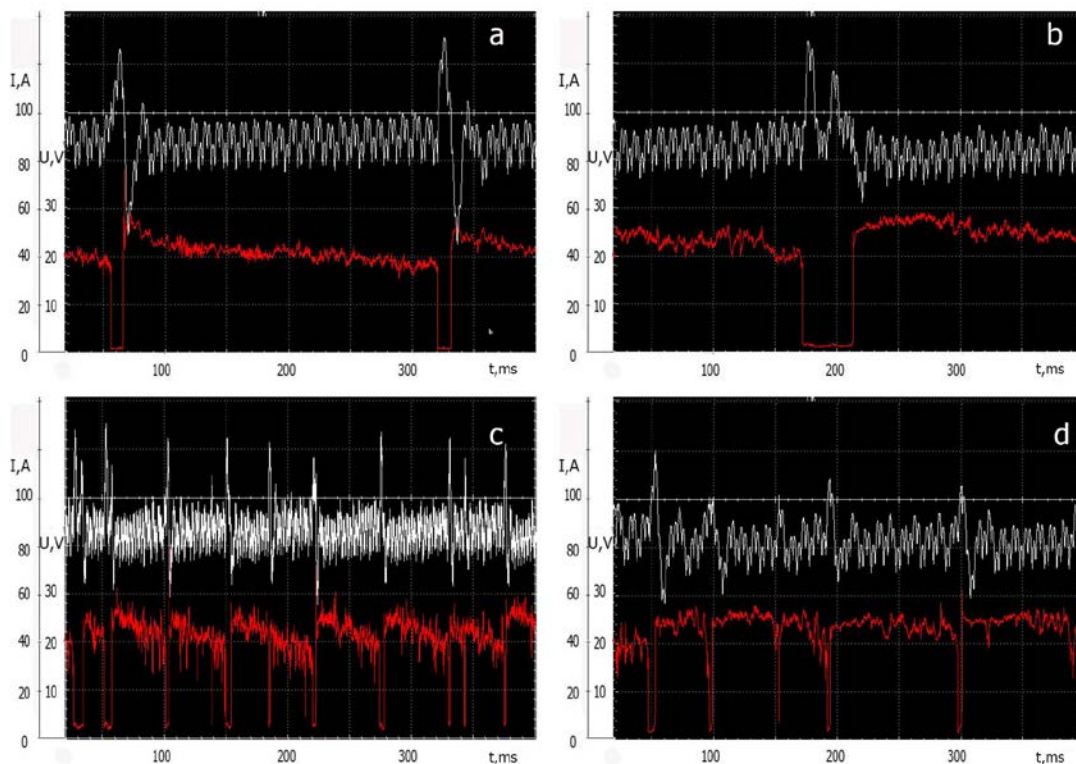


Figure 2. Current and voltage oscillograms in MMA welding with coated electrodes: a) Castolin EC 4001; b) O3Ч-4; c) Sabaros me20|10; d) LB-52U.

Table 2. Statistical data on parameters of electrode metals droplet transfer.

Parameter	Electrode			
	Castolin EC 4001	OZCh-4	Sabaros me20 10	LB-52U
Arc gap period shortcut τ_{sc} , MS± mean root square deviation of period shortcut, $\sigma_{\tau_{sc}}$, ms	34.5±3.1	61.3±9.4	13.3±6.6	13.14±4.13
Period of cycle T_{sc} , MS± mean root square deviation of period of cycle $\sigma_{T_{sc}}$, ms	280±177	750±295	148.7±69.03	162±57
I_{min} , A	49.3±4.6	58.28±1.8	59.7±3	60±5.5
I_{max} , A	127.1±3.8	127±6.5	123±4.7	123.6±6

The use of coated electrodes based on copper (OZCh-4) and aluminum (Castolin EC 4001) alloys for MMA compared to traditionally used metal rod based electrodes (Sabaros me20 | 10, LB-52U) affects the mass transfer characteristics of electrode metal drops. Namely, it increases in the average duration of arc burning at intervals of melting of the electrode and the period of formation of drops of electrode metal up to 4 times.

The experimental patterns established above (table 2) can be explained with the different balance of forces acting on the drop, the welding process using these types of electrodes: Castolin EC 4001, OZCH-4 is large-drop, because a drop of molten electrode metal is in a dense shell formed with an oxide film of aluminum and copper, respectively. Due to the fact that this film has high mechanical strength, a considerable force is required to detach the droplet from the electrode. G.D. Nikiforov [8] believes that as the shell grows, the film stretches and cracks form in it that should lead to its destruction, however, in the presence of oxygen in the atmosphere, the metal oxidizes at the points of rupture and the continuity of the oxide film is restored. The rupture of the film and the transition of the droplet into the weld pool is also facilitated with the pressure of the gases generated in the droplet.

3. Conclusion

The use of coated electrodes based on copper (OZCH-4) and aluminum alloy (Castolin EC 4001) alloys for MMA compared to traditionally used metal rod electrodes (Sabaros me20 | 10, LB-52U) affects the mass transfer characteristics of electrode metal droplets. Namely, there is an increase in the average duration of arc burning at the intervals of electrode melting and the period of formation of drops of electrode metal up to 4 times.

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