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STABILITY OF ARC PROCESS AND METAL TRANSFER AT MULTI-ELECTRODE MMA CLADDING

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The article is devoted to the study of the features of the electrode metal transfer process during surfacing with one electrode and a beam of electrodes for surfacing T-590. Based on the analysis of current and voltage waveforms and comparison of the corresponding coefficients of variation, the possibility is demonstrated that when using an electrode beam, high stability of the arc process and surfacing performance at the level of mechanized methods can be achieved.

The aim of the study is to compare mass transfer, stability of the arc welding process and its performance using a single coated electrode and a beam of electrodes.

The technique is an experimental study of the process of electric arc surfacing using the original UPE-500 installation, which provides for automatic registration and digital processing of the received data while simultaneously stabilizing the parameters of the surfacing mode.

It has been established that when surfacing with a beam of T 590 electrodes, droplet mass transfer occurs according to type G (without short circuits), in contrast to type D (with short circuits of the arc gap) when welding with a single electrode. The electric arc process is characterized by high stability, which is confirmed by the current change coefficients $K_v^i = 3{,}2\ \%$ *and voltage* $K_v^u = 15{,}7\%$*. It has been shown that the productivity of cladding with a beam of three electrodes increases by 1.6 times compared to surfacing with a single electrode and approaches the productivity of mechanized surfacing methods.*

Key words: *arc process, multi-electrode cladding, electrode bundle, stability, coefficient of variation, productivity.*

Ярос Юрій, Бойко Ігор. Стабільність дугового процесу та перенесення металу за багатоелектродного ММА наплавлення

Статтю присвячено дослідженню особливостей процесу перенесення електродного металу за наплавлення одним електродом і пучком електродів для наплавлення Т-590. На основі аналізу сигналів струму і напруги та порівняння відповідних коефіцієнтів варіації продемонстрована можливість, що в разі використання пучка електродів може бути досягнута висока стабільність дугового процесу і продуктивність наплавлення на рівні механізованих методів. Метою дослідження є порівняння масопереносу, стабільності процесу дугового наплавлення та його продуктивності під час використання одного вкритого електрода та пучка електродів. Методика являє собою експериментальне дослідження процесу електродугового наплавлення з використанням оригінальної установки УПЕ-500, яка забезпечує автоматичну реєстрацію і цифрову обробку отриманих даних з одночасною стабілізацією параметрів режиму наплавлення. Встановлено, що в разі наплавлення пучком електродів Т-590 масоперенос крапель відбувається за типом G (без коротких замикань), на відміну від типу D (з короткими замиканнями дугового проміжку) в разі наплавлення одним електродом. Електродуговий процес характеризується високою стабільністю, що підтверджується коефіцієнтами варіації струму $K_v^i = 3{,}2\ \%$ *і напруги* $K_v^u = 15{,}7\%$*. Показано, що продуктивність наплавлення пучком із трьох електродів збільшується в 1,6 раза порівняно з наплавленням одним електродом і наближається до продуктивності механізованих методів наплавлення.*

Ключові слова: *дуговий процес, багатоелектродне наплавлення, пучок електродів, стабільність, коефіцієнт варіації, продуктивність.*

Introduction. Very hard operating conditions of the working bodies of machines and mechanisms of mining, processing and other industries, especially at the enterprises of mining and processing complexes, lead to premature abrasive wear of parts. Therefore, repair, restoration and strengthening surfacing of damaged parts remains an urgent task of welding production. At the same time, repair work is usually carried out not at specialized enterprises, but in the field using various methods of manual or mechanized welding [1; 2]. The advantage of mechanized surfacing over manually coated electrodes is the high productivity of the process (with manual surfacing 1.5...1.8 kg/h., with mechanized-2.5...3.0 kg/h.). But mechanized methods require more complex and expensive equipment, qualified personnel and special organization of work. In addition, the cost of welding materials for mechanized welding is significantly higher than the cost of coated electrodes, so, due to the cheapness, manual coated electrodes remain a common method of repair surfacing in accordance with ISO 4063-111.

Research material and method. The relatively low surfacing performance of coated electrodes is explained by the limited strength of the welding current passing through the electrode rod and overheating it. The method of welding with coated electrodes assembled in a bundle makes it possible to reduce the current density to a safe level. In this case, it is possible to sharply increase the permissible welding current strength for the beam. Surfacing with a beam of electrodes located in a line across the seam brings the process closer to mechanized surfacing with an electrode tape and, accordingly, allows you to generally increase the productivity of the technology of surfacing with coated electrodes [3]. At the same time, the specific consumption of electrical energy is reduced in comparison with surfacing with a single coated electrode, which has a diameter equal to the diameter of individual electrodes assembled in a bundle [4].

For the research, we selected T-590 electrodes (manufactured by the Plasmatec companies group), which are widely used for renewable surfacing of parts operating under abrasive wear conditions. T-590 electrodes are often called “sormait", because they correspond to the E-Fe15 group according to EN 14700, create a solid (58-64 HRC) wear-resistant layer and provide the structure of the deposited metal E-H-Fe-PKE (Primary chromium carbides with austenite-carbide eutectic) [5; 6].

The experiments were performed using a unique UPE 500 installation (Fig. 1), which provides the implementation of the bi-Auto principle, that is, it allows automatic recording, processing and recording of the obtained data by the PicoScope 4444 system and PicoScope 7 software, while simultaneously stabilizing the welding process parameters. The use of this technique ensures complete elimination of the influence of the human factor during experimental studies.

Determination of the type of transfer and assess the stability of the arc process, waveforms of current and voltage across the arc were used, and the surfacing performance was calculated based on the results of control weighing of prototypes. The stability of the electric arc process was determined by the value of the coefficient of variation (the percentage ratio of RMS ripple to Mean) of the selected parameter (current, voltage, short-circuit frequency), and the critical value of the coefficient for recognizing the process as stable was accepted. The research program provided for two series of experiments with T-590 electrodes with a diameter of 4 mm: 1) surfacing with one electrode and 2) surfacing with three electrodes assembled in a linear beam. The surfacing rate was chosen to be the same V_s = 11 cm/min. Surfacing with one electrode, in order to achieve the greatest productivity of the technology, was performed in forced mode with the following parameters: current Ic = 190 A, Arc voltage Ua = 27 V. Analysis

Fig. 1. UPE 500 installation (complex)

of the obtained current and voltage waveforms of the electric arc process (Fig. 3) showed the presence of short circuits in the arc gap – regular current peaks with a multiplicity of more than 1.5 and corresponding voltage "dips" below 20 V are observed. Such features are characteristic of mass transfer of Type D [1]. The current change frequency graph automatically constructed by the PicoScope 7 system made it possible to determine the transfer frequency of electrode metal droplets Fm = 2.795 Hz with a RMS deviation of 0.472 Hz.

The calculated value of the stability parameter of the arc process (short-circuit frequency) for this type of mass transfer is equal to $K_v^{F_m} = 16{,}9\ \%$, i.e. below the accepted limit $K_v^{F_m} = 20\ \%$, and therefore the stability of the electric arc process can be considered quite satisfactory.

The permissible current density during surfacing with one electrode was j = 15 A/mm^2, and the surfacing capacity calculated from changes in the mass of the prototype plate was 1.8 kg/h. Thus, it was found that, despite the sufficient stability of the arc process, the use of a single electrode practically does not increase the surfacing performance, even in forced mode.

For studies of the electric arc process during surfacing with a beam of three electrodes, the mode parameters were selected based on the condition of their implementation on standard industrial power supplies with a rated current of Inom = 315...350 A, namely: In = 310 A, Ua = 32 V. Analysis of current and voltage waveforms showed that in this case, mass transfer occurs in the absence of short circuits in the arc

Fig. 2. Cladded by three electrode bundle deposit layer

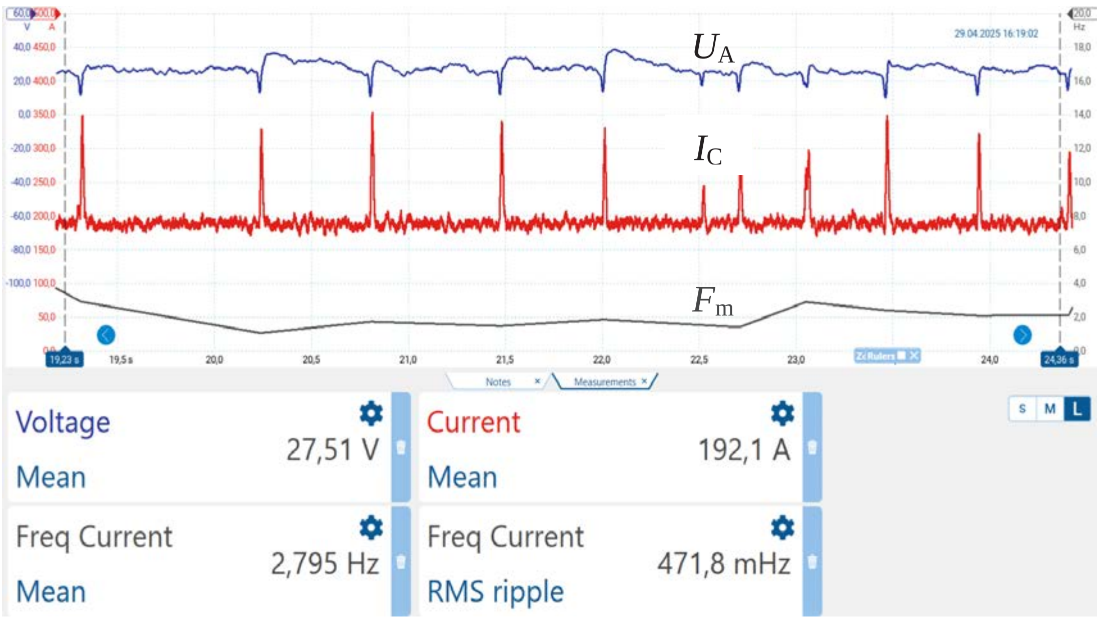


Fig. 3. Waveforms of Arc voltage (Ua), current (Ic), and mass transfer frequency (Fm) graph at surfacing with a single electrode

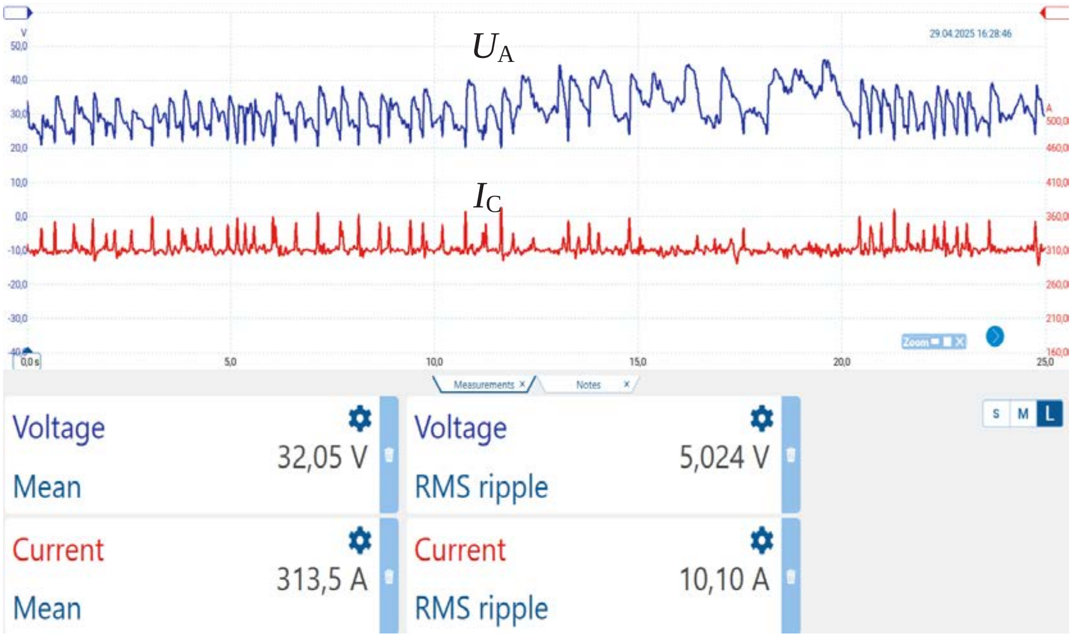


Fig. 4. Waveforms of Arc voltage (Ua), current (Ic), and mass transfer frequency (Fm) graph at surfacing with a bundle of three electrodes

gap. Observed (Fig. 3) irregular current peaks with a multiplicity of less than 1.2 and a decrease in the arc voltage to a minimum value of U_A = 20 V, which is much higher than the short-circuit voltage. A sufficiently high coefficient of voltage variation indicates a periodic significant decrease in the arc length, which is explained by the formation of large droplets, which, however, break away from the electrode without a short circuit. Thus, the considered type of mass transfer can be classified according to [1] as G – DROP.

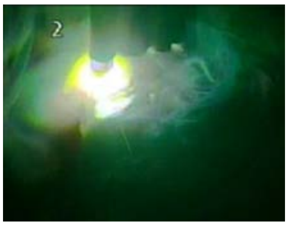
The calculated value of the current coefficient of variation adopted for this type of mass transfer is significantly lower than the permissible limit of 20% and determines the high stability of the electric arc process.

The calculated surfacing capacity in this experiment was 2. kg/h, that is, it exceeded the productivity of surfacing with one electrode by more than 1.6 times and achieved the productivity of mechanized surfacing.

Results. Comparison of the results of the conducted studies confirms the undoubted advantage of the technology of surfacing with a beam of electrodes. In particular, a significant increase in surfacing performance is associated with the possibility of increasing the current density passing through each beam electrode without the risk of overheating of the metal rod. An increase in the current density leads to a more intense dynamic melting of each electrode and, accordingly, to a change in the type of drip mass transfer compared to surfacing with a single electrode: with short circuits of the arc gap to transfer without short circuits.

The change in the type of mass transfer can be explained by visual observations of the migration of the anode spot of the welding arc between the beam electrodes, similar to the known process of Arc migration during welding with tape electrodes. So, during the initial excitation of the arc, the anode spot is located at the end of the electrode that is located at the minimum distance from the surface of the deposited part. As this electrode melts, the cross-sectional area of the drop formed and removed from the end of the electrode increases, and the arc length increases until, according to the Steenbeck thermodynamic minimum principle, the voltage on the elongated arc does not reach the value of the excitation voltage of the arc process at the end of another electrode. The arc is instantly transferred to the end of the adjacent electrode and then the anode spot cyclically moves between the ends of all the beam electrodes.

The nature of Arc migration and the process of separating the drop from the end of the electrode are evidenced by photographic materials obtained using a specially created video surveillance system. At the same time, the high stability of the arc process is confirmed by the results of calculations of the coefficients of variation of current and voltage. The possibility of obtaining a high permissible arc current density when surfacing with a beam of electrodes makes it possible to bring the surfacing performance to the level of mechanized methods.



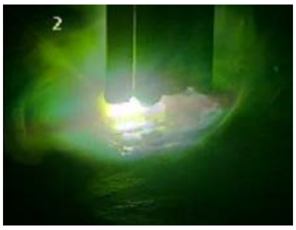


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Fig 5. Migration of the welding arc between the beam electrodes

The possibility of obtaining a high permissible arc current density when surfacing with a beam of electrodes makes it possible to bring the surfacing performance to the level of mechanized methods.

Conclutions

1. It is established that when surfacing with a beam of coated electrodes of the T-590 brand, a drop transfer of the electrode metal occurs without short circuits (Type G according to ISO 4063:2009), in contrast to surfacing with a single electrode, when there is a mass transfer with short circuits of the arc gap (Type D according to ISO 4063:2009).

2. Calculations of the coefficients of variation of parameters characteristic of the studied types of mass transfer, as well as experimentally confirmed the high stability of the electric arc process when surfacing with a beam of three electrodes in comparison with surfacing with a single electrode.

3. The high average beam welding current density j = 24.7 A/mm2, which is unattainable for surfacing with a single electrode, makes it possible to bring the surfacing performance closer to the level of mechanized methods.

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