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IMPROVEMENT OF ELECTRON DEVICES FOR INITIAL AND REPEATED IGNITIONS OF ALTERNATING CURRENT ARC

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Taking into account earlier carried investigations, considered are the issues of development of the electron devices for contactless initial and repeated ignitions of alternating current arc in mechanized arc welding. They generate high and increased voltage pulses being injected in an inter-electrode gap. It is shown that the most reasonable way for improvement of the electron devices is a development of combined striker-stabilizers. They have a possibility to function in a mode of initial ignition (striking) of the arc as well as in a mode of its burning stabilizing. It can be reached by means of using at least two independent forming circuits in the generators of high or increased voltage pulses of the striker-stabilizers. A variant of circuit solutions for the combined electron arc striker-stabilizer having series connection to welding circuit is presented and described for mechanized consumable electrode AC welding. 22 Ref., 2 Figures.

Keywords: *mechanized arc welding, alternating current, initial and repeated arc ignitions, arc stability, electron striker-stabilizers of arc, generators of high and increased voltage pulses*

Up to the moment the most widespread method of contactless initial ignition (striking) of welding or pilot arc in an inter-electrode gap is its impact ionization by means of electric breakdown of this gap by high-voltage pulses, being generated with the help of special generators (arc strikers) [1–7].

The methods based on application of increase voltage pulses have gained the widest application among the well-known methods for increase of AC welding arc stability. Such pulses are generated by special voltage boosters (arc stabilizers) and being fed in the inter-electrode gap once in a period (at the moments of beginning of cathode formation on a part) or at each change of welding current polarity. Also different methods which provide for high speed of change of arc voltage and current at current zero values are used [1–5, 7–12].

Regardless the fact that a nature of processes of initial and repeated welding arc ignition is different [3–5, 7, 9, 10], a design structures of special strikers and stabilizers of arc is the same. Along with, due to the process peculiarities which are realized by these devices, they differ from each other not only by amplitude, energy and time parameters of the output pulses, but algorithms and modes of control assemblies. In this connection, the design of striker-stabilizers in course of long time was realized via combination in a one block virtually two independent devices. One of the devices is functioning in a mode of initial ignition and being controlled by open-circuit voltage of AC power source. The second one operates in a mode of arc reignition in welding with arc voltage regulation. The examples of such a solution can serve the arc striking and stabilizing blocks of UDG-301 and UDG-501 units for TIG welding of aluminum and its alloys, UDGU-301, UDGU-302 and UDGU-502 units for TIG welding of steels and non-ferrous metals [5].

Based on mentioned above, the researchers and developers in a course of long time have been trying to develop the combined electron arc striker-stabilizers which can effectively function in a mode of arc initial ignition as well as in a mode of its reignition. A series of such devices [5, 7, 13–19 as an example], was developed up to the moment, however, area of their application is limited by such arc welding methods as manual and automatic non-consumable welding in inert gases (TIG) and manual metal arc welding (MMA). A number of difficulties and limitations in application [9, 10, 20] were found in development of the combined electron arc striker-stabilizers for mechanized AC metal arc welding in shielding gas (MIG/MAG).

Therefore, the development of efficient striker-stabilizers of arc for MIG/MAG welding is still relevant tasks. The analysis of circuit design and structural peculiarities of known combined electron arc striker-stabilizers shows that the solution of this problem is possible under conditions of improvement of operation algorithms of these devices and their control assemblies as well as functional assemblies of their power part, first of all, generators of high and increased voltage pulses (GVP).

The aim of present paper lies in consideration of some proposals, developed at the E.O. Paton Electric Welding Institute, on creation and improvement of the functional assemblies of power part of the combined arc strikers-stabilizers for AC MIG/MAG welding and presentation of the results of these investigations and experimental works in this direction.

Main peculiarities of design of combined striker-stabilizers for mechanized welding. Comparison of the requirements with main parameters of high-voltage pulses and stabilizing increased voltage pulses, which was carried out taking into account calculation relationships and recommendations given in works [13, 15, 21], as well as results of earlier provided investigations and experience of practical application of the combined electron striker-stabilizers shows that:

- for safe initial ignition of arc in MIG/MAG welding the strikers' initial high-voltage pulses should have energy $W_{\text{sr.p}}$ from 0.2 to 0.5 J, amplitude $U_{m\,\text{sr.p}}$ from 3 to 3 kV and duration $\tau_{\text{sr.p}}$ (at the level of $0.05U_{m\,\text{sr.p}}$) from 5 to 20 μm;
- for stability of AC arc in MIG/MAG welding the arc stabilizers' increased voltage output pulses should have energy $W_{m\,\text{st}}$ from 0.6 to 1.0 J, amplitude $U_{m\,\text{st.p}}$ from 400 to 950 V and $\tau_{\text{st.p}}$ (at the level of $0.05U_{m\,\text{st.p}}$) from 100 to 1000 μm;
- since $W_{\text{st.p}}$ values are virtually always exceed $W_{\text{sr.p}}$ values, and value of energy W_{c}, accumulated in a capacitive storage of GVP forming circuit, is determines as $W_{\text{c}} = C_{\text{c}} U_{\text{c}0}^2 / 2$ (where C_{c} is the capacitive storage condenser (condensers) capacity, and $U_{\text{c}0}$ is the set voltage of its charge), then at the same $U_{\text{c}0}$ value the capacity $C_{\text{c}2}$ of GVP circuit, forming stabilizing pulse, should not less than $W_{\text{st.p}}/W_{\text{sr.p}}$ times exceed $C_{\text{c}1}$ capacity, necessary for formation in GVP circuit of the pulses providing initial ignition (striking) of the arc;
- for mechanized methods of metal electrode welding and series connection of voltaic pulses in the welding circuit using pulse transformer, its coefficient of transformation $k_{\text{tr}} = N_{III}/N_I$ should equal one (where N_{III} is the number of winds of pulse transformer secondary coil; N_I is the number of winds of this transformer primary coil for the mode of primary initiation as well as for the mode of generation of stabilizing pulses);
- the largest value of I_{Cm} current amplitude in GVP forming circuit, determined by formula $I_{Cm} = U_{c0}\sqrt{C_{\text{c}}} / L_{\text{c}}$ [15, 16], in the mode of pulse generation for initial arc ignition, makes from 80 to 445 A, and it is from 50 to 170 A in the mode of stabilizing pulse generation.

Analysis of the differences in required values of main parameters of high-voltage pulses and increased voltage pulses show that GVP of striker-stabilizer should include at least two independent from each other switching *LC*-circuits for such pulses generation.

At that for optimizing the design of power part of the striker-stabilizers it is reasonable to support stable supply voltage as well as use feedback signals on voltage $U_{\text{f.b.v}}$ in the inter-electrode gap and on arc current $U_{\text{f.b.c}}$ in all modes of its operation.

The E.O. Paton Electric Welding Institute together with SE «Research Engineering Center of Welding and Control in Power Engineering» has developed and tested a series of the combined striker-stabilizers for mechanized AC welding using consumable electrode, description of base design model of which is given below. This work follows from mentioned above processes of contact-free initial and repeated ignitions of the arc and determined by these peculiarities requirements to main parameters of high-voltage pulses and increased voltage pulses initiating these processes.

Design of base model of the combined striker-stabilizer for AC mechanized welding. Figure 1 shows a design-functional scheme of base model of the combined striker for AC MIG/MAG welding*. The device is a modernized variant of asynchronous arc striker-stabilizer (AASS) with output pulse transformer *TV*1, where number of winds in each of coils equals one. The secondary coil *III* of this transformer is formed by consumable electrode part moving via opening of transformer ferromagnetic core from cassette to arc.

One of the ends of coil *III*, turned directly to the arc, is a stick-out of the consumable electrode contacting with welding electrode tip, and the second end is the sliding contact of moving consumable electrode with contact surfaces of embedded in the device contact assembly being located as close as possible to the outlet of guiding channel of output pulse transformer *TV*1. The device in addition to transformer *TV*1 contains storage capacitors *C*1, *C*2 and protective capacitor *C*3, output rectifier *1*, direct current voltage multipliers *2* and *3*, control block *4*, controlled high-voltage switching keys *5–8*, contact assembly *9*, at that keys *5–7* can have unidirectional conductance and key *8* — double-directional.

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*Makhlin N.M., Korotynsky O.E., Skopyuk M.I. Device for ignition and stabilization of AC arc burning in mechanized consumable electrode welding: Pat. appl. 10698 UA. Fill. 03.11.2015.

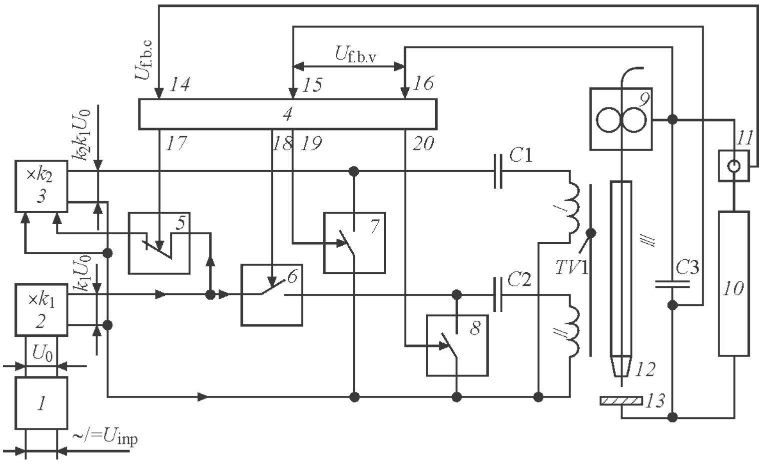

Figure 1. Block diagram of striker-stabilizer for mechanized AC welding using consumable electrode (see designations in the text)

In a primary stage of welding process in the mode of arc initial ignition keys *6*, *7* and *8* are switched off, and key *5* is switched on by a signal from control output *17* of control block *4*. U_{inp} voltage of input rectifier *1* is subjected to rectification, smoothing and filtering. It is supplied to input of this rectifier from AC mains or arc power supply secondary coil or from its outputs of alternating or direct current.

Smoothed and filtered voltage U_0 from input rectifier *1* is supplied to input of voltage multiplier *2*, where this voltage is raised to k_1U_0 level. Simultaneously, voltage k_1U_0 from multiplier output *2* is supplied via switched on key *5* to multiplier input *3*, using which this voltage is increased to $k_2k_1U_0$ level, i.e. to set charge level of storage capacitor *C*1.

Key *7* starts to generate control signal at the end of charge of this capacitor in the moment of time determined by control block *4* using voltage feedback signal $U_{\text{f.b.v}}$ which are supplied to inputs *15* and *16* of control block *4*, and corresponding to (80±5) el. deg phase of voltage of AC mains or open-circuit voltage of AC arc power supply. This signal from control output *19* of control block *4* will be supplied to control input of key *7* that causes switching on of the latter.

In turn, key *7* switching promotes for a recharge of storage capacitor *C*1 via primary coil *I* of output pulse transformer *TV*1, that results in formation of high-voltage pulse on coils *I* and *III*. Key *7* is switched off after finishing the recharging of storage capacitor *C*1. Process of capacitor *C*1 charging is renewed from this moment. Further all the processes of charging and recharging of this capacitor are repeated as described above. High-voltage pulses from coil *III* of output pulse transformer *TV*1 are applied via protective capacitor *C*3 to the inter-electrode gap, which is formed by stick-out of consumable electrode *12* and part being welded *13*, and initiate spark discharge in it. This provides for impact ionizing of the inter-electrode gap and creates the conditions for ignition in it of stable arc discharge with the help of AC power source *10*.

Signal $U_{\text{f.b.c}}$ is supplied from information output of arc current probe *11* to input *14* of control block *4* from the moment of formation of stable arc discharge in the inter-electrode gap. The level of it is proportional to arc current, which leads to complete termination of supply of any signals from outputs *17* and *19* of control block *4* to control inputs of keys *5* and *7*. It respectively stops formation of the high-voltage pulses and their injection in the inter-electrode gap. A signal of key switching on is supplied from output *18* of control block *4* to control input of key *6* simultaneously with keys *5* and *7* switching on. This promotes for start of storage capacitor *C*2 charging to k_1U_0 level. Pulse signal of key switching on is supplied from output *20* of control block *4* to control input of key *8* at the end of charge of storage capacitor *C*2 in the moment time, which is determined by control block *4* with the help of $U_{\text{f.b.v}}$ signals and corresponds to phase of 68–75 el. deg relatively to zero phase of power supply *10* open-circuit voltage.

At double-directional conduction of key *8* will promote oscillatory discharge and recharge of storage capacitor *C*2 via primary coil *II* of output pulse transformer *TV*1 due to what damping HF oscillations will appear in *C*2–key *8*–coil *II* circuit of transformer *TV*1. Thus, capacity of storage capacitor *C*2 is obviously more than the capacity of capacitor *C*1, then HF pulse of increased voltage is formed in primary *II* and secondary *III* coils of transformer *TV*1. Amplitude and frequency of HF oscillations of the pulse is significantly lower and duration is significantly larger then in the HF pulse being formed in recharge of storage capacitor *C*1. In the moment of finish of charge and recharge of capacitor *C*2, key *8* is switched off and process of charge of storage capacitor *C*2 is renewed. Further all the processes of charge, discharge and recharge are repeated as described above. The HF pulses of increased voltage from secondary coil *III* of output pulse transformer *TV*1 are supplied via protective capacitor *C*3 in the inter-electrode gap promoting at that rapid increase of conductivity of this gap in the intervals of no-current conditions, which inevitably appear in arc current polarity change, thus creating conditions for free ignition of each next semi-wave of arc current.

If there is a break in stability of AC arc during welding, it provokes for termination of supply of $U_{\text{f.b.c}}$ signal to input *14* of control block *4*, that will promote corresponding change in state of outputs *17–20* of control block *4*. As a result, the device for mechanized AC consumable-electrode welding automatically return to function in the mode of initial arc ignition, and after repeated generation of stable arc discharge in the inter-electrode gap it automatically passes to function in the mode of AC arc reignition.

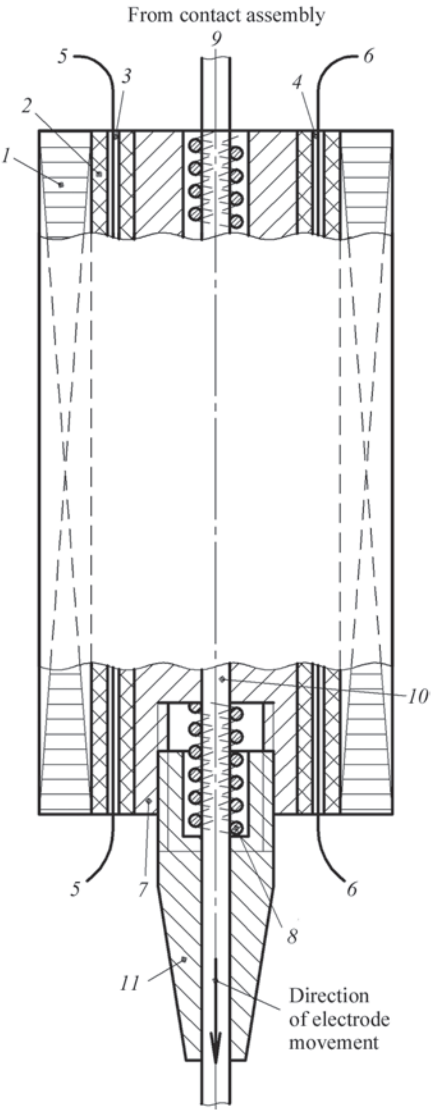

Figure 2. Variant of design scheme of output pulse transformer of striker-stabilizer for mechanized consumable-electrode welding (see designations in the text)

Among the peculiarities of developed combined striker-stabilizer for mechanized consumable-electrode welding is the necessity in use of high-voltage keys and feedbacks on arc current and voltage, special structure of output pulse transformer and presence of contact assembly.

The semiconductor power devices, for example, 65–95 class thyristors of T600N95 TOH type or FZ-75065KE3 type modules of INFINEON company [22] calculated for maximum-allowable collector-emitter 6500 B IGBT, can be used as electron high-voltage keys *5–8*. The relationships and recommendations given in [14, 15] can be used in selection and calculation of parameters of the rest elements in design and construction of the striker-stabilizer for mechanized consumable-electrode welding and devices similar to it.

Figure 2 gives a scheme of one of the possible variants of design of the output pulse transformer of striker-stabilizer for mechanized consumable-electrode welding. The transformer consists of ferromagnetic core *1* being a solid tubular cylinder or set of ring cores, manufactured from ferrite mixtures or sprayed iron [15], internal insulation high-temperature bush *2* with two longitudinal holes *3* and *4* in each of which a wind of separate primary coil of the transformer is located (for example, a wind of primary coil *5* in hole *3*, and wind of primary coil *6* in hole *4*), guiding channel, set in insulation bush *2*, containing rigid external non-magnetic bush *7* and spring internal non-magnetic bush *8* with low friction resistance in movement along it of consumable electrode *9*, which forms transformer secondary coil with it part *10*. From the side faced to the arc, rigid tubular bush *7* is connected (for example by thread) with welding torch tip *11*. Electrode wire *9* is wind off from cassette and with the help of feeder of automatic and semi-automatic device is forced through to the arc via the contact assembly of developed striker-stabilizer, guiding channel of its output pulse transformer and tip *11*. Ferromagnetic core *1* and primary coils *5* or *6* provide for electromagnetic coupling with part *10* of electrode *9* during generation in GVP of the developed striker-stabilizer the high-voltage pulses or pulses of increased voltage, which stabilize arc burning. It results in formation of pulses in part *10* of electrode *9* with virtually the same parameters as in corresponding primary coil of the output pulse transformer.

The contact assembly of the developed striker-stabilizer can be made in form of one of the wide-known clamping mechanisms. One of the examples of design of such clamping mechanism can be a structure, the main elements of which represent two contacts. One of them is stable and rigidly fixed to contact assembly body structure through insulation. The second can be moved in the direction normal to consumable electrode longitudinal axis up to reaching such clamping level which would provide, on the one hand, virtually, free movement of the consumable electrode, and on the other hand, safe sliding contact with it. Both contacts from the side turned to the consumable electrode are equipped with semi-cylinder grooves, forming cylinder-like cavity. It is used for pushing the consumable electrode through the guiding channel of the output pulse transformer under effect of feeder of automatic and semi-automatic device in the direction from cassette to arc.

The striker-stabilizers, designed based on scheme with the output pulse transformer (see Figure 1), the example of design solution of which is given in Figure 2, are successfully used in the experimental special units for spot argon-arc welding of aluminum sheets of building structures as well as in the pilot samples of the equipment for mechanized welding using 1.6–3.0 mm diameter consumable electrode.

Conclusions

1. It was determined, based on considered peculiarities of initial and repeated ignition of AC arc, that improvement of design of arc striker-stabilizers is possible by means of introduction in the power part of this devices of additional GVP circuit including, at least, additional semi-conductor key and series capacitive storages and additional primary coil of step-up pulse transformer and application together with it feedbacks on current and arc voltage.

2. Developed striker-stabilizer for mechanized gas-shielded consumable-electrode welding allows significant expansion in application of alternating current with this method of arc welding.

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