Improvement of a single-phase rectifier for manual arc welding by stick electrode for thin-sheet constructions

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Abstract. The article shows the results of work to improve the single-phase rectifier for manual arc welding of thin-sheet structures. An additional unit is proposed, which is an electronic switch that includes a control circuit for the rectifier thyristors for two half-periods with a constant frequency, a multiple of the number of half-periods of the rectified current. At the same time, the selection of mode parameters for manual arc welding with a coated electrode allows for a stable quasistationary process of melting and transfer of the electrode metal. The use of an additional unit provides welding thin-sheet structures without reducing the diameter of the coated electrode, by analogy with the known processes for welding in protective gas.

1. Introduction
In the production of modern steel products, thin-walled structures, whose arc welding with consumable electrode causes difficulties, are becoming increasingly important. Especially these difficulties arise in the manufacture of body parts of various techniques and welding of unavoidable gaps when arc welding with a coated electrode is used, and the process itself is carried out in the conditions of repair companies having difficulties in acquiring special, modern, expensive welding and auxiliary equipment. The use of universal power sources that can, apart from standard technologies, provide manual arc welding with the most common electrodes of unavoidable gaps, surfacing on thin-walled structural elements and their welding will significantly reduce the costs of such production.

2. Statement of a problem
Currently, processes of arc welding in shielding gases have been developed, which are distinguished by reduced heating of the metal being welded and provide reliable connections with a stable melting of the electrode wire with a diameter of more than 1 mm. These are adaptive technologies with a pulse current change depending on the state of the molten metal at the end of the electrode wire, which are implemented in the welding module consisting of an inverter power source and feed mechanism in welding methods such as SteelRoot [1], WiseRoot [2], and others.

The essence of these methods lies in the fact that when the short circuit current is limited, the transfer of the electrode metal occurs at a decrease in current, and stable arc burning at low currents between the metal transfer is achieved by applying an additional current pulse, which creates the necessary volume of liquid metal at the end of the electrode burning arc. This ensures a controlled periodic pulse welding process with low heat input to the metal being welded.

However, the cost of such modules with adaptive technologies significantly exceeds the cost of sources without frequency conversion. Therefore, work is underway to create conventional power sources with improved welding properties that can successfully compete with inverter sources [3-5].

Based on this, it is of interest to develop such equipment for manual arc welding with coated
electrodes of thin-walled structures without the use of an inverter power source.

The purpose of this work is to develop a power source for welding steel with a thickness of 1 mm coated electrode with the most common diameter of 3 mm.

3. Theory

Manual arc welding of thin-sheet structures presents considerable difficulties due to the low arc stability at low currents. To increase the arc stability, a transition to welding with modulated current, welding from special single-phase rectifiers, etc. is proposed [3, 4, 5]. All this provided a significant reduction in the average welding current with a steady process. These sources have a special complex construction of a welding transformer or a choke and are intended only for specific developed processes.

Since the temporal characteristics of the transfer process of the electrode metal increase with increasing diameter of the melting electrode, to achieve this goal the most suitable source for such technologies with pulsating (pulsed) current is a single-phase rectifier. When welding from a single-phase rectifier, self-regulation occurs, at which the transfer frequency of electrode metal droplets becomes a multiple of the pulsation frequency of the rectified current for most modes [6], and the current reduction during natural pulsations eliminates complex switching devices of the above-mentioned modules.

4. Results of the experiments and discussion

The object of the study was a single-phase universal welding rectifier with a thyristor regulator [7], which has a relay feedback between the thyristor switch-on phase and the current in the process of transferring a drop of electrode metal during a short circuit. In this case, such a control is possible, in which a drop of electrode metal during manual arc welding with a coated electrode is transferred during a short circuit due to the decay of the pulsating current [8], which is also characteristic of the above-mentioned new technologies analyzed in [9]. An additional SW unit was introduced into the control circuit of this rectifier, which ensures that the controlled rectified welding current is switched on from the main source for two half periods in order to ensure the formation and transfer of the electrode metal. Figure 1 shows a single-phase rectifier circuit with a thyristor regulator and an additional unit. 1. The functional diagram of the additional unit is shown in Fig. 2

![Figure 1. Single-phase rectifier circuit with an additional SW unit](image)
An additional block is an electronic switch VT, which includes a control circuit for the rectifier thyristors for two half periods with a constant frequency, a multiple of the half periods of the rectified current. The number of these half-periods is set by the switch S of the DD logic circuit to which the binary-decimal counter CT is connected. The generator impulses GN are fed to the input of the counter. The power supply G provides circuit operation. Thus, when the thyristor control circuit is turned off, the welding arc is powered only from an additional low-current unregulated source, the current of which is determined by the capacitance of the capacitor C, Fig. 1. Current oscillograms when the source operates at constant load with a ballast resistor with different settings of the relay feedback controller R4 (Fig. 1) of the rectifier are shown in Fig. 3.

For reliable initial ignition of the arc during welding, the additional unit was briefly switched off for 1...2 s for which special contacts were provided. To test the rectifier's performance, welding or cladding was carried out on low-carbon steel plates with a thickness of 1 or 1.2 mm. As a result of the experiments, it was possible to obtain a stable quasistationary process of the welding arc welding from a coated electrode with a diameter of 3 mm at a low heat input with satisfactory formation of the weld metal. Oscillograms of the welding process with a covered electrode and for comparison by the methods of SteelRoot and WiseRoot in protective gases are shown in Fig. 4.
As follows from the analysis of the oscillograms, in the process obtained, a short circuit of the arc gap with a drop of electrode metal and its subsequent transfer into the weld pool occurs after the welding current drops due to surface tension without a significant increase in penetration. Such features of the transfer process allow welding of thin-walled metal joints in weight.

5. Conclusion
An additional unit to a single-phase rectifier is proposed, which is an electronic switch that includes a control circuit for the rectifier thyristors for two half-periods with a constant periodicity that is a multiple of the half-periods of the rectified current. In addition, for manual arc welding, the selection of mode parameters allows for a stable, quasi-stationary process of melting and transfer of the electrode metal without introducing additional analog or digital feedback and switching devices for reducing the current. The use of an additional unit provides welding thin-sheet structures without reducing the diameter of the coated electrode, by analogy with the known processes for welding in protective gas.

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