Table 2. Comparison of results of estimation of welding properties (average values of indicators on results of deposition of several beads)

Parameter	Estimation by automated system	Average estimate of welder 1	Average estimate of welder 2
Initial arc ignition	4.6	4.5	5.0
Stability of welding process	4.9	4.0	4.0
Metal spattering	4.3	4.4	4.7
Quality of weld formation	4.3	4.1	4.0
Arc elasticity	4.8	4.7	4.6

Two methods were used for monitoring of system operation by comparison of results of estimation for «Fronius TPS 5000» inverter power source: in accordance with GOST 25616–83 standard, recruiting two high-qualified welders and using developed automated system. Estimation was carried out for the conditions of manual arc welding. Digital system for collection and recording of data was used for registration of welding current and voltage. It consists of current and voltage sensors based on Hall effect, analogue-to-digital transformer and PC. PowerGraph program was used for recording and analyzing of oscillograms.

As a result, the estimate of each welding property and general estimation by automated system were obtained (Table 1). Gathered data were transferred into a scale, regulated by GOST 25616–83 (Table 2) for comparison of results of automated system with results of welders' estimation. The result was multiplied 5 for transfer. The estimation of welding properties was carried out in accordance with test procedure, indicated in the standard.

CONCLUSIONS

1. Application of the automated systems based on fuzzy logic algorithms can solve a task of determination of windowed multicriteria estimation of quality indicators of the power sources.

2. Using of fuzzy logic and computer systems for data collection and processing provides the possibility of development of flexible systems for estimate of welding properties of the power sources for automatic arc welding. This allows reducing to minimum influence of the human factor on the estimation of welding properties.

1. *DSTU 60974-1–2003*: Arc welding equipment. Pt 1: Welding power sources. Valid from 01.07.2004.
2. *GOST 25616–83*: Arc welding power sources. Methods for testing of welding properties. Introd. 28.01.83.
3. Troitsky, V.A. (1981) Elements of defectology. In: *Nondestructive testing of welded joints*. Kiev: PWI.
4. Pokhodnya, I.K., Ponomarev, V.E., Zaruba, I.I. et al. (1992) Procedure of complex evaluation of welding-technological properties of power sources. In: *New welding power sources*. Kiev: PWI.
5. Troitsky, V.A. (1983) Quantitative evaluation of quality level of welding processes and equipment. *Avtomatich. Svarka*, **4**, 62–66.
6. Krichevsky, M.L. (2005) *Intellectual analysis of data in management*: Manual. St.-Petersburg: SPbGUAP.
7. Zhiznyakov, S.N., Sidlin, Z.A. (2006) *Manual arc welding. Materials. Equipment. Technology*. Kiev: Ekotekhnologiya.
8. Scotti, A., Ponomarev, V. (2008) *Soldagem MIG/MAG melhor entendimento, melhor desempenho*. SanPaulo: Artliber Editora.

UPGRADING OF ELECTRIC CIRCUIT OF A-1150 MACHINE FOR VERTICAL WELDING

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A-1150U machine designed in 1960s is still in demand in its upgraded form in shipbuilding, bridge and storage tank construction. Pilot Plant of Welding Equipment of the E.O. Paton Electric Welding Institute (PWI PPWE) developed a new control circuit based on modern components and control units. The new circuit provides substantial improvement of technical and service characteristics of the machine, and simplifies implementation of the welding process with forced weld formation. The machine with the new electric circuit is additionally designated by «K» index (A-1150K).

Keywords: *A-1150K machine, welding process with forced formation, weld metal, new electric circuit, small-sized panel-handle, electronic control circuit with feedbacks*

The industry of CIS and foreign countries has used A-1150 machine for welding vertical and inclined welds for more than 40 years now. During this period PWI PPWE has manufactured more than 150 equipment sets based on orders from users, which points to a high quality of the development and need for it in production.

Idea of development of a self-propelled machine for automatic welding of vertical butt welds, which could move directly over the butt without any guides of rack type, was put forward by Prof. B.E. Paton. Such equipment was required in ship-building, and

bridge and tank construction. In these industries there is a need to perform large volumes of welding of extended vertical and inclined butt welds. Performance of this work required a large number of highly-qualified manual welders. Replacement of manual welding by automatic process was the only way to solve this important national economy problem.

Work on welding technology and machine design was performed at the PWI Design Bureau. A-1150 machine enabled realization of a highly efficient process of flux-cored wire welding with forced formation of weld metal using two copper water-cooled shoes, which are placed from the weld face and reverse side. Application of the above welding process enabled an essential improvement of the efficiency of welding vertical and inclined welds compared to manual welding. Thus, while in manual arc welding of 20 mm thick metal (09G2S steel) with UONI-13/55 electrodes (4 mm diameter, 140–150 A welding current) welding speed was equal to 0.4–0.5 m/h, the process of welding with forced formation by flux-cored wire of PP-AN5 grade allowed welding at currents of 400–420 A, achieving the welding speed of 4.8–5.2 m/h [1]. The main advantage of the proposed process consisted in that quality welding of critical welds could be performed by welders of a low qualification after short practical training.

First samples of A-1150 machine were introduced in the Kherson Shipbuilding Plant. After receiving positive practical results and approval of the technological process by the USSR Register, technology and equipment became widely applied in the shipbuilding plants [2], as well as in tank and bridge construction.

Machine design was continuously improved. Mainly the machine mechanical components were upgraded, which currently satisfy users of this equipment, unlike the electrical components. As a rule, changes in the electrical components were made at replacement of welding current source in the machine. In the first variant of A-1150 machine, welding arc and electric circuit were powered from welding generator converter of PSG-500 type. The next variant of the machine electric circuit (A-1150U) was developed after the industry has mastered manufacturing of welding rectifiers of VDU-504 (505, 506) type. In this variant power of machine control circuit was disconnected from the welding source, and it was powered independently from 380 V mains. Such a change noticeably improved the quality of welding process control. However, despite the made changes, electrical components of A-1150U machine do not meet the current requirements. In particular, the electric circuit is based on outdated components, electronic circuits for control of motors of machine displacement and electrode wire feed drives are absent. Change of motor rotation speed is performed by a simple circuit, without any feedbacks. In such a control system, most of the motor power is lost, particularly at motor operations at low revolutions. In addition, there is no possibility for visual control of the welding speed and electrode wire feed rate in machine preparation for operation and during welding. A certain inconvenience of machine control is related to the specifics of performance of the welding process with forced formation: the process requires continuous visual control of weld pool position relative to the upper edge of the forming shoe. This problem is solved by selection of the speed of machine movement using a resistor, which his traditionally located on the control panel. The only problem is that when looking for the resistor, the welder has to ignore the welding zone for a short time, which may lead to defects in welds.

Figure 1. Appearance of A-1150K machine

Considering the current need for machines of A-1150 type, a decision was taken to develop a new circuit based on modern components, which proved to be reliable in the equipment batch-produced by the plant. This work was performed when manufacturing two A-1150 machines for Bridge Construction Team of «Mostobud»(Dnepropetrovsk). Variant of A-1150 machine with a new electric circuit is marked by «K» index (A-1150K) (Figure 1).

New electric circuit was developed by plant specialists in keeping with the specification, which was prepared taking the above-mentioned drawbacks into

Figure 2. Front control panel of A-1150K machine

Figure 3. Small-sized panel-handle of A-1150K machine

account. Machine block-diagram includes the power unit, control panel, small-sized panel-handle, drive mechanisms and control drives. Electric circuit is independently powered from external 380 V, 50 Hz circuit. Control circuits are powered from 29 V constant voltage, which is generated in the power unit.

The front control panel (Figure 2) carries welding process controls: toggle switch and light indicator CIRCUIT ON; ammeter for welding current monitoring; voltmeter for visual monitoring of arc voltage U_a, electrode wire feed rate v_{el}, welding carriage speed v_c, button for monitoring shielding gas feed; switch for controlled parameter setting; two switches for setting the direction of electrode feed and carriage movement, and light indicator WELDING ON.

Visual monitoring of welding mode parameters at setting up is performed by readings of the voltmeter, which measures welding source voltage or armature voltage of motors of electrode feed and carriage movement mechanisms, when setting the mode parameter switch to the controlled parameter and pressing the button to switch on the reading. Welding mode parameters can be controlled both at setting up and in welding.

For convenience of process control in welding, the machine is fitted with a small-sized panel-handle (Figure 3), which carries the toggle switch for welding process switching on and off, STOP button for electrode feed and STOP for the carriage, button for switching on welding carriage travel speed, as well as a resistor to control the carriage speed.

The new electric circuit is arranged so that the controls used for machine setting up for welding, are located on the control panel and panel-handle, and all the controls used in performance of the welding process with forced formation of the weld metal, are located only on the panel-handle. During welding, the operator is holding the panel-handle in his hand, and its design enables performance of all the required operations with the fingers of the same hand, which is holding it. The following operations can be performed from the panel-handle: stop the machine travel carriage, switch on the travel speed of carriage movement, perform smooth adjustment of welding speed, stop electrode wire feed, switch the welding process on and off (switch on the welding source, electrode feed and shielding gas). All these operations are performed from the panel-handle without using the control panel. Thus, the welding process can now be controlled while keeping the weld pool in sight that is practically impossible, when operating the old variant of the equipment.

Main technical characteristics of A-1150U and A-1150K machines

Parameter	A-1150U	A-1150K
Mains voltage, V (50 Hz)	380	380
Control circuit supply voltage, V	29	29
Welding current at 100% duty cycle, A	500	500
Thickness of metal being welded, mm	8–30	8–30
Smooth adjustment of electrode feed rate, m/min	3.0–3.7	2.0–5.4
Smooth adjustment of welding speed, m/min	0.03–0.20	0.03–0.25
Electrode wire diameter, mm	2.5; 3.0; 3.5	2.5; 3.0; 3.5
Tractive force of movement mechanism, kg, not less than	120	140
Tractive force of electrode feed mechanism, kg, not less than	30	38
Machine weight (without cassette with electrode wire), kg, not less than	32	32

As drives of electrode feed and machine displacement mechanisms, the machine uses electric mechanisms with DC motors of 130 W power with permanent magnets in the excitation system (in A-1150U machine electric mechanisms with 90 W motors were used). For motor control the new circuit uses power units with feedbacks, providing minimum power losses at motor operation at low revolutions, and rotation stabilization at unauthorized load changes.

Testing of A-1150K machines showed that the used design solutions improved the service properties and simplified practical realization of the process of welding with forced formation of weld metal. Upgraded A-1150 K machine provides a high quality of welded joints and is recommended for application in different industries.

1. Pokhodnya, I.K., Dubovetsky, V.Ya., Shlepakov, V.N. et al. (1966) Vertical arc welding with weld forced formation. *Avtomatich. Svarka*, **11**, 67–70.
2. Voinov, S.V. (1982) *Automatic vertical welding*. Leningrad: Sudostroenie.