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# APPLICATION OF ADJUSTABLE ELECTRIC DRIVES WITH BRUSHLESS ELECTRIC MOTORS IN ARC WELDING

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The paper deals with the possibility of application of electric drives with step and valve motors in welding equipment. Examples of performed developments of mechanized and automatic welding-surfacing equipment for various purposes are used to demonstrate the advantages of application of brushless motors as a set with computerized systems of control and regulation in different units to perform diverse technological functions. Effectiveness of application of step and valve electric drives for modulated and pulsed feed of electrode wire is particularly emphasized. Goods prospects for development of equipment with application of electric drives with step and valve electric motors are noted. 11 Ref., 8 Figures.

***Keywords:*** *arc welding-surfacing, mechanized equipment, control, electric drive, brushless electric motors*

Constantly coming new tasks, set by industry for welding fabrication, require continuous attention of developers and designers to improvement of mechanized equipment for arc processes of welding and surfacing. Spheres of equipment application with the need for conducting the processes in different positions in space, different media and conditions, are expanding [1]. Prevalence of such equipment predetermines the high degree of economic effectiveness while obtaining new technical and technological advantages. In many cases new results can be achieved by upgrading mechanized equipment, its systems and realizing new technological processes on this base.

The objective of this work was assessment of the possibilities of obtaining effective results in welding-surfacing with application of a new generation of adjustable electric drives with electric motors of brushless type in different systems of mechanized and automatic equipment. Until recently, predominantly electric drives with brushless DC motors, and in small quantities also asynchronous three-phase electric motors, were used in systems of mechanized and automatic equipment for arc welding-surfacing.

The limit of possibilities of the influence of electric drives with commutator motors on the technological process, is realization on their base of modulated operation modes at feeding electrode wires with up to 2.0–2.5 Hz frequencies [2] and welding tool oscillations in the same range. All this is due to inertia properties of electric motors and respective motion converters. It is practically impossible to implement controllable electrode metal transfer, using a feeding system with commutator motors without additional mechanical motion converters, as it requires ensuring the frequency of pulsed movement of electrode wire in the controlled mode in the range of 10–60 Hz. No significant improvement of dynamic characteristics of such electric drives can be achieved even with very perfect systems of regulation. A significant disadvantage of application of such electric drives is presence of a commutator that considerably reduces equipment reliability characteristics (electric erosion, mechanical wear). This particularly acutely affects the design and performance of semi-automatic machines for wet underwater welding, where commutator assembly of electric motor operates in the liquid medium.

Three-phase asynchronous electric motors with modern systems of frequency control and regulation of different types having ample capabilities, are highly attractive for application in welding equipment. This can refer to systems of movement of welding tool, item being welded or surfaced. However, in electrode wire feeding system of mechanized equipment (semi-automatic machines for welding and surfacing), application of three-phase asynchronous electric motors (380 V) is practically impossible, because of the level of supply voltage. Our efforts to find the considered electric drives with safe power level on voltage failed, as there are certain difficulties in their development.

Proceeding from the above-said, comparative testing was used to search for the most effective electric drives, in order to apply them in mechanized and au-


**Figure 1.** Appearance of deposited beads: *1* — regular wire feed; *2* — modulated feed

tomatic equipment for consumable electrode welding-surfacing, which would correspond to a range of capabilities, namely high values of dynamic characteristics; absence of contact assemblies (commutator assembly); shaft torque ensuring electric motor operation without an additional reducer; small weight and dimensional parameters; low cost and possibility of application for large-scale production in semi-automatic machines for various applications.

Comparative analysis showed that proceeding from the total set of parameters two types of electric drives can be applied, namely those based on step and on valve electric motors.

Let us consider the capabilities of adjustable electric drives with step and valve electric motors in different systems of welding equipment with subsequent assessment of the probability of their application. Here, the problem of reducer elimination should be solved. Actuator of welding equipment mechanism (feed roller) should be mounted directly on the shaft of brushless electric drive of any of the above types.


**Figure 2.** Appearance of pipe cap with welded-in plug: *L* — real gap between the cap and pipe

*Electric drive with step electric motor.* As there are no manufacturers of this type of equipment in Ukraine, electric drives with step electric motors were selected as a set (electric motor and controller), batch-produced by a quite large number of companies. To minimize the cost, preference was given to electric motor with the required shaft torque for the respective mechanism of welding equipment, without built-in feedback system.

*Electric drive with valve electric motor.* In this case special development of Ukrainian experts was used. With the assistance of SC «EDTB of E.O. Paton Electric Welding Institute of NASU» they designed and manufactured an electric drive, where systems of control and regulation with specifically selected properties, have been implemented [3]. This electric drive provides maximum possible speed and minimum distortion of reproduction of the shape of assigned algorithm of electrode wire movement at acceptable weight and dimensional characteristics of both the electric motor, and the control module.

In actual developments of equipment for mechanized welding and surfacing of various objects, also during performance of wet underwater processes, computerized electric drive with bipolar step electric motor of Kinco and Schneider Electric Companies was used. We will give examples of several successful engineering solutions.

There is experience of application of electric drives with step electric motors in underwater automatic welding equipment for solving a number of problems. Electric drive was programmed to implement modulated modes of operation using an algorithm (level and time of pulse and pause) of electrode wire feed, specially selected from the conditions of weld pool solidification. It was also applied to perform welding tool oscillations with controllable parameters and producing a weld with the required characteristics at non-guaranteed gap size. Figure 1 presents the comparative results of bead deposition under water by the wet process. These beads were produced by a semi-automatic machine with step electric motor, on a vertical plane with regular and modulated feed of flux-cored wire of 1.6 mm diameter at 200–220 A current and 25–27 V voltage. Modulation was performed with specially, in this case, experimentally, selected parameters: pulse of 0.7 s, pause of 0.5 s. Note that performance of wet underwater welding or surfacing on a vertical plane is problematic. Application of modulated process allows an essential improvement of weld quality and facilitating the task of welder-diver.

Figure 2 presents the result of application of controllable oscillations of welding tool by step electric

drive in an automatic machine, designed for deep-sea (more than 200 m) wet underwater welding. Specially developed automatic machine with computerized control shown as a fragment in Figure 3 provided quality solution of the problem of welding caps to a pipe of small inner diameter [4] with the gap between pipe wall and plug in the range of 2–5 mm, at currents of 180–200 A and voltage of 24–26 V.

Note that in the described units, electric motors without built-in systems of formation and transmission of signals of feedback by motor rotor position were applied, in order to avoid the influence of interference on operation of computerized electric drive.

It should be specially mentioned that when certain conditions are satisfied, step electric motors are capable of long-term operation in the medium of isolating, lubricating liquids of semi-automatic machines for wet underwater welding.

Semi-automatic machines with application of step electric motors are manufactured in small batches and used for welding and cutting in water facilities in fresh and sea water.

In our opinion, promising is the use of computerized electric drives to generate controllable oscillations of items being surfaced, in order to widen the surfacing zone, as well as ensure a favourable structure of deposited bead metal [5].

Highly attractive is the task of providing controllable pulsed movement of electrode wire with up to 50–60 Hz frequencies for solving a range of technical and technological problems, the results of which are given, for instance in [6].

Application of step electric motors for pulsed feed of electrode wire is described in [7]. It gives the results of experimental study of the technology of automatic submerged-arc welding of structural steel with application of the mechanism of electrode wire feed, based on step motor. Influence of parameters of pulsed wire feed mode on the process of drop formation at the electrode tip, deposition rate and deposited bead geometry, is noted. Strictly speaking, the produced rather good result is not the consequence of desired controlled pulsed feed. It is based on the impact on electrode metal drop of a packet of feed pulses generated by step electric motor, which is indicated by oscillograms characteristic for this process (Figure 4). We can state that the obtained process is a certain variant of transition from modulation to pulsed feed of electrode wire.

Experimenting with different types of step electric motors produced in series and having built-in regulators of rotation frequency, with comprehensive approach to weight and dimensional characteristics, traction capabilities, frequency properties, so far has not led to selection of an optimum variant to achieve controllable pulsed feed of electrode wire. Work in this direction is going on.

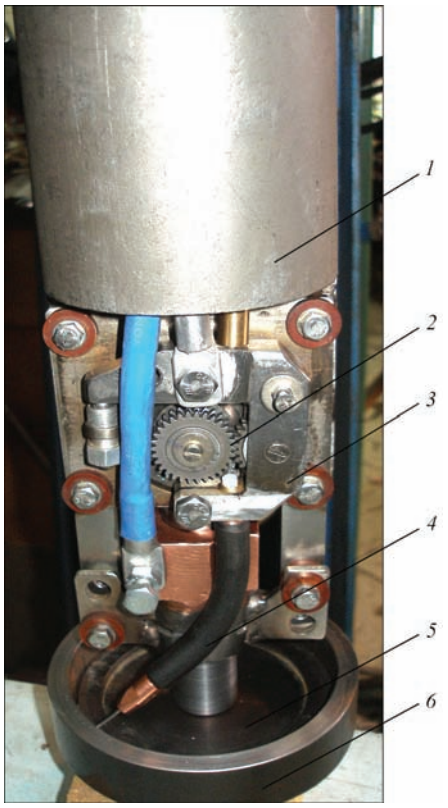


**Figure 3.** Welding assembly of the apparatus for deep-sea welding: *1* — body; *2* — feed mechanism; *3* — oscillation mechanism; *4* — welding torch; *5* — plug; *6* — pipe fragment

The problem of providing controllable pulsed feed of electrode wire can be solved in its entirety now only at application of specially developed computerized electric drive with valve electric motor, having the shaft torque, sufficient for wire feeding even in

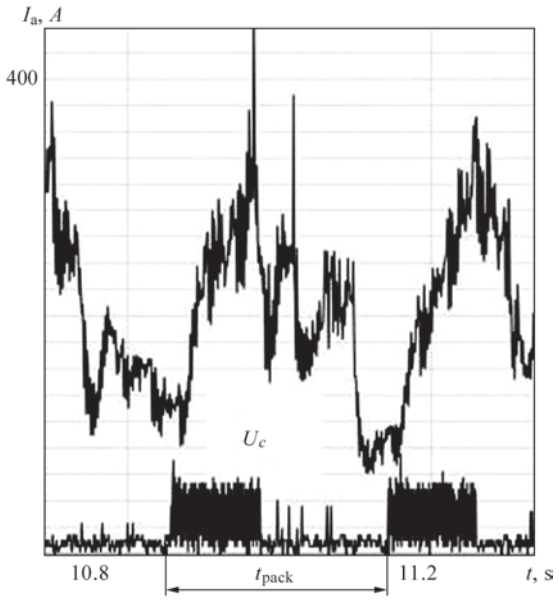


**Figure 4.** Oscillograms of current and control voltage in step motor in welding by pulse packets ($t_{pack}$ — period of pulse packet action; $U_c$ — control voltage)

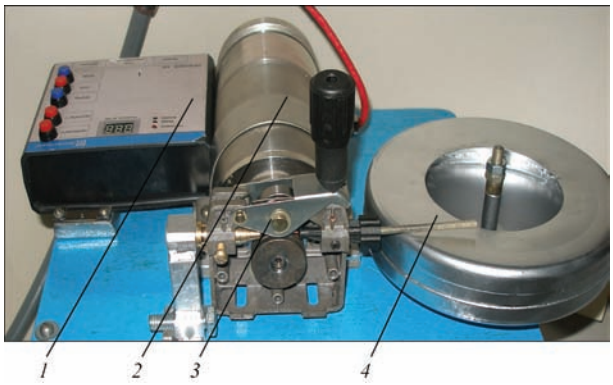


**Figure 5.** Pulsed feed mechanism based on valve electric drive: *1* — digital control block; *2* — valve motor; *3* — device for pressing press-down roller to feed roller; *4* — wire cassette

the pulsed mode [8]. Figure 5 shows a set of specially developed valve electric drive for welding equipment. Valve type electric motor can be built into feed mechanism of any welding equipment. Weight-dimensional characteristics of this assembly are 1.5–2.9 times lower than in the traditional units. Unlike electric drives with step motors, regulator of such an electric drive is synthesized purposefully to provide maximum speed with minimum overshoot at start and reverse. Oscillogram of speed of electrode wire pulsed movement, provided by the considered type of electric drive, in the feeding mode, is shown in Figure 6.

Results of application of electric drive with valve motor are essential improvements of practically all welding-surfacing indices. This pertains to bead formation, penetration, HAZ, weld metal structure and sanitary-hygienic characteristics.

As an illustration, Figure 7 gives macrosections of beads deposited in $CO_2$ at different values of frequencies, amplitudes, relative duration of pulses of feeding Sv-08G2S wire at the same integral values of current and voltage of the process (160 A, 24 V). Essential changes in bead geometry, and penetration depth at the change of controllable parameters of pulsed feed are obvious. Considerable saving of material and energy resources (lowering of electrode metal losses for spattering and power consumed for conducting the process) is achieved.

It is important to note that in this case pulsed feed provided the welding process with controlled short-circuiting.

Valve motor is fitted with an incremental sensor of rotor position, the signal of which is fed into computerized electric drive through channels protected from interference.

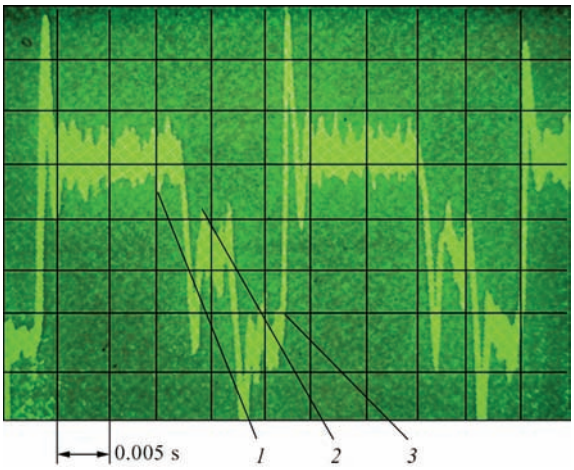


**Figure 6.** Oscillogram of pulsed feed rate: *1* — pulse; *2* — pause; *3* — reverse

Valve electric drive for welding equipment has the capability of introducing various feedback signals by arc process parameters that both significantly expands the functional capabilities of the unit, and simplifies setting up pulsed feed parameters.

By entering and processing the results of experimental studies using oscillograms, it was found that change of the step of displacement in the pulse in keeping with the following relationship, will be the most effective for changing the integral speed of wire feed:

$$I_w = k_1 v_f = k_1 f_p h,$$

where $h$ is the feed step in the pulse; $k_1$ is the coefficient, determining the dependence between welding current $I_w$ and feed rate $v_f$; $f_p$ is the frequency of pulsed feed.

This is exactly the step change that was accepted in realization of dependence $U_w = f(I_w)$, and parameter $U_w$ is taken as feedback signal. This engineering solution, essentially, is one of the kinds of synergetic control of arc welding process by analogy with pulsed arc power sources with synergetic control [9], but already based on algorithms of pulsed electrode wire feed [10].

A new welding process is being developed now, based on application of valve electric drive. This process with electrode wire feed dosed by arc process parameters is realized both with short-circuiting and without it. The method allows conducting welding-surfacing process with flux-cored self-shielded and gas-shielded electrode wires with controlled transfer of electrode metal drops.

The problem of providing the welding process with simultaneous use of pulsed algorithms of func-

**Figure 7.** Microsections of deposited beads at pulsed feed of electrode wire

tioning of welding current sources and mechanism with pulsed feed of electrode wire remains urgent.

Such electric drives are applied to ensure other movements of welding tool. Automatic welding-surfacing machine shown in Figure 8, is an example of application of valve electric drive with provision of two-axis displacement of the support with the welding tool and electrode wire feed mechanism. Such an automatic machine can perform programmable displacements in the horizontal or vertical plane by signals of built-in incremental sensors [11].

## Conclusions

1. Experience of application of valve and step electric drives in welding equipment gives an indication of their high efficiency and rationality of wide application in mechanized and automatic welding equipment. Continuous work should be performed on its improvement as regards design and control system, with the purpose of their simplification, reducing their cost, and further improvement of their reliability, for instance, in operation with long lines of signal transmission.

2. The most effective application of electric drives with brushless motors are electrode wire feed mechanisms, where quite significant results have been achieved as regards bead formation, penetration, HAZ, solving energy- and resources-saving problems.

3. Application of electric drives based on valve and step electric motors enables automation of welding operations, in particular, under the water at 200 m and greater depth.

4. Results achieved in application of step and valve electric drives in welding equipment, are the base for further efforts on improvement of equipment and technology for mechanized and automatic arc welding.

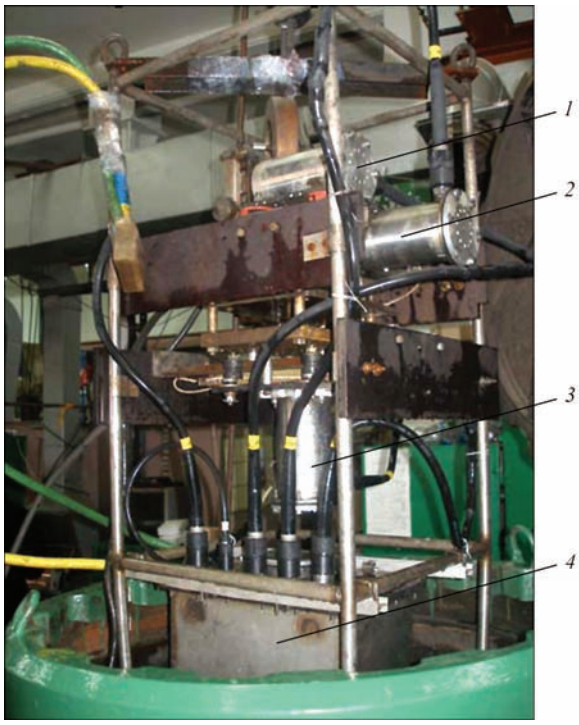


**Figure 8.** Automatic machine for welding-surfacing under the water with electric motors of mechanisms of: *1* — longitudinal; *2* — transverse displacement; *3* — electrode wire feed; *4* — immersible control block

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