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V. Lebedev, ScD.,
O. Kozyrko

THE REALIZATION OF TASKS FOR COORDINATE CONTROL OF INSTRUMENT AND WORK PIECE MOTION AT MECHANIZED AND AUTOMATIC ARC WELDING

Abstract. *The paper considers various systems to ensure movement of tool and work piece in the equipment for arc welding and mechanized welding with consumable electrode including the wire feeding system. It was noted that there get more and more spread new technologies of arc welding and surfacing with pulsed algorithms for coordinate motion of systems and semi-automatic machines for welding and surfacing with sophisticated motion algorithms that require use of new highly dynamic systems with stepper and brushless electric drive units.*

Keywords: *arc welding, mechanical equipment, machines, welding tools, transfer, control, precision, electronic components*

В. А. Лебедев, д-р техн. наук,
О. А. Козырко

РЕАЛИЗАЦИЯ ЗАДАЧ КООРДИНАТНОГО УПРАВЛЕНИЯ ПЕРЕМЕЩЕНИЕМ ИНСТРУМЕНТА И ИЗДЕЛИЯ ПРИ ДУГОВОЙ МЕХАНИЗИРОВАННОЙ И АВТОМАТИЧЕСКОЙ СВАРКЕ

Аннотация. *В работе рассматриваются различные системы, обеспечивающие перемещение инструмента и изделия в оборудовании для дуговой механизированной сварки и наплавки плавящимся электродом, включая систему подачи электродной проволоки. Отмечено, что получают всё большее распространение новые технологии дуговой сварки и наплавки с применением импульсных алгоритмов координатного движения систем автоматов и полуавтоматов для сварки и наплавки со сложными алгоритмами движения, требующими применения новых высокодинамичных систем с шаговыми и вентильными электроприводами.*

Ключевые слова*: дуговая сварка, механизированное оборудование, автоматы, сварочный инструмент, перемещение, управление, точность, элементная база*

В. О. Лебедєв, д-р техн. наук,
О. А. Козирко

РЕАЛІЗАЦІЯ ЗАВДАНЬ КООРДИНАТНОГО УПРАВЛІННЯ ПЕРЕМІЩЕННЯМ ІНСТРУМЕНТУ І ВИРОБУ ПРИ ДУГОВОГО МЕХАНІЗОВАНОГОЇ Й АВТОМАТИЧНОГО ЗВАРЮВАННЯ

Анотація. *У роботі розглядаються різні системи, що забезпечують переміщення інструмента та вироби в обладнанні для дугового механізованого зварювання та наплавлення плавиться, включаючи систему подачі електродного дроту. Відзначено, що отримують все більше поширення нові технології дугового зварювання й наплавлення із застосуванням імпульсних алгоритмів координатного руху систем автоматів і напівавтоматів для зварювання та наплавлення зі складними алгоритмами руху, які вимагають застосування нових високодинамічних систем з кроковими і вентильними електроприводами.*

Ключові слова: *дугове зварювання, механізоване обладнання, автомати, зварювальний інструмент, переміщення, управління, точність, елементна база*

Introduction. Mechanized and automatic arc welding as well as weld metal, surfacing are presently main techniques for bonding of metals, strengthening and reconditioning of wearing parts and components for various industrial and agricultural equipment.

By distinguishing variety of arc welding and surfacing processes one should point out the most common type of such processes – welding with consumable electrode. It is worth mentioning that this one is the most widely used type of technological equipment under consideration. Besides, the equipment utilized for its implementation (both mechanized and automatic ones) is the most replicable one, and hence shall be pretty well developed and represent itself a rational construction.

It shall also be noted that, depending on the tasks to be solved in the flow of welding and surfacing, the automatic welding and surfacing equipment by its design may contain a different number of coordinate-motion drives, which as a rule operate in automatic cycle:

– movement of electrode wire;
– welding travel (relative motion) of the welding tool (welding head) or a work piece;
– tracking movement of the welding travel;
– oscillatory movement of the welding tool.

It shall be pointed out that low-power electric drives are used in mechanized and automatic equipment for the arc welding and surfacing, which capacity normally does not exceed 120 W.

All the above mentioned types of the coordinate movements of welding tool and work piece with more or less identical positioning accuracy are carried out with use of traditional types of electric drives with the known types of control devices on the basis of the direct-current motors (thyristor, transistor motors), or asynchronous electric drives with frequency control. Unfortunately, the serially-produced asynchronous electric drive is designed for power supply of 220 or 380 VAC, which may not be acceptable for a large number of welding equipment, which operates in high-hazard conditions, with an allowable low-level voltage supply for its systems.

Taking into account the above mentioned types of the electric drives it shall be noted that mechatronic systems for coordinate movement with different types of motion converters [1], [2], [3] have been developed and widely used in the mechanized and automatic equipment for arc welding and surfacing. Such mechatronic systems are often unified, and produced as complete sets. The common cycle control systems for welding equipment having mechatronic design of coordinate control systems may be implemented in a number of different ways:

– fixed programming with utilization of contact-relay systems or systems with microcircuit and technical elements (microcircuitry, microprocessor engineering elements);

– flexible control system using programmable controllers.

The following are several ways of improvement of the achieved level of systems for coordinate control of welding equipment and, therefore, for the whole equipment in general:

– improvement of reliability and as a consequence the repair ability;

– reduction the equipment cost, and what is rather up-to-date, the cost for adjustment and operation;

– possibility of multi-purpose utilization of the welding and surfacing equipment developed devices, with minimal costs to customize to the specific type of the work piece;

– utilization of the more advanced types of motion converters, such as ball screw transmission;

A good example of rather exquisite welding equipment design which utilizes a full set of mechatronic systems of traditional-type coordinate control is an automatic welding and surfacing machine that is shown in Fig. 1.

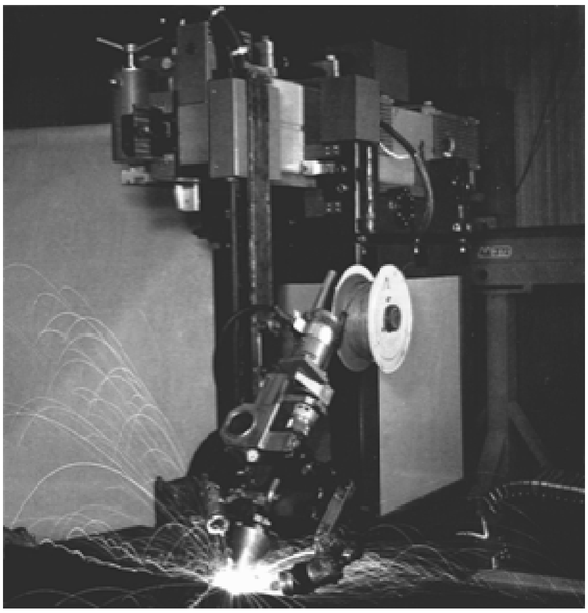

Fig. 1. Automatic welding and surfacing machine of AD400 series, structured by modular-assembly design principle, with utilization of mechatronics principles

Lately, the range of tasks that can be solved using the coordinate movement systems has significantly extended. This is connected with development of arc welding and surfacing hardware and techniques with use of consumable electrodes, that helps to solve the issue of increasing the process productivity, improve quality of the welded metal and near-weld area, and as a result, it contributes to strengthening the metal works and durability of the surfaced metal assemblies and parts. The mentioned development is primarily pre-conditioned by introduction of the controlled mechanical oscillations, which may be applied in almost all the systems of coordinate control. For example, besides the well-known processes of welding and surfacing using the pulsed feed of electrode wire [4 – 5], as well as oscillatory movement of the welding tool relatively to the surfacing or welded seam [6], a new method of welding which utilizes the controlled pulse oscillations of the work piece, is well in progress. All this helps to greatly affect the weld metal structure by changing the unfavourable form of crystallization, which, in many cases, is typical for the fusion welding process. This, in turn, leads to resolution of the main task of the arc welding and surfacing processes – obtaining a welded joint or surfaced layer with the specified (required) strength characteristics.

New mechatronic systems for welding equipment
It is possible to solve a new set of tasks on the pulse coordinate control of systems for mechanized and automatic welding equipment by using up-to-date developments of highly dynamic electric drives, including models with Step-type and Permanent Magnet Synchronous Motors (PMSM).

This is due to the necessity to obtain the coordinate movements with frequencies up to 100 Hz (for the electrode wire feed system) and 12 ,..., 20 Hz for oscillation of the welding tool or work piece, with specified amplitude (acceleration) and pulse-pause ratio characteristics. Certainly, sometimes it is expedient to use gearless type electric drives for precise repetition of coordinate movement trajectory with the specified parameters. Besides, in many cases, there is simply no alternative to it.

The step-type electric drive that is manufactured industrially can successfully be employed in almost all systems for coordinate movement of welding equipment, including utilization of pulsed-type algorithms. There is quite a number of systems for coordinate movement of the welding equipment units using step-type electric drives. As a rule, computer-controlled systems are used in conjunction with step-type electric drive usage, which besides controls of the motor shaft speed, additionally helps to solve tasks of cyclic control, while the electric motor properties - to calculate and set the trajectory of movement. Certain drawbacks of such systems usage (rather high cost and complexity) are compensated by the minimal sizes of systems and accuracy of repetition of specified algorithms of their functioning.

By using step-type electric drives it is also possible to solve the tasks of pulse displacement of the mentioned welding equipment systems [7]. The system was developed for the pulse movement of electrode wire with a function of movement frequency control (up to 50 ,..., 60 Hz) [8]. It shall be noted that the step-type electric drive that is used in the welding equipment is capable to operate both in the open and in closed system of rotation frequency limiter. The electric drive's open system is usually used when the welding equipment is located at a considerable distance from the control system. Such structural layout is the most resistant to interferences. However, it is so far impossible to reproduce the algorithm of motion of the welding equipment systems with controlled values of amplitude, relative pulse duration, travel increment, especially when providing movement of rather heavy masses (welding head, work piece being welded or surfaced), while fulfilling the small-size conditions. Several versions of the specialized computerized PMSM electric drives [9], ensuring the work of welding equipment system, both in the unperturbed motion and with different algorithms of pulse movement, were developed to solve these problems.

An example of a new design. The basis for such a design is a quick-action PMSM electric drive the optimized calculation of which was made on the basis of the model that is presented in the form of a simplified block diagram in Fig. 2 [10].

It is worth mentioning that the PMSM-type electric motor is with a good reason represented by the DC-type electric motor with independent excitation, in the present diagram.

A complete PMSM-type electric drive that has been specifically designed for the welding equipment systems is presented in Fig. 3.

Considering the mechanical characteristics of the electric drive (Fig. 4), we can conclude that the guaranteed nominal momentum on the electric driving motor shaft (2.0 Nm) provides for reliable operation of all equipment systems in a gearless version for mechanized arc welding and surfacing with use of consumable electrode. In so doing, virtually all the controlled pulsed modes with a complex control algorithms are realized in practically entire range of the motor shaft rotation frequencies. Up-to-the-minute task was solved for the welding equipment in the new design – minimization of weight and size characteristics of the actuators, to ensure high degree of equipment mobility. It shall be noted that the complete commercially available step-type electric drives do not comply with such requirements.

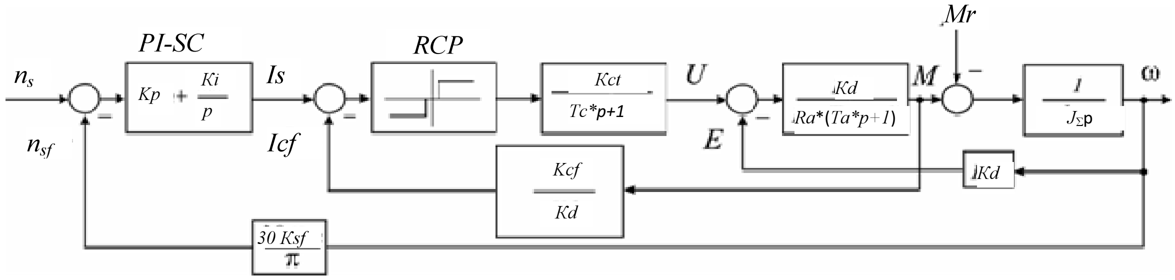

Fig. 2. PMSM electric drive design structural diagram:
n_s – rotation frequency setting; n_{sf} – speed feedback; *Is* – current setting; *Icf* – current feedback; *Kp* – proportional factor of PI-controller; *Ki* – integrated factor of PI-controller; *Kct* – converter transmission factor; *U* – converter output voltage; *E* – electric motor rotation electromotive force; *Kcf* – current feedback factor; *Ksf* – speed feedback factor; *Kd* – electric motor design factor; *Tc* – converter time constant; *Ra* – electric motor resistive impedance in hot state; *Ta* – phase time constant of electric motor; J_Σ - momentum of inertia reduced to electric motor shaft; *M* – electromagnetic momentum of electric motor; *Mr* – moment of resistance on the electric motor shaft; *p* – Laplasian operator

Fig. 3. Complete PMSM-type electric drive for welding equipment

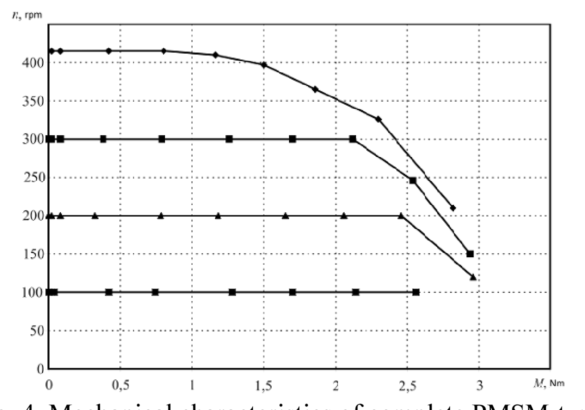

Fig. 4. Mechanical characteristics of complete PMSM-type electric drive for welding equipment systems

The new specialized machine of the PMSM-type electric drive that was carried out for welding equipment systems of Ukrainian enterprises has no analogues on the technical parameters and possibilities complex for new welding and surfacing technologies.

It shall be noted that new developments of welding and surfacing methods which utilize pulsed oscillations of the work piece having in some instants high values of inertia factors may not always be implemented in the optimal area (weight, size, cost, specifications) by the technical means that are available to designers.

For such cases, we have offered and presently have under development a number of technical solutions in a number of applications:

– development of the original motion converters, which reduce the impulse loads on the shaft of the electric drive motor significantly;

– use of electromagnetic oscillators;

– use of pneumatic systems.

It can further be noted that the utilization of electromagnetic systems in some cases is associated with influence of quite strong fields on the welding arc, and therefore is limited. Taking into account the current state of commercially available systems of pneumatic actuators, the use of the pneumatic systems may be pretty well promising.

Conclusion

1. The equipment that is used for implementation of arc welding and surfacing processes with utilization of mechanized and automatic aids are complicated mechatronic systems, the design of which requires a very specific approach.
2. The new technologies of the welding production with utilization of pulsed algorithms for movement of the welding equipment systems set forth the challenges of the highly dynamic electric drives usage, which include the models with step-type and and PMSM-type electric motors. In particular, for the PMSM-type electric drives these are the dedicated developments.
3. In the paper a complete electric drive sample is presented, that was developed specifically for a variety of welding equipment systems. The drive provides for the necessary power characteristics of feeding mechanisms, welding movement, oscillatory movement with controlled parameters (frequency of about 60 Hz, amplitude of movement - up to 10 mm, moment on the shaft – 2,0 ,… , 5,0 Nm).

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Lebedev
Vladimir A., Doctor of Engineering Science, Chief Engineer of E.O. Paton Electric Welding Institute Ukraine.
03150, Kiev, Bozhenko str., 15, bldg. 7, Ukraine.
Tel: +38(44)2008288.
E-mail: valpaton@ukr.net

Kozyrko,
Oleg A., Managing Partner DMT Marine Equipment®,
Buz’kiy bulvar 11.
Nikolaev, Ukraine.
Tel: +38(051)2366542.
E-mail:
o.kozyrko@dmt-winches.com