Automated Electric Drive for the Control System of a Two-Coordinate Welding Machine

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Abstract—A two-coordinate welding machine has been considered in this paper. Similar equipment is used to obtain welds on various elements of high-quality metal structures. The main disadvantage of the existing equipment is that the work with this machine is currently manual, which is quite dangerous and monotonous during operation. Moreover, a hydraulic drive is used as the main drive of the system. Substitution of an electric drive for the hydraulic drive of a two-coordinate welding machine to increase the efficiency of the whole system has been justified. An automated electric drive for a two-coordinate machine for welding of embedded parts, which is controlled with the use of a programmable logic controller, has been developed. The electric drive of the object has been designed. The necessary elements of the developed automation system have been selected. An algorithm that makes it possible to automate the welding process of embedded parts has been developed based on the technological process. The algorithm provides the necessary security measures by means of carrying out self-diagnostics at the startup stage. To check the performance of the developed algorithm, an automated electric drive was simulated using the Matlab Simulink software. The system contains two internal and three external circuits that control the required parameters: speed, current, torque, flux linkage, and force. The dynamic characteristics of the presented parameters, which confirm the operability of the developed automated electric drive system, have been obtained. Economic calculations of the automation system suggested for implementation have been carried out. The total cost of modernization will be about 55 thousand rubles with a payback period of about one year.

Keywords: ferrous metallurgy, pipe industry, AC motor, two-coordinate welding machine, frequency converter, electric drive, hydraulic drive, vector control

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In a competitive environment of the modern world, industrial manufacturers are forced to the maximum use of equipment [1–3]. Even a slight increase in the productivity of working machines can lead to an increase in the profit of the enterprise [4]. Ferrous metallurgy was no exception, in which special attention is paid to the modernization of equipment [5–7].

This paper considers the welding complex installed at the OAO Rifar (Gai, Orenburg region) [8]. The object for study is a two-coordinate machine for welding of embedded parts, in which the problem of substantial losses during the operation of a hydraulic drive and the absence of an automation system to control the welding process is revealed. This machine can produce products that can be used in ferrous metallurgy. Embedded parts are always used in the building of a new facility or lighting poles, which is inevitable at an enterprise of any industry. For example, lighting pole installation, pipe embedded elements (such as Phase Transformer), and embedded fundamental blocks are often used. They represent a metal structure consisting of a pipe with a certain section and with a flange welded to it [9]. The aim of this work is to develop an automated electric drive of a two-coordinate welding machine, which will improve the quality of seams and reduce the time of a welding cycle. To achieve this goal, it is necessary to solve the following tasks:

— justify and implement the substitution of electric drive in a two-coordinate machine for welding of embedded parts for a hydraulic drive;

— develop an algorithm for the two-coordinate for welding of embedded parts;

— develop and research a model of an electric drive pressing in a two-coordinate machine for welding of embedded parts.
DESCRIPTION OF SETUP DIAGRAM

The general view and elements of a two-coordinate welding machine, which is designed for welding of the halves of embedded part under the action of contact welding, is shown in Fig. 1 [10].

The machine operation is based on the hydraulic drive, which consists of three hydraulic cylinders and five hydraulic valves: one safety valve, three working valves going to hydraulic cylinders, and one backup valve. The machine is also equipped with an electric drive for driving the valve of the right side of an embedded detail [11].

The disadvantages of the hydraulic drive are as follows:

– the design complexity and high requirements to the technology of manufacturing individual elements of the hydraulic drive;
– sufficiently high complexity of pipelines under high pressure;
– sensitive performance and high cost.

Therefore, the replacement of the hydraulic drive with an electric drive devoid of these disadvantages is a necessary step.

An electric drive of a two-coordinate machine for welding of embedded parts should meet the following requirements:

– positioning and stopping accuracy;
– the minimum acceleration and deceleration time (not more than 0.5 s);
– ensuring an effort that corresponds to the power process characteristics;
– wide range of operating temperatures;
– reliability;
– ensuring the reliability of work;
– ensuring the required level of automation;
– resistance to shock vibration loads;
– ensuring performance under the action of constant magnetic and alternating fields of a network frequency [12].

For the electric drive of a two-coordinate machine for welding of embedded parts, the system of electric drive as “frequency converter–asynchronous engine” (FC-AE) has been selected as having the greatest advantages over other systems of electric drive [13–16].

To monitor the state of elements that carry out the movement, the developed automatic system of a two-coordinate machine has sensors for the left and right pressing, upper home position and lower working position, and two sensors that monitor the presence of embedded items. The VBI-M12-60R-1113-S.51 non-contact inductive switch with an increased operating distance, which is produced by the Sensor Company, is used as sensors [17].

The diagram of the control system of a two-coordinate welding machine is shown in Fig. 2, where a control object and means of its automation are also shown.

An algorithm for the operation of a two-coordinate machine for welding of embedded items has been developed. During starting of the system, the emergency buttons are polled to check the readiness of a machine for operation. At the next stage, the readiness poll of the frequency converter system is carried out. This is followed by the check of readiness of the welding inverter.

The algorithm for further actions is shown in detail in Fig. 3. Directly during the operation, the sensors of the right clamp are polled. The received ready signal is sent to the welding manifold and allows for implementing welding of embedded parts. After the welding process, the welding inverter is polled about the end, as a result of which the embedded parts are unlocked, and the clamps are removed to their original position. At this point, the welding process comes to end, and the operator can pull out the embedded parts for further transportation.
Three electric drives shown in Fig. 2 work according to a single algorithm (Fig. 3). However, it is of great interest to carry out further research and meet the requirements presented above, as well as to implement a larger number of actions of the algorithm, the electric drive of right side pressing, which contains electric engine E3 (see Fig. 2). The block diagram of an electric drive has been developed in the Matlab Simulink program based on well-known techniques [18–20] (Fig. 4).

The circuit includes two internal current control loops with a feedback coefficient $K_{cf}$ as well as three external control loops: flux linkage with a flux link feedback coefficient $K_{\Psi}$, speed with a speed feedback coefficient $K_{sf}$, and a force control loop with a force feedback coefficient $K_{ff}$.

A feature of the presented block diagram of the electric drive is the presence of a force control loop, which allows one to obtain the smoothness of the applied force (without impacts and overshoot) to eliminate damages to the workpiece. As a result of simulations in the Matlab Simulink software, a speed-time curve for the machine operating mode was obtained. It is shown in Fig. 5.

As follows from the curve shown in Fig. 5, the magnitude of overshoot during shift of right-side pressing is zero. The rate of rise of the process is smooth, without fluctuations. Hence, the requirement to provide a force corresponding to the power characteristics of a process is reached. The nominal speed is reached for the period not higher than 0.5 s (regulation time), which meets the requirements on positioning accuracy and acceleration time.

CONCLUSIONS

Based on the disadvantages of a hydraulic drive, the substitution of an electric drive for a hydraulic one has been substantiated.

The developed algorithm for the operation of a two-coordinate welding machine is studied using the developed mathematical model of an electric drive of right side pressing. The reliability of the calculations and construction of the model is confirmed by the obtained speed curve. The obtained transient speed process, the absence of overshoot, the transient process acceleration time equal to 0.27 s, and smooth acceleration and deceleration due to the absence of oscillations all corroborate the validity of the calculations and the possibility to use the developed algorithm for a two-coordinate welding machine.

When implementing the suggested solution at the JSC Rifar, the total cost of modernization will be...
Fig. 3. Algorithm of machine operation.
about 55 thousand rubles with a payback period of one year.

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