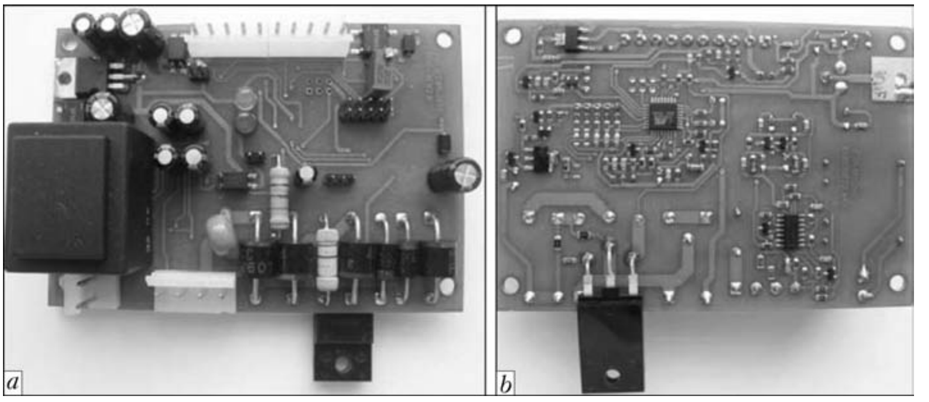

Figure 3. General view of front (*a*) and rear (*b*) side of board for pulse stabilizer of AC welding arc

voltage in it can be equal zero in this moment. However, the second pulse coinciding with the maximum value of open-circuit voltage and summing with the latter follows the first one after one fourth of the period (the time is stated by operator) and provides safe arc ignition. It should be noted that appearance of the energy pulse during arcing will make no notable influence on the process of welding due to short-term activity of the pulse.

If the arc extinction takes place during the first fourth of the period it can be easily ignited due to pulse following the first after one fourth of the period and coinciding with the amplitude value of open-circuit voltage. Arc ignition will take some time if its extinction takes place during the part of the period with sine drop of voltage. There can be no arc ignition at polarity change but it will be ignited by second pulse also summing with the maximum of open-circuit voltage.

New pulse devices (Figure 3) have already find commercial application as AC arc stabilizers and oscillators for argon-arc welding and other cases.

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ELECTRODE COMPRESSION DRIVE FOR RESISTANCE SPOT MICROWELDING

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Electrode compression drive for resistance spot microwelding was developed on a base of a step motor for spring dosing of the compression force. The drive allows implementation of complex cyclograms of compression of electrodes and programmed variation of their feed speeds.

Keywords: *resistance spot microwelding, electrode compression drive, microcontrol*

The electrode compression drive for resistance spot welding should provide displacement of the upper electrode relative to the fixed lower one and compression of the workpieces welded at a preset force. In resistance spot welding machines the stroke of the movable electrode is usually 5–20 mm, and the electrode compression force is adjustable from 1 to 80 N [1].

Based on the peculiarities of the process of resistance spot welding, its optimal cyclogram should correspond to that shown in Figure 1 [2]. The cyclogram has three stages: *I*, *II* and *III*. In stage *I*, preliminary reduction F_r serves to remove gaps between the workpieces and provide the required values of electrode–workpiece contact resistances in the cold state. Monotonous growth of F_w in stage *II* allows maintaining the stable pressure between the workpieces, despite increase in the contact area and liquid nugget diameter. Two regions *a* and *b* can be distinguished in stage *III*: F_w in a small first region is kept constant (usually for 0.03–0.10 s) to provide some cooling of the external metal layers of the workpieces and prevent deep dents in forging; and forging force F_f is applied and maintained in the second region to decrease tensile stresses and buckling of the joints, and to prevent hot cracks and cavities. However, in practice the force cyclogram is made simpler depending on the thickness, properties, configuration and degree of criticality of

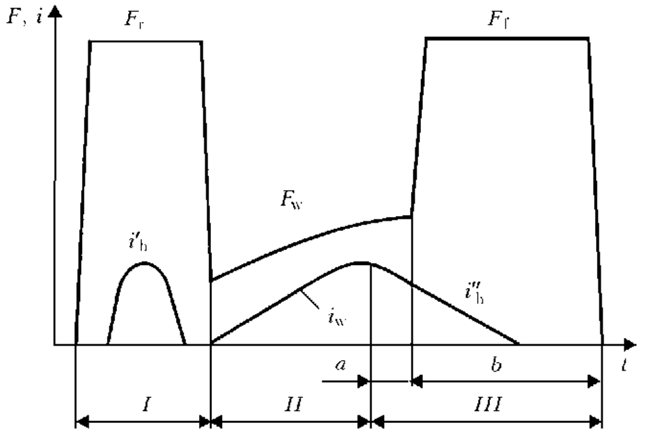

Figure 1. Optimal spot welding cyclogram: i_w — welding current; i'_h — heating current; i''_h — postweld heating current

the joints, quality of fit-up, as well as real capabilities of the welding equipment.

The following drives are used in resistance spot microwelding machines to displace the movable electrode and generate the compression force for the workpieces welded: pedal-load, spring, pneumatic, hydraulic, electromagnetic and pneumatic-hydraulic. Spring drives received wide acceptance in the machines for resistance spot microwelding of small thicknesses [1]. These drives generate the force due to compression of springs, which is provided by pressing the foot pedal by a welder using a separate pneumatic drive, electromagnet or electric drive with eccentric.

Below we describe the spring drive for displacement and compression of electrodes, based on a linear drive with a step motor (SM). Kinematic diagram of the drive is shown in Figure 2. Casing *7* of the electrode displacement and compression drive is immovable and fixed to the frame of the resistance spot microwelding machine. Electrode *8* together with cup *4* is moved along fluoroplastic guides *5* with respect to casing *7*. Prior to welding, electrode *8* together with cup 4 is located in the upper position, i.e. the electrode is lifted. When motor *1* is switched on «to rotation», screw *2* connected to the shaft starts rotating. As a result, nut *3* is moved down along the screw. Through spring *6* the nut affects cup *4* and electrode *8* connected to it. The latter is moved down to touch the workpiece surface. Spring *6* is not practically compressed because of a low sliding friction force in contact between polished cup *4* and fluoroplastic guides *5*.

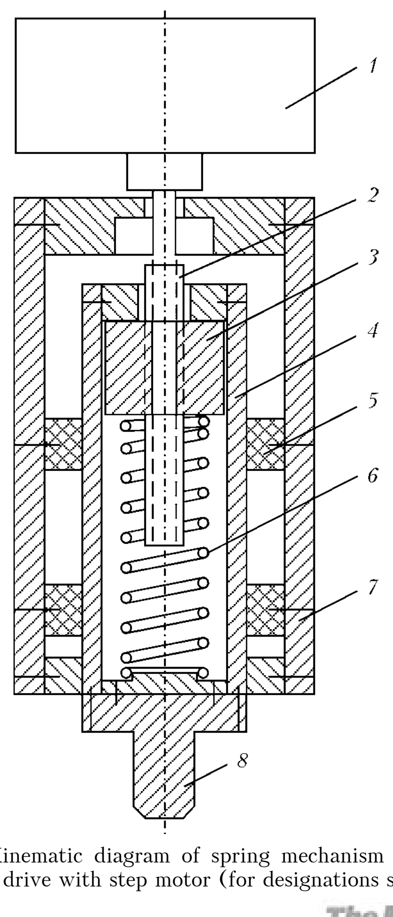

Figure 2. Kinematic diagram of spring mechanism of electrode compression drive with step motor (for designations see the text)

The electrode stops moving after it touches the worpiece surface, and nut *3* while moving down starts compressing spring *6*. The force of compression of the spring is transferred to electrode *8*, thus generating the welding force. The value of this force is proportional to the force of compression of the spring, i.e. the stroke of the nut, and can be easily adjusted by the quantity of steps of SM *1* after touching the workpiece by the electrode.

To provide sound welded joints in microwelding of wire to sheet, wire to wire, etc., it is required that the compression mechanism be characterised by a low time lag [1]. The drive developed meets in full this requirement. The mass of the movable part in it is determined only by masses of electrode *8* and cup *4*, i.e. it is minimal.

The use of SM makes the control system much simpler, as no displacement sensors are required to determine displacement of the electrode and compression of the spring. Structural diagram of control of the electrode compression drive is shown in Figure 3. «Microchip» microcontroller *3* performs all the main control functions. Signals from control panel *2* and sensor *1* of touching a workpiece by the electrodes are fed to its inputs. Microcontroller *3* feeds control signals to SM controller *4*. Output signals of controller *4* control full-bridge driver *5*, which SM *6* is connected to. Acyclic four-winding SM with permanent electromagnets DShI-200-2 provides torque of 0.225 N·m at an acceleration frequency of 1000 Hz.

The angle of rotation of the motor shaft in perormance of one control pulse is 1.8° (200 ppr). Microcontroller *3* feeds a series of pulses to motor controller *4*, the frequency of which determines the speed of the motor, and the quantity of which — the angle of rotation of the shaft and, hence, the length of displacement of nut *3* (Figure 2). In addition, the microcontroller sets the direction of rotation and length of step of the motor. Controller *4* allows decreasing the step of the motor two times (from 1.8 to 0.9 deg/step) to provide a smoother motion of the motor.

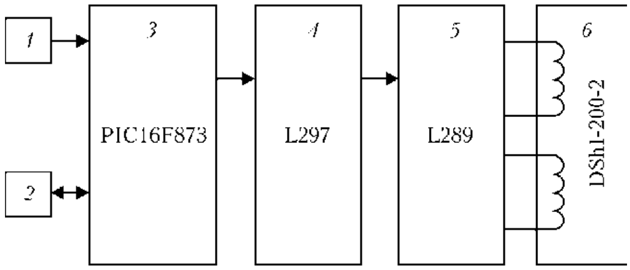

Figure 3. Structural diagram of control of electrode compression drive (for designations see the text)

The mode setting and welding switch on buttons, as well as the alphanumeric display of parameters are located on control panel *2*.

The maximal acceleration frequency of DShI-200-2 (the maximal control frequency, at which the unloaded motor can be started up and stopped without step skipping) is 1000 Hz. A smooth acceleration by gradually increasing the control frequency is used to achieve a higher rotation speed. The smooth acceleration for our drive allowed doubling the frequency of steps of SM compared to the acceleration frequency.

Owing to the use of SM and microprocessor control the developed drive makes it possible to implement any algorithm of displacement and compression of electrodes, e.g. indicated in study [1]. Figure 4 shows implementation of optimisation of the electrode displacement and compression force cyclogram similar to that shown in Figure 1. The electrode compression force is set by the quantity of steps of SM. The maximal compression force equal to 60 N is varied at discreteness of 0.07 N and maximal speed of 120 N/s.

Like the electrode compression force, the electrode displacement length is determined by the quantity of steps of SM by feeding a preset quantity of control pulses to it from the microcontroller, and the displacement speed is determined by the frequency of these pulses. The said parameters can be varied over wide ranges. The maximal stroke of the electrode is 10 mm, discreteness of setting of the displacement is 0.07 mm,

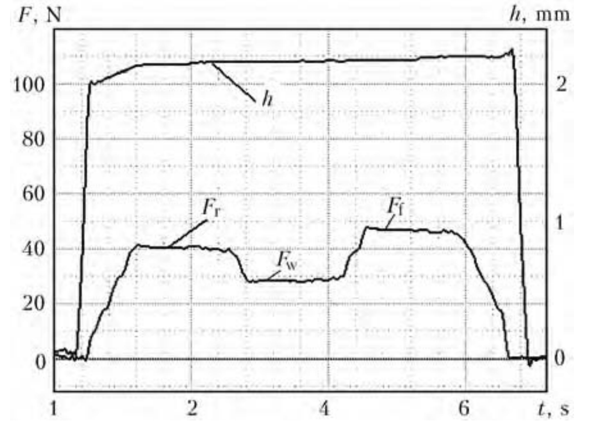

Figure 4. Cyclogram of operation of the electrode displacement and compression drive: h — electrode displacement length

and the maximal displacement speed is 14 mm/s. The drive allows performing the shock-free operation of the electrodes by using the programmed decrease of speed of SM before touching the workpiece by the electrode. This provides decrease in mechanical wear of the electrode tip, increase in sharpening intervals, rise in productivity and extension of service life of the electrodes.

CONCLUSION

The developed electrode compression drive for resistance spot microwelding machines provides precise performance of setting of the displacement and variations in the electrode compression force following the any complexity programs. The drive is characterised by compactness, relative simplicity and low time lag of its movable part. Its drawback is a lower operation speed compared to pneumatic and hydraulic electrode compression drives.

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