SYSTEMS OF PROCESS CONTROL AND MONITORING OF CONDITIONS — THE IMPORTANT FACTORS OF QUALITY ASSURANCE IN ELECTROSLAG WELDING OF THICK METAL

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At the NKMZ the installation, unique by its technical capabilities, is successfully used for electroslag welding of large-size parts, allowing manufacture of welded-cast, rolled-welded and welded-forged steel billets of weld section of up to 5000 × 6000 mm and weight of more than 100 t. The required quality of metal of welded joint is provided due to a strict keeping of preset welding condition parameters during the whole period of weld fulfilment without forced interruptions of the welding process. This is attained by a high reliability of operation of electric control circuit and drives of executive units of the installation, as well as by application of method of doubling the feeding of electrode wires into the zone of welding. Setting of selected condition parameters, control and visual inspection of the welding process are realized from two central panels, and also using the automatic system of welding conditions monitoring. The system of control represents a multi-functional complex, in which the control of parameters of the technological process (acquisition and processing of information) is realized by the controller SIMATIC S7-300, and the display of parameters, recording and record-keeping of accumulated information are realized by an industrial computer in a panel-type version PC 670 and text panels of operator OP 7. Software of the control system was developed using the Siemens package of programs WinCC V5.1 and operates under the control of operational system Microsoft Windows. 3 Ref., 6 Figures.

Keywords: *specialized equipment for welding of thick metal, electroslag welding with consumable nozzle, control systems, monitoring of welding conditions, doubling of feeding the electrode wires, reliability in electroslag process fulfilment*

The NKMZ is the leader in production of large-size steel metal structures of heavy machine-building units using electroslag welding with a consumable nozzle (ESW CN).

The new stage in the development of technology and equipment of ESW CN started in 2002 when a new installation, unique by its technical capabilities, for ESW of large-size thick parts was manufactured and put into service in the plant [1], having no analogues in the world practice of the welding production. Using this installation it is possible to produce welded-cast, rolled-welded and welded-forged steel billets of butt section of up to 5000 × 6000 mm and more than 100 t weight. It also makes it possible to perform ESW of two butts of up to 2000 × × 6000 mm section simultaneously.

In welding of products with large-size butts the forced interruptions of the ESW lead, as a rule, to the formation of almost non-repairable defects in the weld, causing high material losses and decreasing the efficiency of the technological welding process. The reliability of the ESW process is guaranteed by a strict keeping of preset parameters over the period of weld making without forced interruptions of the welding process for the time exceeding 1.5–3.0 min [2].

Welding equipment of the installation provides a high reliability of the ESW CN process with producing the guaranteed quality of the electroslag joints, first of all, due to reliability of electric control circuit and drives of executive controls of the installation, and also by applying the method of doubling the feeding of electrode wires into the zone of welding [3]. The doubling is realized by scheme «36 working + 36 spare». Moreover, working and doubling wires are fed from independent drives. The total number of simultaneous wire feeding can reach 72 pieces.

Welding equipment of the installation includes two, independent from each other, blocks (left and right). Each block is completed with twelve three-electrode welding machines ASh-110, assembled on traverses (Figure 1) so that to provide the doubling welding wire feeding in the guiding channels of consumable nozzles (Fi-

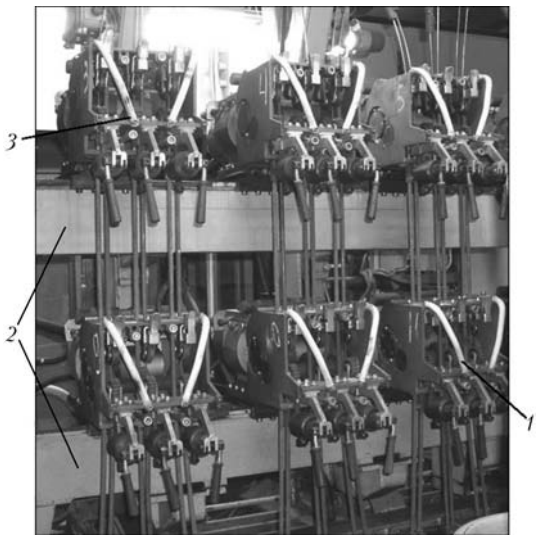

Figure 1. Appearance of welding machines ASh-110 assembled into blocks: *1*, *3* — working and doubling welding machines, respectively; *2* — traverses for fastening the machines

gure 2). The supply is realized from four power sources TShS 3000/3 (A-481 E), connected in parallel (two for each block). Setting of selected condition parameters, control and visual inspection of the welding process are realized by means of two central panels, as well as by automatic system of monitoring the welding conditions, arranged in a central cabin (Figure 3).

To fulfil the preparatory and setting-up works (before and after welding), local control panels are used, located in site of the preparatory operations. Electric systems of control and drives of all the elements of the installation are mounted in control cabinets, arranged on its gantry.

Industrial experience shows that the reliability of ESW process is provided mainly by elimination of forced interruptions of electrode wire feeding into the zone of welding. The ESW process is started (mainly from «liquid start») by feeding the working wires, while the doubling ones are located in the «waiting» mode, which is characterized by the feed speed, equal to zero, or by so-called advancing speed, amounting to 10–20 % of working one. In case of a forced interruption of the working wire the control system is automatically switches on the feeding of proper doubling machine, switches off the ma-

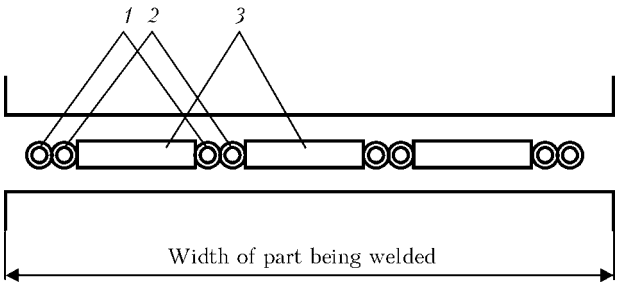

Figure 2. Scheme of consumable nozzles with channels for wire feeding (variant for one phase): *1*, *2* — channels for movement of working and doubling welding wires, respectively; *3* — plates of consumable nozzle

Figure 3. Central cabin of control of installation machines: *1*, *2* — respectively, control panels of right and left blocks; *3* — industrial computer PC 670 of system of welding conditions monitoring; *4* — signal lamps of control of welding wires movement

chine, coming out of order, and sends simultaneously signals to the central cabin about the situation by a light indication and also by a sound. Then the welders-operators detect the cause of interruption and eliminate the occurred trouble. After trouble elimination the manager of works from the central cabin takes a decision about the replacement of the doubling machine by the remedied working one. In this case the remedied machine becomes a doubling one and can be used in interruption of wire movement on the already operating machine.

The automatic computer system provides continuous objective control and monitoring of main condition parameters, as well as thermodeformational cycle of welding. The control system represents a multi-functional complex, in which the control of technological process parameters (acquisition and processing of information) is realized by a controller SIMATIC S7-300, and the display of parameters, recording and record-keeping if accumulated information are realized by an industrial computer in a panel-type version PC 670 and text panels of the operator OP 7. The software of the control system was developed by using the package of programs WinCC V5.1 of «Siemens» and it is governed by the operational system Microsoft Windows. The appear-

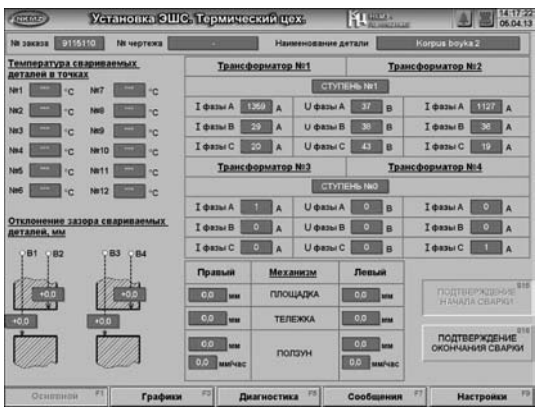

Figure 4. Appearance of main window of control and monitoring system

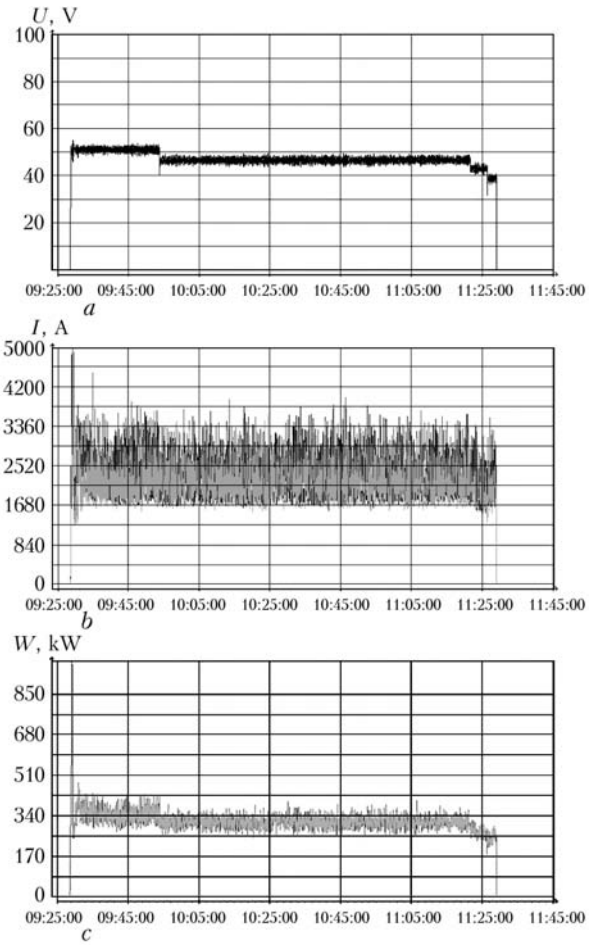

Figure 5. Appearance of general graphic information obtained in the system of monitoring: *a* — welding voltage; *b* — welding current; *c* — electric power of welding

ance of the main window of control and monitoring system is shown in Figure 4.

The system of control and monitoring allows recording on-line such important parameters of the welding process as voltage, current, generated electric power, rate of electrode wire feeding (Figure 5), welding speed, heating temperature of edges being welded, etc.

The required technological information is taken from specialized sensors and other electric equipment directly in site. Signals from sensors are processed by a controller, which transforms the input data by a definite algorithm into appropriate technological parameters of the process.

All the electric parameters of the process (welding voltage, current, electric power, welding wire feed rate) can be observed directly during welding with separation by binding to power welding circuit of the installation. For example, it is possible to display the values of voltage or current separately at each phase for each power source or in binding with other values, while the wire feed rate — at each machine. The obtained values of the mentioned parameters can be corrected by the manager of works in central control panels.

Oscillograms of records of condition parameters are the objective characteristics of the welding process, which confirm the quality of the fulfilled process (its compliance with preset welding conditions) and promote consolidation of technological discipline among the welders. The decoding of records of a definite case (in time coordinates) can help, if necessary, in finding the causes of defect formation in the weld or for evaluating the conditions during the interested time of welding (Figure 6).

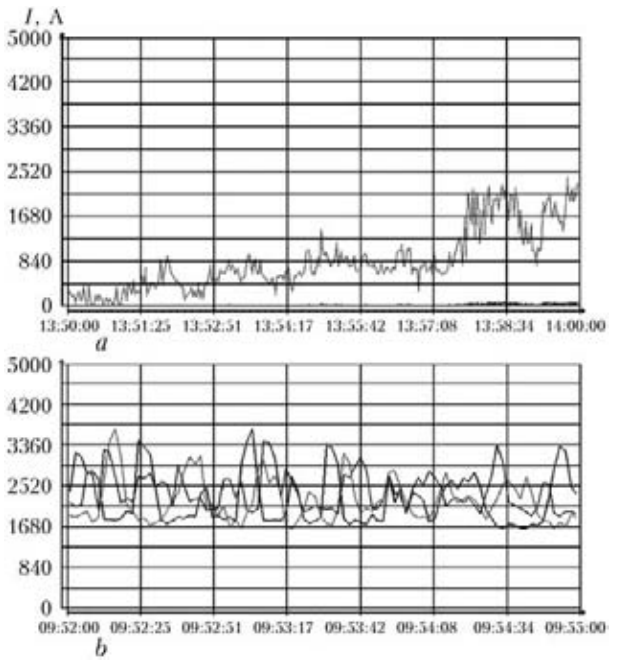

Figure 6. Oscillograms of welding current for single-phase of consumable nozzle at the area of weld after 50 min since the welding beginning ($v_{w.f}$ = 115 m/h) (*a*) and three-phase scheme of consumable nozzles after 32 min since the welding beginning ($v_{w.f}$ = 150 m/h) (*b*)

It is important to note that the analysis of obtained records of oscillograms can be useful also in optimizing the conditions and technique of welding for the new technological processes of ESW CN of thick metal of the new products.

In conclusion, it can be outlined that the high reliability of operation of executive settings of the installation for manufacture of large-sized metal structures by ESW CN in combination with use of method of doubling the electrode wire feeding into the zone of welding, and also the obligatory control and monitoring of welding conditions provide the effective guaranteed producing of welded joints of thick-section metal of the required quality.

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