EVALUATION OF STABILITY OF THE FLASHING PROCESS IN FLASH BUTT WELDING

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Procedure was developed for monitoring the process of continuous flash butt welding. The feasibility of using neural networks for evaluation of stability of the welding process was established.

Keywords: *flash butt welding, continuous flashing, process stability, defects in joints, deviation of process parameters, monitoring of quality, neuron networks*

Non-destructive testing of welded joints in flash butt welding does not always allow a reliable detection of defects. Given that properties of the welded joints directly depend on the welding process parameters, stability of the latter is often determined by the presence of their deviation from the specified values.

Normally, the satisfactory quality of the welded joints in continuous flash butt welding is achieved by providing the optimal temperature distributions in the near-contact zone over the entire cross section area prior to upsetting, as well as the upsetting value and speed. As in a number of cases the above characteristics are very difficult or impossible to measure directly, the measurements are carried out on other parameters that affect heating of workpieces, such as welding voltage, speed of feeding of workpieces, etc. Consistent values of the above indicators provide the optimal heating of workpieces and, as a result, quality of the joints. In this case, the maximum permissible deviation of open-circuit voltage from the specified value is 10 %, that of the speed of feeding of workpieces is 20 %, and deviations of the values of workpiece extension should not exceed 5 % [1]. This approach allows fixing the deviations of each of the above parameters separately, but it gives no idea of their total effect on the process stability.

The information required for evaluation of the quality of a welded joint can be obtained from the results of analysis of basic physical parameters of the welding process, the electric parameters in particular [1–3]. In continuous flash butt welding the process of formation of liquid bridges, their heating, destruction and formation of the new ones can be described by the probability methods. The course of this process is determined by instantaneous values of the welding parameters (both electric and mechanical), as well as by different kinds of random disturbances, including the technological ones, related to preparation of workpieces for welding and their arrangement in clamps of the welding machine. Effect of the disturbances on the course of the process is most often characterised by deviation of the basic process parameters from the specified values, i.e. the change of voltage during the flashing process is of a probability character, while the secondary voltage itself is one of the welding process parameters that is most sensitive to disturbances.

As preconditions that determine deterioration of quality indicators of the joints may form at all stages of the welding process, one of the variants of evaluation of the quality can be analysis of voltage oscillograms and their division into groups corresponding to deviations of the basic parameters. Therefore, the task of monitoring of the quality is reduced to the task of classification.

A procedure was developed for monitoring of the continuous flash butt welding process to reveal deviations of welding voltage in real time. Experiments on continuous flash butt welding of 14 mm diameter reinforcing rods of class A400S were conducted by using machine MSO-606 with a positive electromechanical flashing drive without feedbacks. Voltage in the secondary circuit of the machine was registered by using analogue-digital converter E-140 (L-Card, Russia).

The optimal conditions, as well as three cases of deviation of the process parameters deteriorating quality characteristics of the joints, which most often occur during welding, such as decrease in workpiece feed speed v, decrease in machine open-circuit voltage $U_{o.-c}$, and change in workpiece extension l, were evaluated.

Deviations of the process parameters were caused by inducing disturbances that exceeded those permitted by the quality assurance conditions. The joints produced as a result of the experiments differed in the heating zone and presence of defects, such as discontinuities (Figure 1). It can be seen from oscillograms of the welding voltage obtained under different welding conditions (Figure 2) that the sufficiently informative signal reflecting the course of the explosive-spark process is a frequency component, which was separated by means of a digital filter.

After primary processing of the data, the arrays were divided into blocks equal to ten periods of the industrial mains voltage, based on the permissible du-

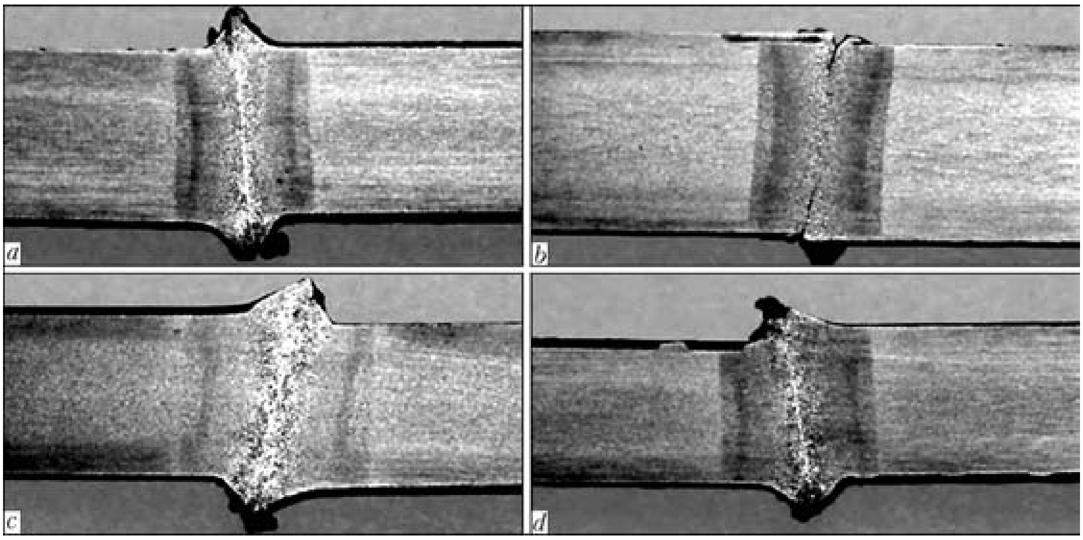

Figure 1. Macrosections of the joints produced under different welding conditions: here and below in Figures 2 and 3: *a* — optimal conditions; *b* and *c* — decreased speed and voltage, respectively; *d* — increased extension

ration of deviations during the flashing process [1]. Mathematical expectation of a random quantity module reflecting the intensity of flashing at a given stage of oscillogram was determined for each block. This resulted in the data arrays reflecting the intensity of flashing (Figure 3).

The data arrays were different even for the joints welded under conditions with the identical parameters, although the limits of variations in values of the parameters can be determined for each group of the joints. This brings about a problem of automatic classification of the arrays.

This problem can be successfully solved by using neuron networks for data classification and clustering. The Probability Neural Network (PNN), which belongs to the radial-base networks, and Learning Vector Quantization (LVQ), i.e. the network for discretisation of learning vectors, were used for classification.

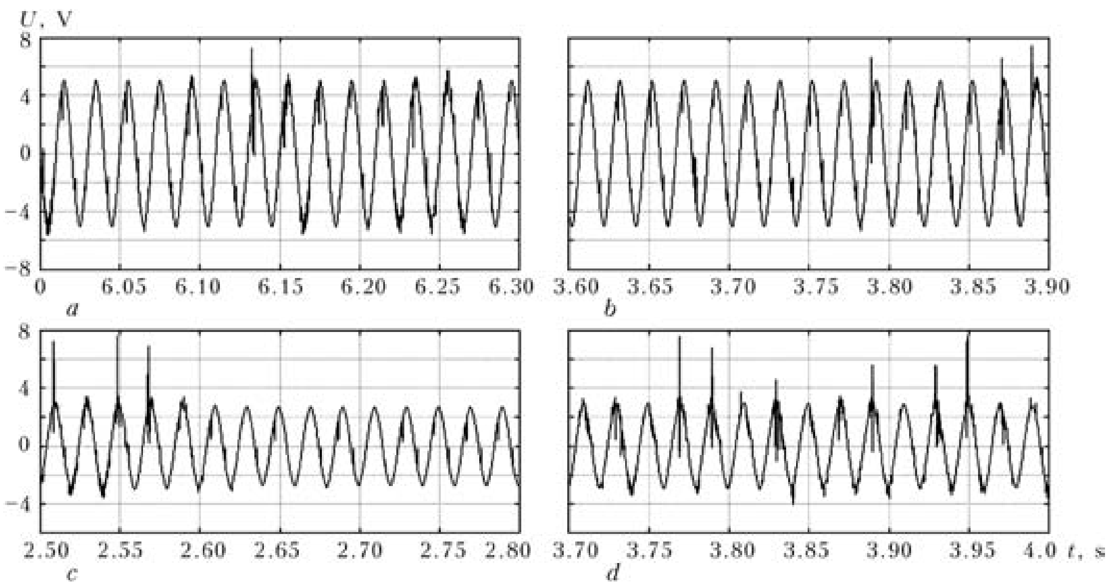

Figure 2. Typical voltage oscillograms at different welding parameters

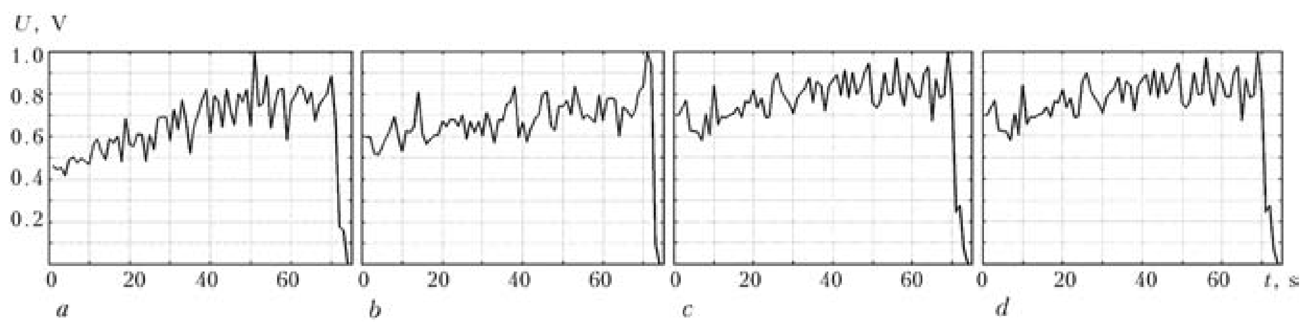

Figure 3. Typical data arrays (*a*–*d*) reflecting the intensity of flashing for groups of joints

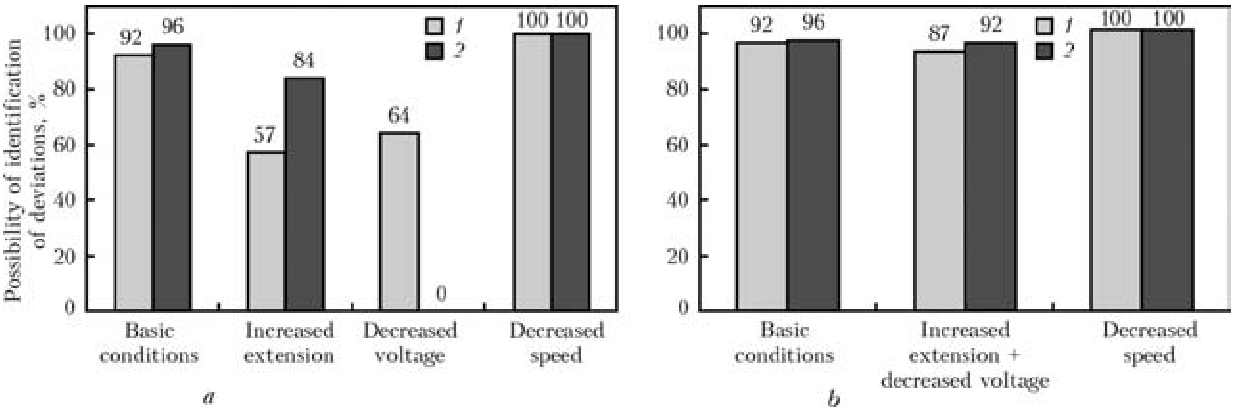

Figure 4. Results of operation of PNN (*1*) and LVQ (*2*) networks: primary (*a*) and after repeated learning (*b*)

Both networks are classed with the self-organising ones [4]. Classification was based on a criterion of the presence of deviation of one of the process parameters (v, $U_{o.-c}$, l). Therefore, the data were divided into four classes.

The data obtained during the experiments were used for network learning. One learning sequence was applied for both types of the networks. It included 15 data arrays for each group of the parameters. PNN had 4 neurons, and LVQ had 4 neurons in the second layer. Performance of the networks was tested on ranges of the values which were not used in their learning.

A relative error in identification of the data arrays for the joints welded under the optimal conditions was not in excess of 8 % (Figure 4, *a*). The data arrays belonging to a group of parameters with the decreased speed were determined unmistakably. In identification of the data arrays referring to parameters with the decreased voltage and increased extension, the error was more than 16 %. This is related to the fact that both deviations lead to formation of similar changes in the course of the process (e.g. see Figure 3).

Repeated learning of the network was carried out. For it the two groups of the joints were joined together. A new PNN network had 3 neurons, and LVQ had 3 neurons in the second layer. The network learning parameters remained unchanged. The error in revealing disturbances in this case was not in excess of 8 % for LVQ, and 13 % for PNN (Figure 4, *b*).

The results obtained proved the feasibility of using the artificial neuron networks for evaluation of stability of the process in continuous flash butt welding.

CONCLUSIONS

1. Analysis of a high-frequency component of voltage of the welding machine allows efficient realisation of 100 % monitoring of the flash butt welding process.

2. It is reasonable to use the classification and clustering neuron networks for automatic monitoring based on analysis of the intensity of flashing.

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