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Method of researching the influence of isothermic annealing modes on welding of hauling track rails used in mine workings

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Abstract. Modern problems of butt welding of hauling tracks in mine workings are considered. The article describes the method for studying the influence of isothermal annealing modes of a welded joint of samples from rail steel. The cutoff layout of samples used for experiments and the equipment are provided. The developed method allows the temperature to be measured in the weld metal and the heat-affected zone in the process of welding the samples from rail steel. Using the developed method it is proposed to study the effect of thermal cycles of butt welding on the structure of rail steel. The result of using this method is shown as an example.

1. Introduction

When constructing and repairing continuous welded railroad tracks, electrocontact and aluminothermic welding of rails is used. In Russia, the greater part of rails is welded by electrocontact method [1, 2]. Welding by the method of continuous flash welding with preheating was changed by the method of pulsed flash welding.

This method of contact welding is the most economical and technological in comparison with continuous flashing. During the contact welding of rails, as well as using other types of welding, heating and continuous cooling of metal in the heat-affected zone (HAZ) occurs. Depending on the chemical composition of the steel, the welding process is selected using the existing methods of flushing – continuous or pulsed that determine the linear magnitude and temperature fields in the welded joint HAZ [3, 4]. The choice of the thermal mode is based on the exclusion of the hardening structures formation (martensite and bainite), causing additional stresses and cracks, which lead to the destruction of rails [5]. Thus [6, 7], the development of modes for rails of high-speed railways made of chromium steel is of particular importance.

It is known that the increase in the chromium content in steel causes a shift to the right of the C-shaped curves of the austenite decay beginning and end on the diagram of austenite isothermal decay, which in turn leads to a decrease in the critical cooling rate at which the austenite is converted to martensite [8, 9]. A high-strength layer with a martensite structure is formed during the rapid heating of the welded joint by the method of pulsed flashing and subsequent intensive cooling of HAZ in microvolumes with a high content of chromium, nickel and carbon. Martensite sections [5] play the role of stress concentrators and lead to the formation of defects in welded joints (development of fatigue cracks in the head, web and base of a rail with a brittle fracture).

This problem in the process of production of a seamless welded rail is solved by the mandatory heat treatment of the welded joint. Heat treatment is carried out using induction plants, which in turn increases costs. This disadvantage in practice is suggested to be corrected by combining continuous and pulsed flash methods, changing the heating intensity during welding and controlling the cooling rate [6]. At the same time, partially using the method of continuous flashing, there might be defects of welding nature inherent to continuous reflow.

The alternative way of solving the problem is proposed, which allows any of the considered flashing methods to be used. After upsetting and cooling the welded joint at the time of reaching the required temperature, it is proposed to perform isothermal annealing by passing pulses of alternating electric current through the welded joint [10].

2. Methods of research

This article describes the method used for researching the effect produced by modes of isothermal annealing of samples welded joints from rail steel by passing pulses of alternating electric current through the welded joint. To avoid the formation of hardening structures, the aging temperature is selected based on obtaining a finer dispersed structure of the weld metal. The exposure time is determined by the incubation period of the formation of the required structure and is controlled by the number of current pulses.

3. Results and discussion

Samples with dimensions 90 mm × 30 mm × 10 mm are cut from the rail steel for the test (figure 1), further the contact butt welding is performed in different isothermal tempering modes.

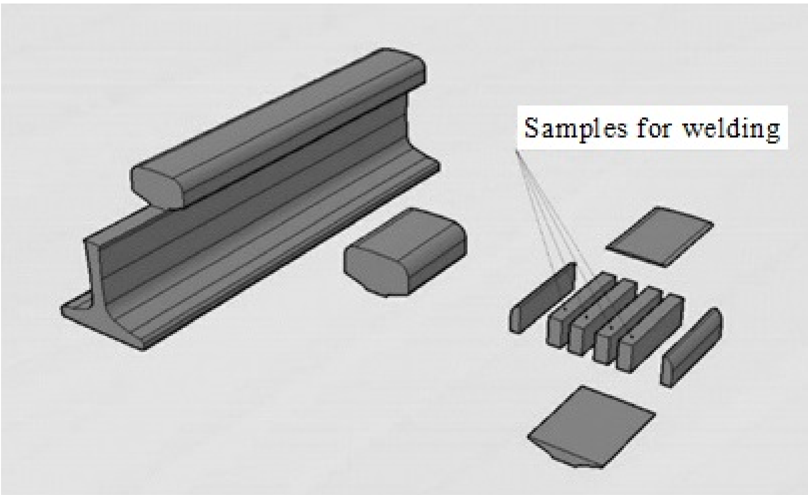


Figure 1. Layout of cutting samples with sizes 90 mm × 30 mm × 10 mm.

Welding of samples is carried out on the modernized machine for contact butt welding MS-2008M (figure 3). The welding modes are controlled by a personal computer.

To obtain information on the thermal effect on the metal structure, a method for measuring the temperatures in the heat-affected zone during welding has been developed. In this case, the welding current is measured for further adjustment of modes. The scheme of equipment interaction is shown in figure 2.

The machine for contact butt welding by flashing operates in the following way:

Before the welding begins, the welded parts are installed and clamped in the movable 2 and fixed 3 clamps, using the clamping devices of the welded parts. If the parts are installed correctly, the operator on the control panel switches on welding. The contactor of the welding current 11 comes into action, which in turn switches on the welding transformer 7. At the same time, the electric motor 12 of the flashing and tempering 12 is turned on. The flashing process begins. As the ends of the welded parts draw together, at the end of flashing and at the beginning of the upsetting, the limit switch is activated used to give a signal to the controller 13, installed on the block of limit switches 10, about the beginning of the heat treatment, the contactor of the welding current turning on switches off. The upsetting ends without current. At the end of the upsetting, the limit switch is activated, which is responsible for the operation of the electric motor 12 of flashing and upsetting driver, and it stops.

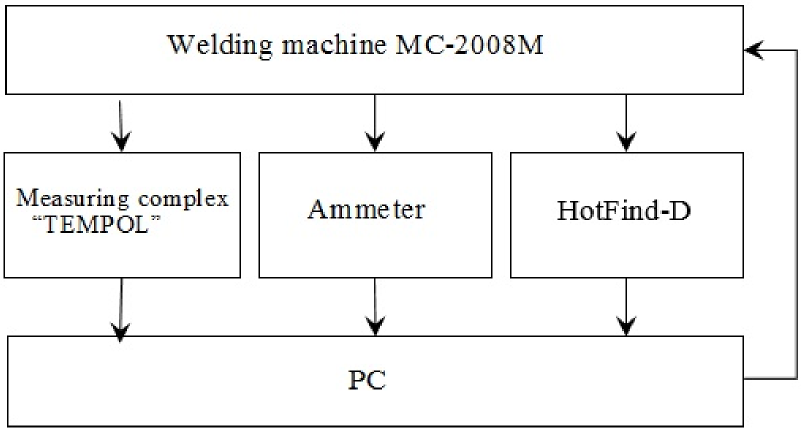


Figure 2. The scheme of equipment interaction.

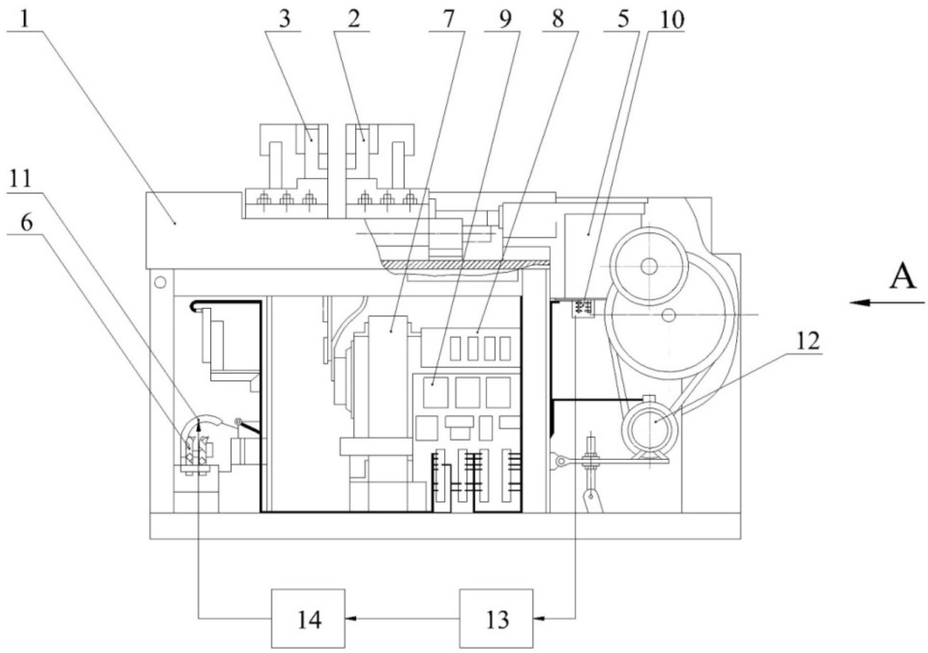
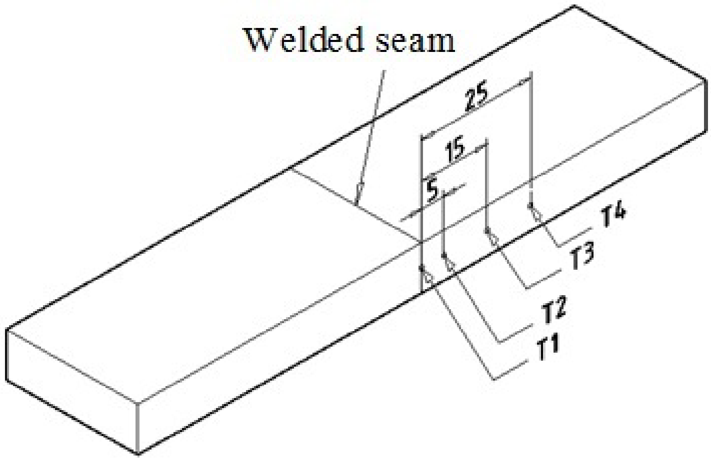


Figure 3. General view of the machine for contact butt welding MS-2008M.

In this case, the controller 13 supplies a voltage in the programmed time interval to the symistor 14 to activate the contact relay, which in its turn switches on the contactor of welding current turning on 11, thus, switching on the welding transformer 7. Through the clamped part in clamps 1 and 2 from the welding transformer 7 flows electric current, as a result of which the welded joint is heated to a certain temperature. At the end of the programmed time, the controller 13 stops sending a signal to the symistor 14, disconnecting the welding transformer 7. The welded joint is cooled to a certain temperature. The switching on of the welding transformer 7 is repeated the required number of times and at the necessary intervals according to the program in the controller 13. Thus, the process of welded parts heat treatment the takes place. At the end of the process, the operator removes the welded product for further cooling in the specially designated area.

The temperature is measured at points T1, T2, T3, T4. The proposed zone of thermal influence varies in different modes from 15 to 25 mm from the seam center, which corresponds to the maximum distance of the thermocouple placement at point T4. Since it is impossible to measure the temperature in the center of the seam, the temperature is measured by the HotFind-D thermal imager at point T1. The location of the points in which the temperature is measured is shown in figure 4.



T1 – is measured by the thermal imager, T2, T3, T4 – are measured by thermocouples.

Figure 4. The location of the points in which the temperature is measured.

Thermocouples XA (chromel-alumel) are used for measuring the metal temperature. The standard calibration of thermocouples XA is provided in accordance with the state standards GOST 3044-84 (ST SEV 1059-85). The thermocouples are made of a thermoelectrode wire with diameter 0.1-0.5 mm by brazing (using a protective quartz cap) or by stranding (when measured by a bare junction). To isolate thermoelectrodes from each other quartz straw (diameter 0.5-1.0 mm), two-channel corundum and porcelain tubes (outside diameter 3.5 mm) are used.

The collection and processing of data obtained from thermocouples is carried out with the help of the measuring complex "Tempol". The microprocessor modules used in the complex allow the measurement of the analog signal in the range from 15 mV to 2.5 V to be performed. A PC controls the complex using the developed software operating in MS DOS and WINDOWS 95/98/2000/XP environments. The complex allows the collection, registration and storage of analog signals on the hard disk of the PC to be performed with the possibility of scaling up to 2048 channels. The software of the measuring complex includes two programs written in the Basic programming language for MS DOS and MS Windows operating systems and Microsoft Excel spreadsheet. The software allows the link with the I-7018 module to be set up, which is connected to the "SOM1" serial port of the computer through I-7520 converter, and the measurements from 8 sensors to be record sequentially into the table of a specified format. At the end of the measurement process, the resulting data array is converted into a graphic image depending on the research tasks.

The HotFind-D thermal imager allows temperature measurements up to 1500 ° C to be performed. The thermal imager is equipped with a non-coolable micro-bolometric matrix in the focal plane of the lens with a resolution 160 × 120 pixels. The transfer of the video image of thermograms to the PC is carried out using the video capture card of an analog signal in the NTSC format with a frequency 60 Hz.

Figure 5 shows an example of how to use the method for determining the temperature change in the welding process.

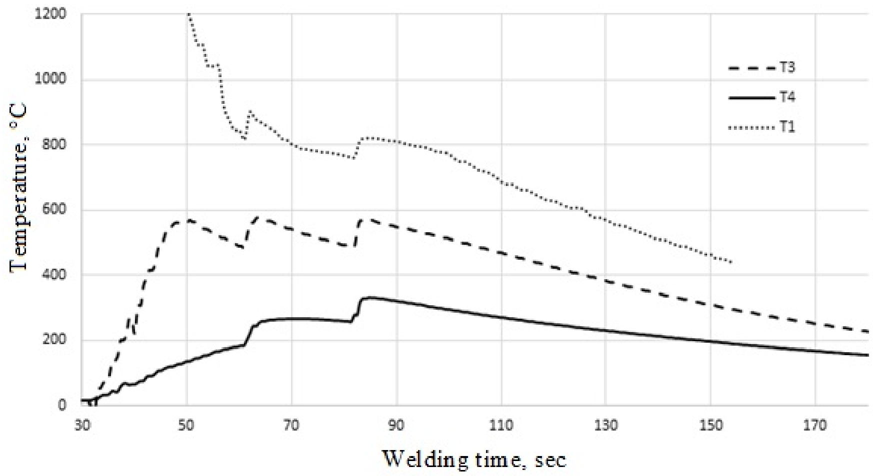


Figure 5. The example of the measured thermal cycle of welding samples.

4. Conclusion
The proposed method allows the thermal cycles of contact butt welding of rail steel samples to be measured on the machine MS-2008M, and the cooling rate of weld metal and the zone of thermal influence to be calculated, also the resulting structure of steel with a certain chemical composition to be predicted. The measurement of the welding current makes it possible to correct the heat input during welding.

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