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PORTABLE MODULE FOR HEAT TREATMENT OF WELDED JOINTS OF RAILWAY RAILS

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The design features of the portable module for heat treatment of welded joints of railway rails produced by the method of flash butt welding are considered. The process of heat treatment includes an induction heating of welded joints with the currents of 2.4 kHz frequency and a subsequent hardening of the rolling surface of the head by a compressed air. The design of the portable module includes inductors connected directly to matching transformers. The inducing wires repeat the shape of the rail surface bend with increased air gaps above the web and feathers and contain magnetic conductors located above the rolling surface, side surfaces of the head, web and flange of a rail. It was shown that in the welded joints of R65 type rails made of K76F steel after heat treatment in a portable module in the zone of hardening cooling of the head, a uniform fine-grained structure with hardness is formed, reaching the level of hardness of the base metal. The hardness of the metal in the deep layers of the rail head increases also relative to the hardness of the base metal at the appropriate depth. 10 Ref., 2 Tables, 5 Figures.

Keywords: rails, welded joints, heat treatment, portable module, metal hardness

The problem areas of welded joints of railway rails made by the method of flash butt welding are local zones with the change in the structure and hardness of the metal in the area of the heat-affected-zone (HAZ). To achieve structural homogeneity of the metal and increase the mechanical properties of welded joints, heat treatment (HT) is used. The technology of HT of welded joints with high frequency currents provides a uniform heating of rail elements in the butt zone, required rate of phase transformations in the HAZ metal structure, low temperature difference between the surface and deep layers of a rail [1, 2]. As a result of using new types of high-strength rails on the world's railways, it became necessary to improve the technology and equipment for HT of welded joints. In the studies conducted in China, the effect of HT on the structure and hardness of welded joints metal was studied. It was found that mechanical properties of welded joints are improved after heating to the normalization temperature [3]. During the construction of railways in China, in the equipment for HT of welded joints detachable single-turn inductors without magnetic conductors with parallel inducing wires were used [4]. In the Russian Federation the complexes for HT of welded joints with the currents of 8–15 kHz frequency were created, in which multi-turn inductors without magnetic conductors are applied [5].

At the PWI the works are carried out to improve the technology and equipment for HT of welded joints of railway rails. A portable module for HT of joints of rails of type R50, R65 and R75 with the currents of 2.4 kHz was created. The process of HT includes heating of welded joints of the rails to a temperature of 850–950 °C and a subsequent hardening of the rolling surface of the head by a compressed air. The portable module is designed for application in track conditions as a part of mobile rail welding machines and in workshop conditions of rail welding enterprises.

In this paper, the design features of the portable module are considered and the results of its testing at HT of welded joints of R65 type rails made of K76F steel are presented. As a power source for high-frequency currents, thyristor frequency converter TPChT-160/2.4 was used.

In the design of the portable module, the inductors 1 are directly connected to the matching transformers, forming the heating units *2* (Figure 1). The heating units are located on the frame *3*. To move the heating units to the side surfaces of the rail *4*, the actuators are used. The frame is also equipped with the sprayer *5* with the unit *7* for compressed air supply, the control panel *6*, the units *8* and *9* are used for supply and drain of cooling liquid, the clamps *10* are used for mounting the portable module on a rail, the laser pointer is used to guide inductors to a welded butt, limit switches, connectors for connecting a high frequency power source. The pyrometer for measuring the temperature of heating joints is mounted on one of the heating units. The electrical circuit of the portable module provides a sequence of operations for heating welded joints and hardening of the rolling surface of rails. The weight of the portable module is 65 kg [6, 7].

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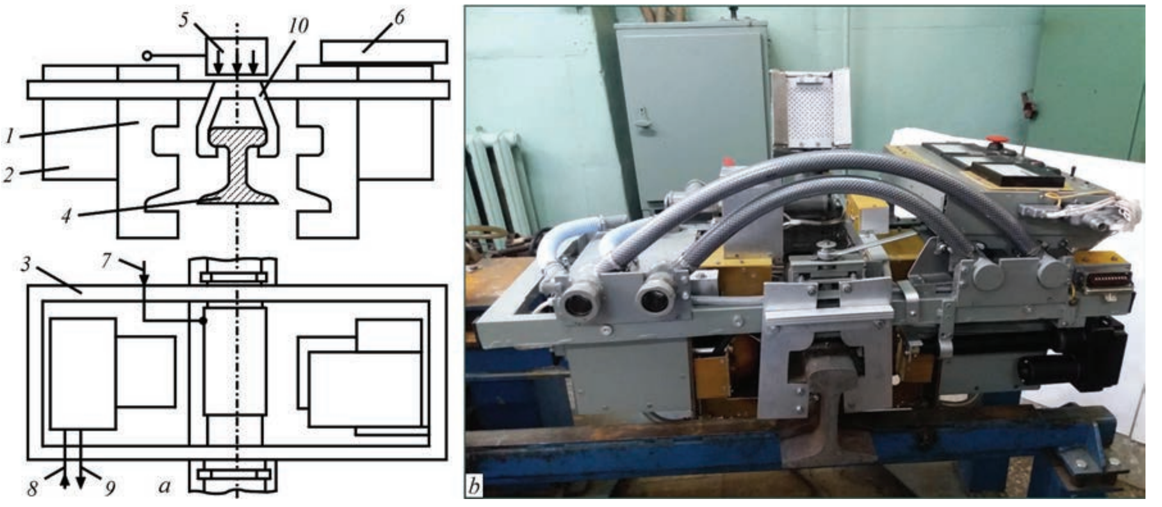

Figure 1. Portable module for heat treatment of welded joints of railway rails: design scheme (*a*) and general view (*b*) (description *1–10* see in the text)

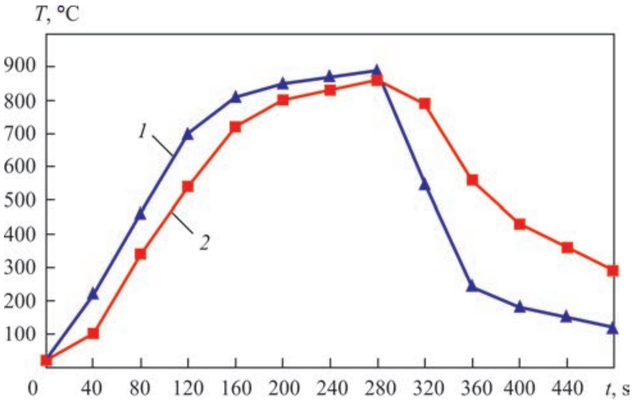

Figure 2. Time dependences of temperature of heating rolling surface (RS) of rail and layer at a depth of 25 mm from the rolling surface (25 mm from RS) while performing HT in the portable module: *1* — RS; *2* — 25 mm from RS

The required power distribution on rail elements is achieved by the fact that the inducing wires of the inductors repeat the shape of the rail bend surface with increased air gaps above the web and feathers and contain magnetic conductors above the rolling surface, side surfaces of the head, web and flange of the rail. After heating the welded joints for 140 s, the temperature difference between the rolling surface of the rail and the layer at a depth of 25 mm did not exceed 60 °C [8, 9]. To reduce the temperature drop to 40 °C, the heating time of the joints on the portable module was increased to 260–280 s. The heating rate of the rolling surface of the rail R65 to the temperature of magnetic transformations was 5.4 °C/s and at a depth of 25 mm from the rolling surface it was 4.6 °C/s (Figure 2). After the loss of the magnetic properties by the

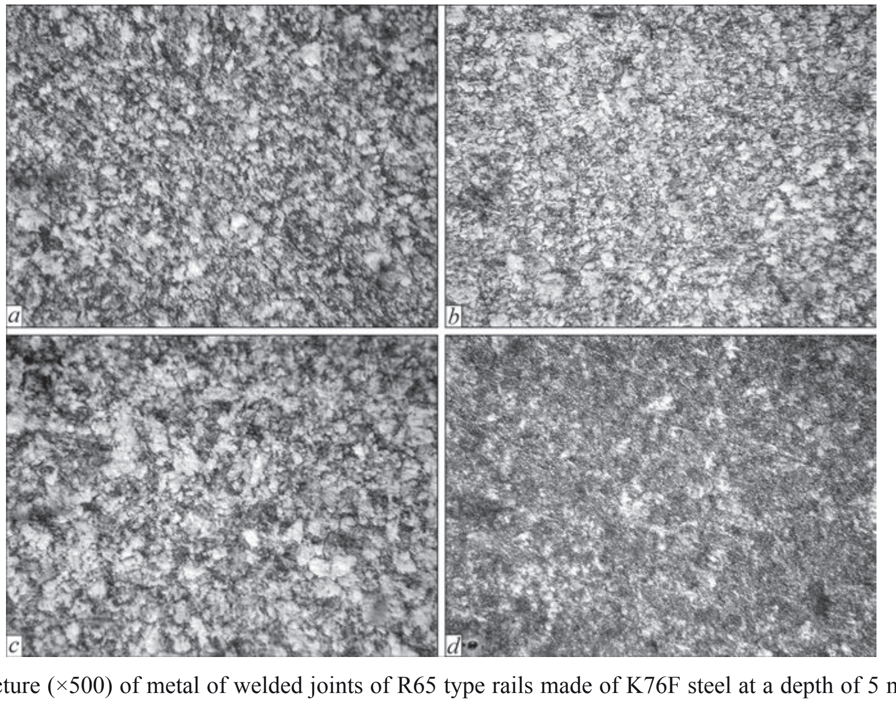

Figure 3. Microstructure (×500) of metal of welded joints of R65 type rails made of K76F steel at a depth of 5 mm from the rolling surface: *a* — base metal; *b* — joint line; *c* — 10 mm from the joint line; *d* — zone of partial recrystallization

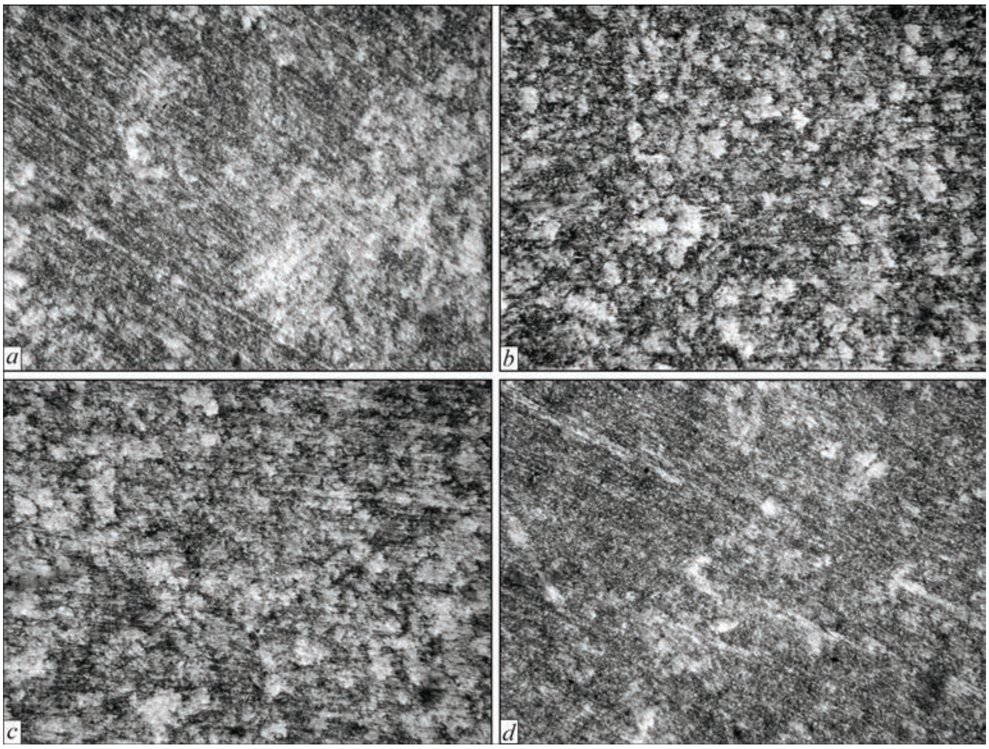

Figure 4. Microstructure (×500) of metal of welded joints of R65 type rails made of K76F steel at a depth of 25 mm from the rolling surface: *a* — base metal; *b* — joint line; *c* — 10 mm from the joint line; *d* — zone of partial recrystallization

metal, the heating rate of the rolling surface decreased to 1.06–1.08 °C/s. The width of HAZ of welded joints after HT reached 52–58 mm, which is greater than the width of HAZ of joints of high-strength and high-alloy rails after welding [10].

In the study of welded joint metal, longitudinal specimens were used. The surface of the specimens coincided with the axis of symmetry of the rail. To reveal the microstructure of the metal, the method of chemical etching of polished specimen surfaces in a 4 % alcohol nitric acid solution was used. The grain size of the metal was determined according to GOST 5639-82.1. The integral hardness of metal *HRC* was measured in a hardness tester TK-2M at a load of 150 kg.

The studies showed that in the zone of hardening of the base metal, at a depth of 5 mm from the rolling surface, the areas of sorbite and troostite were present (Figure 3). The structure is fine-grained, grain size number is 8 (Table 1). After HT of welded joints, the metal at a depth of 5 mm from the rolling surface along the joint line had a uniform grain of the sorbite type with a grain size number 10. At a distance of 10 mm from the joint line a medium and heterogeneous structure of the sorbite type with areas of troostite are present. Grain size number is 7–8. In the zone of partial recrystallization at a distance of 22–24 mm from the joint line, the grain is fine dispersed, uniform, of the sorbite type with the areas of troostite. Grain size number is 10. At a depth of 25 mm from the rolling surface in the structure of the base metal the areas of ferrite and sorbite were present (Figure 4). The base metal had a clear heterogeneity. Grain size number is 7 (Table 2). The structure of the metal in the HAZ width has the type of sorbite and a uniform grain. As compared to the hardening zone metal, the grain number decreased to 7–8.

At a depth of 5 mm from the rolling surface of rails, the hardness of the base metal was *HRC* 37–38 (Figure 5). After HT of welded joints, the metal at a depth of 5 mm from the rolling surface along the joint line had a hardness of *HRC* 33, which is lower than the hardness of the base metal. At a distance of 10 mm from the joint line, the hardness of the metal approached the level of the base metal; in the zone of a partial recrystallization at a distance of 22–24 mm from the joint line it decreased to *HRC* 29–30. At a depth of 25 mm from the rolling surface of the rail,

Table 1. Grain size number of metal of welded joints of R65 rails from K76F steel at a depth of 5 mm from the rolling surface

Joint line	10 mm from the joint line	Partial recrystallization zone	Base metal
10	7–8	10	8

Table 2. Grain size number of metal of welded joints of R65 rails from K76F steel at a depth of 25 mm from the rolling surface

Joint line	10 mm from the joint line	Partial recrystallization zone	Base metal
7–8	7	7–8	7

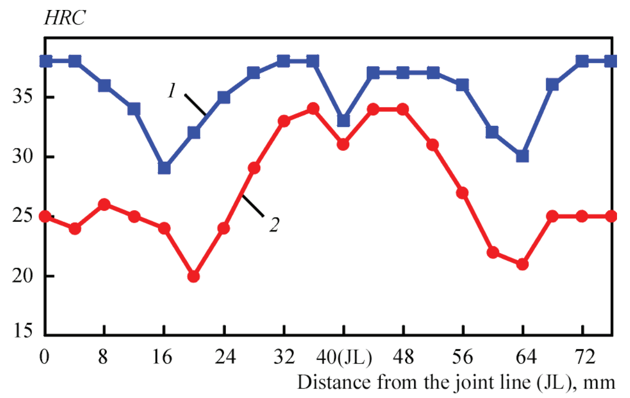

Figure 5. Distribution of metal hardness along the HAZ width at a depth of 5 mm and 25 mm from the rolling surface (RS) of welded joints of R65 rails made of steel K76F: *1* — 5 mm from RS after HT; *2* — 25 mm from RS after HT

the hardness of the base metal of the rail was *HRC* 24–25. The hardness of the metal between the zones of a partial recrystallization increased to *HRC* 31–34, which is higher than the hardness of the base metal at such a depth (*HRC* 24–25). In the zones of a partial recrystallization the hardness decreased to *HRC* 20–22.

Conclusions

1. The portable module for HT of welded joints of railway rails produced by the method of flash butt welding was created. The technology of HT of welded joints includes induction heating with the currents of 2.4 kHz and a subsequent hardening of the rolling surface of the head by a compressed air.

2. The portable module is designed for application in track and workshop conditions.

3. The heating equipment of the portable module provides a uniform heating of rail elements in the zone of welded joints.

4. Investigations of welded joints of R65 type rails made of K76F steel after HT in a portable module showed that a uniform fine-grained structure with a hardness reaching the level of hardness of the base metal is formed in the zone of hardening cooling of a rail head. Also the hardness of the metal in the deep layers of the rail head increases relative to the hardness of the base metal at the appropriate depth.

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