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INDUCTORS FOR HEAT TREATMENT OF WELDED BUTT JOINTS OF RAILWAY AND TRAM GROOVED RAILS

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ABSTRACT

The aim of the work is to create inductors for heat treatment of welded butt joints of railway and tram grooved rails. For heat treatment of welded butt joints of railway rails, the inductors were proposed, located opposite each other on the two sides of the rail. Investigation of local heating of railway and tram grooved rails with a frequency of 2.4 kHz showed that the inductors provide a uniform heating of cross-section rail elements, a low difference in the temperature between the surface and deep layers of the metal in the head of the rails and a decrease in heating time from the workshop temperature to the normalization temperature.

KEYWORDS: rails, rail welded butt joints, heat treatment, induction heating, inductors

INTRODUCTION

The reliability and service properties of the rail track depend to a large extent on the quality of welded butt joints of the rails. Under the conditions of high loads and speed of railway transport, welded butt joints are damaged more often than the base metal of the rails. The negative impact of welding is manifested in the appearance of a local decrease in hardness, unfavourable diagram of inner residual stresses across the HAZ, changes in the uniformity of microstructure, creation of conditions for arising inner defects, which are stress concentrators and weaken the sections of rails with a welded butt joint [1]. The most effective mean to improve the quality of welded butt joints is heat treatment. It consists in the local heating of welded butt joints and share of the base metal adjacent to them, to the normalization temperature of 850–950 °C, cooling of the web and the foot in a calm air and hardening of the rolling surface of the head with a compressed air. A high rate of local heating is provided by an induction method of heating metals by high frequency currents [2, 3]. Now, while performing the heat treatment of welded butt joints of railway rails in track and workshop conditions, the local heating of rails is performed by the currents of 8.0–16.0 kHz frequency. As a power source, frequency converters on IGBT transistors are used. The composition of the heating devices includes inductors without magnetic conductors. The technology and equipment provide heating of welded butt joints of railway rails of type R65 from different grades to the normalization temperature within a time of up to 240 s. The width of the HAZ in the head of the rails reaches 80–94 mm, in the foot of the rails it is 140–150 mm [4, 5].

The feasibility of heat treatment of welded butt joints exists for both railway rails as well as rails of other types of rail transport — tram, subway, crane, etc. The rails differ between each other in the shape of a cross-section, metal volume in individual elements and conditions of heat removal in the cold mass of metal. The railway rails have a symmetrical cross-section shape relative to the vertical axis. Tram grooved rails, unlike railway, are equipped with a groove and a lip. A rolling surface, a groove and a lip are displaced relative to the vertical axis. Depending on the method of welding — flash-butt, induction, alumothermic, electric arc, welded butt joints of rails have different width of the HAZ. For example, the width of the HAZ of welded butt joints of railway rails of type R65, produced by flash-butt welding, is 26–32 mm [6], tram grooved rails of type RT62, produced by automatic arc welding with the consumable nozzle, have a width of 45–55 mm. In order to relief inner stresses in the metal of rails, resulting from nonuniformity of volumetric changes in the heating process, it is necessary to provide the same temperature of cross-section rail elements and a low temperature between the surface and deep layers of metal at the end of the heat treatment of welded butt joints. Taking into account the specific features of the effect of high-frequency currents during heating products of a complex shape, certain requirements arise specified to the design of inductors of heating devices and current frequency. Inductors of heating devices should create an appropriate distribution of induced current on the surface of rails and its density, taking into account the conditions of heat removal into the cold mass of metal and not causing overheating of protruding rail elements — feathers and the upper edge of the lip. To achieve a low temperature difference between the surface and deep layers of the rails, it is advisable to increase the depth of current penetration into the metal, i.e. reduce the current frequency.

AIM OF THE WORK

The aim of the work is to create inductors of heating devices for heat treatment of welded butt joints of railway and tram grooved rails, providing a uniform heating of cross-section rail elements and a low temperature drop between the surface and deep layers of metal in the rail head.

DESCRIPTION AND DESIGN FEATURES

Figure 1, *a* shows the scheme of a heating device for heat treatment of welded butt joints of railway rails. The heating device includes inductors *1* and *2* of the same design [7]. The inductors are arranged opposite each other on two sides of the rail *3*. The shape of inducing wires of the inductors repeats the bending shape of the rail surface over the rolling surface of the head, side surfaces of the head, the web and the foot. The width of inducing wires and air gaps to the surface of the rails depend on the width of the HAZ of welded butt joints and the volume of cross-section rail elements. At a small gap, the induced current is concentrated, approximately, across the width of the inducing wire and at a large gap it extends to a considerable width. To enhance the proximity effect, as a result of which the density of induced current is increased, inductors are produced with the smallest air gaps over the head and the foot of the rails and slightly enlarged gaps above the web of the rails. A significant increase in the air gap over the rail feathers leads to a significant decrease in the density of induced current in these elements. Inducing wires of the inductors consist of two parallel wires. This provides an achievement of redistribution of the magnetic field across the width of the inductive wire and approaching the density of inducing current to the outer ends of the inducing wire. The total width of the wires in the inductors for heat treatment of welded butt joints of the rails of type R65 is 60 mm. It is larger than the width of the HAZ and the share of the base metal of the rails that adjacent to it, after flash-butt and automatic arc welding with a consumable nozzle. For the concentration of heating on the side surfaces of the cross-section elements and an overall increase in the efficiency coefficient of the system inductor–rail, magnetic conductors *4* are used, mounted over the rolling surface of the head, side surfaces of the head, the web and a part of the foot of the rail. Magnetic conductors consist of a set of plates of a transformer steel.

Inductors *1* and *2* of the heating devices for heat treatment of welded butt joints of tram grooved rails [8] have different design (Figure 1, *b*). Inducing wire of the inductor 1, mounted on the side of the head of the rail *3*, is extended only before the beginning of the groove *5*. This prevents overheating of the lip, as the magnetic flow into the depression of the groove is weakened by a large air gap. The shape of the inducing wire repeats the bending shape of the rail surface over the rolling surface of the head, the side surface of the head, the web and a part of the foot. The air gaps are enlarged over the web and significantly increased over the rail feathers. Magnetic conductors *4* are mounted over the rolling surface of the head, the side surface of the head, the web and a part of the foot. The inducing wire of the inductor *2*, mounted on the side of the lip *6*, repeats the bending shape of the rail

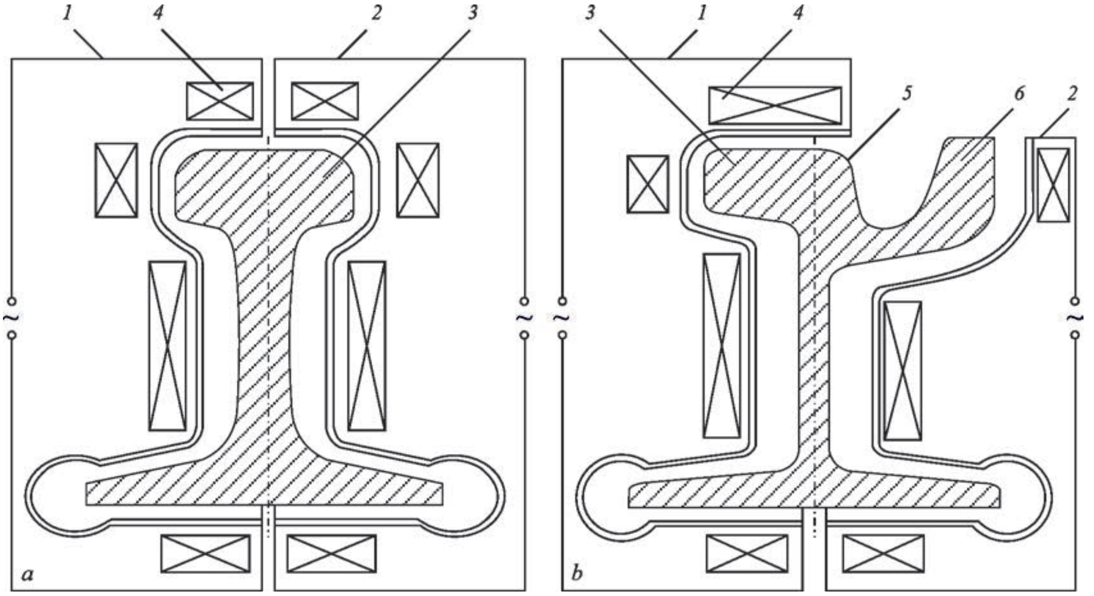

Figure 1. Scheme of heating devices for heat treatment of welded butt joints of railway (*a*) and tram grooved (*b*) rails (description *1–6* see in the text)

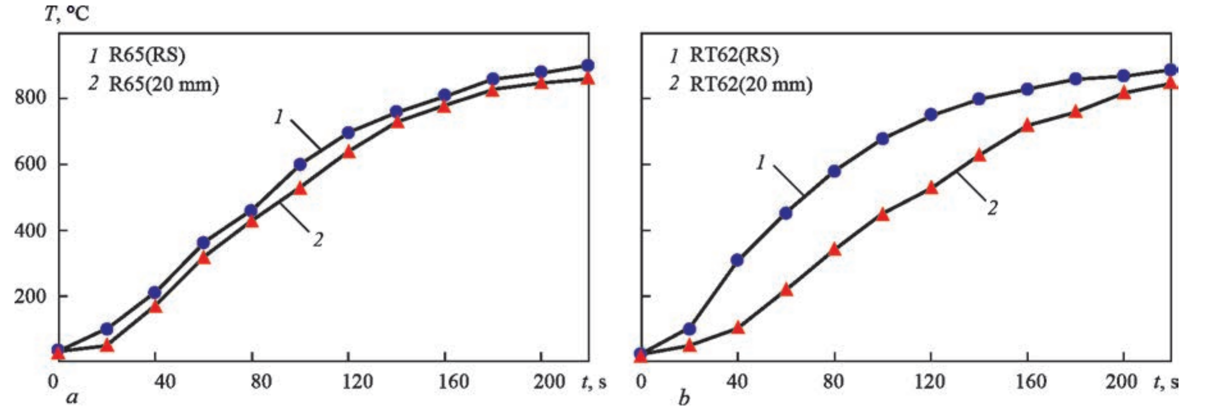

Figure 2. Time dependences of temperature on the rolling surface of the head (RS) and at a depth of 20–22 mm (20 mm) from the rolling surface of railway rails of type R65 (*a*) and tram grooved rails of type RT62 (*b*)

surface over the side surface of the lip, the web and a part of the foot. An inducing wire is extended only to the upper edge of the lip. The air gaps are enlarged over the side surface of the lip, the web and significantly enlarged above the feathers of the rails. Magnetic conductors 4 are mounted over the side surface of the lip, web and a part of the foot of the rail. The metal of the lip is heated partially as a result of thermal conductivity from the heated metal of the head and partially from the induced current on the side surface of the lip. In both inductors, inducing wires also consist of two parallel wires. The total width of the wires exceeds the width of the HAZ of the joints after flash-butt or arc welding.

RESULTS OF STUDIES AND THEIR DISCUSSION

The efficiency of the inductors was investigated in local heating of railway rails of type R65 and tram grooved rails of type RT62 applying currents of 2.4 kHz frequency. The heating temperature was measured on the rolling surface of the head, at a depth of 20–22 mm from the rolling surface, in the centre of the web, at a distance of 10 mm from the edges of the feathers, at the places of transition of the head into the web and the web into the foot, at a depth of 10 mm from the upper edge of the lip and in the centre of the lip. To measure the temperature, chromel-alumel thermocouples were used. The initial temperature of the base metal of the rails was 20 °C. As a power source, a thyristor frequency converter of type TFC-160/2.4 was used. In the process of heating rails to the normalization temperature, the constant value of the TFC rectifier current was maintained. Thus, the reaction of the frequency converter was compensated to the change of the complex load resistance due to the change in the specific electric resistance and magnetic permeability of the rail metal. Figure 2 shows the time dependencies of heating temperature of the head of railway and tram grooved rails. It was found that while heating railway rails during 220 s, the temperature on the rolling surface of the head reached 900 °C. The power at the output of the TFC rectifier varied from 90 to 105 kW. The duration of the heating stage to the temper ture of magnetic transformations, the so-called cold mode, was about 60 % from the time of heating, the average heating rate at this stage was 5.6 °C/s. The duration of heating stage above the temperature of magnetic transformations, the so-called hot mode, was equal to 40 %. The heating rate at this stage decreased to 1.7 °C/s. While heating tram grooved rails during 220 °C, the temperature on the rolling surface of the head reached 890 °C. The power at the output of the TFC rectifier varied from 90 to 100 kW. The duration of the “cold mode” stage was longer than during heating of railway rails. It was about 75 %. The average heating rate was 4.5 °C/s. The duration of the “hot mode” stage decreased to 25 %, the rate of heating at this stage increased to 2.6 °C/s. Figure 3 shows the values of temperature in the cross-section rail elements at the end of the local heating process. In the railway rails the temperature

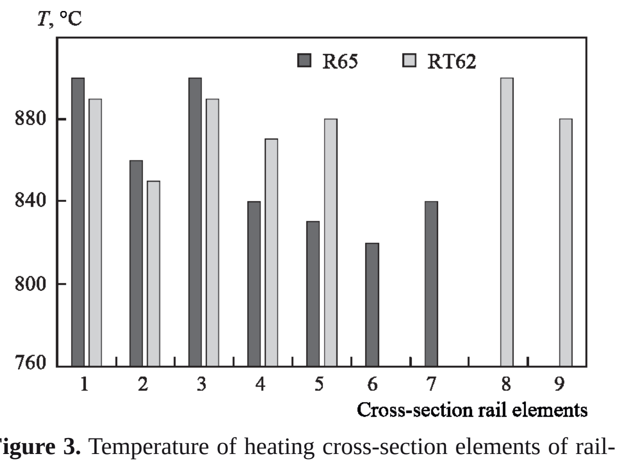

Figure 3. Temperature of heating cross-section elements of railway rails of type R65 and tram grooved rails of type RT62: rolling surface of the head (*1*); at a depth of 20–22 mm from the rolling surface of the head (*2*); web (*3*); feathers (*4*, *5*); place of transition of the head into the web (*6*); place of transition of the web to the foot (*7*); upper edge of the lip (*8*); centre of the lip (*9*)

of the web was equal to the temperature of the rolling surface of the head. The temperature difference between the rolling surface of the head and the layer at a depth of 20 mm was not more than 40 °C, between the centre of the head and the places of transition of the head into the web and the web into the foot did not exceed 20–40 °C. The temperature of the rail feather was at the level of 830–840 °C. The width of the HAZ on the rolling surface of the head, in the centre of the web and the bottom of the foot, was 54 mm. In the places of transition of the head into the web and the web into the foot, the width of the HAZ was by 4–6 mm lower. This is caused by weakening of the proximity effect due to difficulties of mounting magnetic conductors in such places. In the tram grooved rails, the temperature difference between the rolling surface of the head and the layer at a depth of 22 mm was not more than 40 °C. The temperature of the web was equal to the temperature on the rolling surface of the head, the temperature of the rail feather was by 10–20 °C lower. The heating temperature of the upper edge and the centre of the lip almost did not differ from the temperature of other elements.

CONCLUSIONS

Inductors of heating devices for heat treatment of welded butt joints of rail and tram grooved rails performed by the methods of flash-butt or arc welding applying high-frequency currents were developed. Designs of inductors take into account the shape of rails and the volume of cross-section elements.

Checking the efficiency of inductors in a local heating of railway rails of type R65 and tram grooved rails of type RT62 applying the currents of 2.4 kHz frequency showed, that inductors provide a decrease in the heating time of cross-section elements from the workshop temperature to the normalization temperature, the uniform heating of cross-section rail elements, a low temperature difference between the surface and deep layers of metal in the rail head and a reduction in the width of the HAZ after heat treatment as compared to existing equipment.

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