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To cite this article: V A Kuznetsov *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **377** 012023

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The study of the high temperatures effect on the specific electrical resistivity of rail steel in order to create safe conditions for the operation of access roads to open-pit mines

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Abstract. In the present paper the high temperatures effect on the specific electrical resistance of rail steel was investigated. The regression model of the temperature effect on the specific electrical resistivity of rail steel E76KhF was constructed. Application of this regression model will allow the technology of flash butt welding of rails to be optimized.

1. Introduction

To simulate flash butt welding of rails, it is necessary to know the specific electrical resistance of the material being welded. It should be taken into account that the flow of electric current does not occur over the entire cross section of the welded joint [1-6]. For butt welding of rails, an important characteristic of the process is the electrical resistance of rail steel. Thus, the data on the specific resistivity of the materials of the welded parts depending on their chemical composition and heating temperature need to be obtained.

The flashing process is a variation of the method of metals heating by resistance, in which heat is released in contact between parts when current is passed through them. Voltage is applied to the parts to be welded at the moment when they are brought apart, after which their slow convergence begins. When even cut-off ends of parts come into contact, the first contacts between them appear in separate places – in the existing microroughnesses. Unlike other methods of resistance heating, the contacts in this case are brought to melt. For that the input voltage and current density in the contacts must be high enough for the contacts to be destroyed before their area has time to increase significantly in the process of parts convergence. After the explosion of the contacts, a crater forms in their place and the shape of the surface gradually becomes uneven. Therefore, the contacts at each point on the ends surface occur at certain intervals, and the contact points continuously change. At any time the total area occupied by the contacts is significantly less than the cross-sectional area of the parts to be welded. On the most part of the flashing surface between the ends there is a gap, the size of which is not the same over the cross section of the parts [7].

In this case, the heating and melting of microcontacts between the ends of the welded parts occurs due to the heat released in accordance to the Joule-Lenz law:

$$Q = I^2 R t, J \quad (1)$$

Data on the amount of heat released will allow the heat input during welding, the length of the heat-affected zone (HAZ), the formation of the weld structure to be corrected and the quality of the welded



joint to be predicted in advance, as well as the possible formation of defects in rail steel to be warned about. The amount of heat released over a certain period of time depends on the area of the contacting surfaces and on the electrical resistivity of the material being welded.

The specific electrical resistivity is calculated by the formula:

$$\rho = \frac{R \cdot S}{l}, \Omega \cdot m \quad (2)$$

The electrical resistance of the alloy is always higher than the resistance of any of its components. The nature of the change in the electrical conductivity of the alloy depends on the phases and structures in the alloy, which is determined by the state diagram. When steel is heated, a non-equilibrium structure is formed with large lattice distortions and internal stresses. The density of defects throughout the crystal volume increases sharply, which leads to a significant increase in resistivity [8, 9]. Also when heating rail steel (eutectic alloy) above 727 °C, the pearlite structure is transformed into an austenitic structure.

2. Methods of research

For measuring the electrical resistance of rail steel MI 3250 MicroOhm 10A was used – a compact microhmmeter with a test current of 10A, designed to measure the resistances of welded joints, track connections, motor windings and generators, etc. During the measurement, electrodes of a special form were used that help to penetrate through the formed oxide film at high temperatures. For sample heating EKPS 50 muffle furnace was used. The furnace was heated to 950 °C, the samples were set and held for 10 minutes. Samples were removed from the furnace at 900 °C, placed on the metal platform, temperature and electrical resistances were measured. The temperature was measured with HotFind-D thermal imager; it allows the temperatures to be measured up to 1500 °C. The imager is equipped with an uncooled microbolometer matrix in the focal plane of the lens with a resolution of 160×120 pixels. Transmission of video images of thermograms to a PC is performed using an analog video capture card in NTSC format with a frequency of 60 Hz.

3. Results and discussion

The authors studied the effect of the chemical composition of rail steel on specific electrical resistivity [10]. During the experiment the electrical resistance of rail steel in the temperature range from 0 to 700 °C was measured. Samples had sizes 90×30×10mm. Table 1 presents the chemical composition of rail steel used in the study of electrical resistance.

Table 1. The chemical composition of the samples.

Chemical composition of rail steel													
C	Mn	Si	P	S	Cr	V	Cu	Mo	Al	Ni	Nb	Sn	Sb
0.76	0.77	0.53	0.009	0.005	0.37	0.04	0.11	0.005	0.003	0.07	0.001	0.005	0.002

Table 2 presents the results of measuring the sample electrical resistance in $\mu\Omega$ at different temperatures. Electrical resistivity, calculated by formula (2), is presented in figure 1.

Table 2. The dependence of the electrical resistance on the samples temperature.

No. 1		No.2	
T, °C	R, Ohm*10 ⁻⁶	T, °C	R, Ohm*10 ⁻⁶
253	93.4	235	85.9
294	100.4	254	90.1
370	113.1	260	91.1
390	117.2	282	95.7
440	130	285	91.6

490	140	290	97.6
540	150	347	102.3
606	180	352	108.6
		402	117.6
		404	117.6
		410	119
		420	120.9
		425	122.5
		505	138.2
		518	135.4
		530	142.6
		537	145.5
		610	166.8

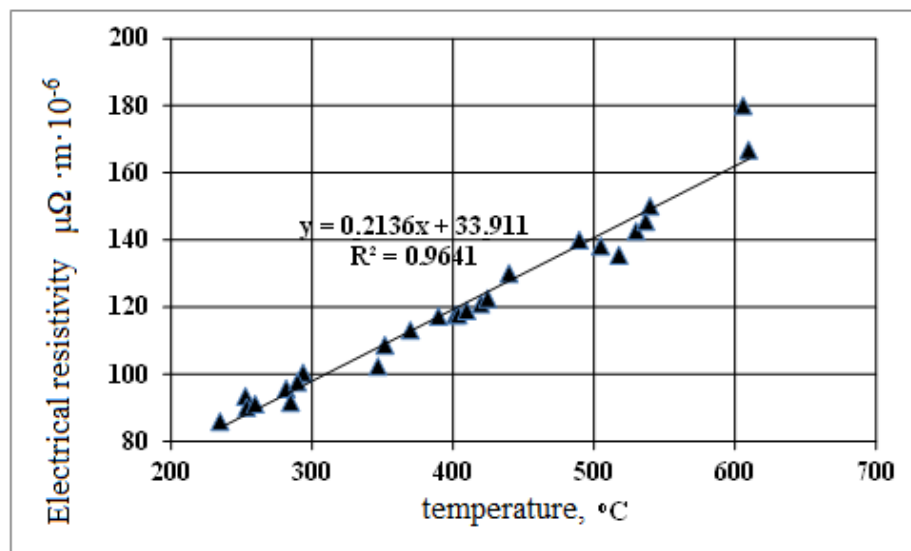


Figure 1. The dependence of the electrical resistivity on the samples temperature.

4. Conclusion

The regression model of the temperature effect on the specific electrical resistivity of rail steel E76KhF was built. The usage of this regression model will help to optimize the technology of flash butt welding of rails.

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