Efficiency of Induction Heating of Rails with Oblong Heaters

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Abstract. Results of laboratory testing on two types of oblong heaters applied to induction heating of rails are presented and discussed in this paper. The article continues the research into practical applications of induction heating to turnouts.

Keywords: induction oblong cup and flat heater, induction heating, rails, turnouts.

1 Introduction

In their earlier work (2010-2011), the authors focussed on developing a simulation model of the induction heating process of 60E1 rail in two-dimensional space using FEMM software [1, 4, 5, 8] and methods of determining key electric and magnetic properties of 60E1 rails, whose knowledge proved necessary to develop a method of turnout induction heating [2, 3, 9]. Time has come therefore to verify the issue in an actual laboratory stand. This paper combines key results of the authors' research with regard to three areas - laboratory testing of rail induction heating process, numerical calculations of magnetic field and eddy currents, and measurements of basic electric and magnetic parameters of a selected rail type.

2 Experimental Stand for Testing of Rail Induction Heating

A laboratory stand for rail induction heating shown in Fig. 1.a) and 1.b) is developed on the basis of testing results of rails' electric and magnetic quantities as well as simulation test results of rail induction heating process executed in FEMM software. This stand comprises two inductor types – thus, two different sources for generation of electromagnetic field.

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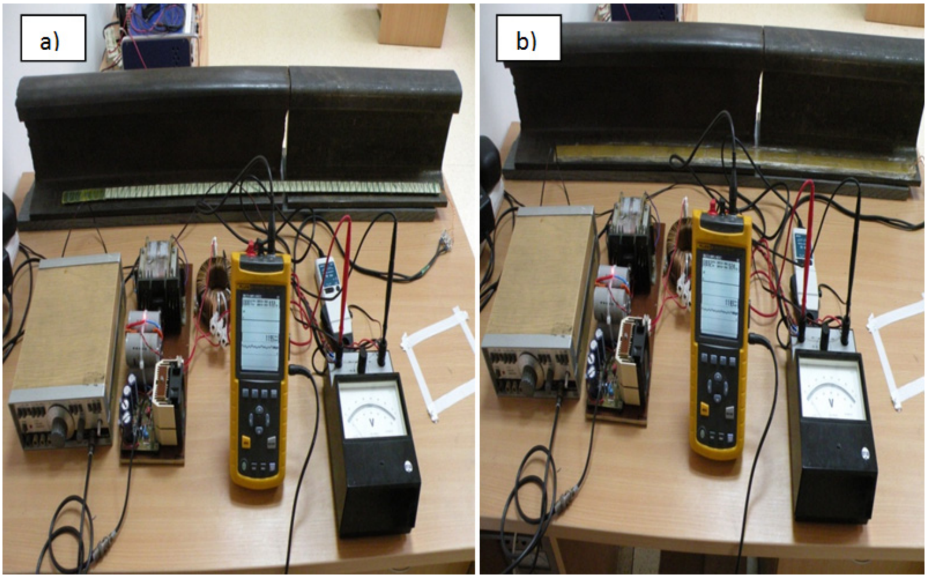

Fig. 1. The laboratory stand with a a) cup, b) flat oblong heater

The heaters used in laboratory testing of rail induction heating are shown in Fig. 2 and Fig. 3.

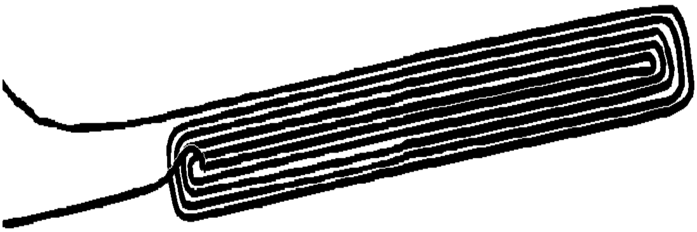

Fig. 2. Oblong flat heater

The laboratory stand under discussion consists of the following elements:

- Two heaters of sizes and dimensions similar to flat-oval heaters applied to electric turnout heating,
- infrared camera,
- functional generator,
- power amplifier,
- analyser of energy quality,
- (mercury and electronic) thermometers,
- personal computer.

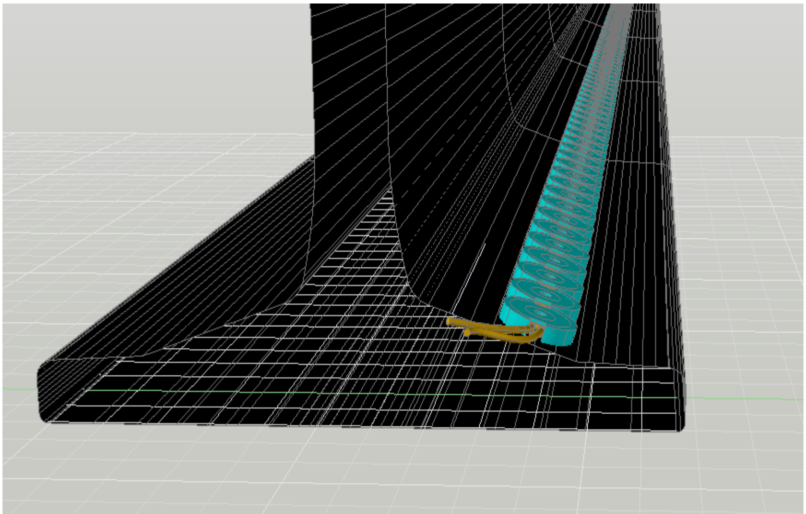

Fig. 3. Oblong cup heater

The magnetic loop of the inductor and receiver consisted of two 1.13m long heaters generating different shapes of the magnetic fields shown in Figures 2 and 3, respectively.

The infrared camera recorded temperature growth in the heated section of rail at selected points in time.

The quality analyzer, equipped with current and voltage measurement probes, tracked current and voltage shapes in the circuit and the angle shift between the tracked courses, thereby the active power [6] lost across a heating element.

The functional generator was designed to generate a sinusoid voltage and supply it to the power amplifier.

A 100W power amplifier served as a source of supply voltage, controlled by the functional generator.

The thermometers read the ambient temperature in the testing room.

The PC recorded measurement data from the experiments.

The following assumptions were adopted for the laboratory testing:

- range of frequency f variations of the supply voltage (0 – 1000)Hz,
- oblong flat and cup heaters are tested at 60W,
- ambient temperature $T_{\text{otoczenia}}$ and air temperature $T_{\text{atmosfery}}$ in the testing room are constant,
- constant emissivity of the tested material is 0.960 (the rail was covered with a layer of soot) and constant air humidity in the testing room is 16%,
- initial rail temperature $T_{\text{p-szyny}}$ and initial heater temperature $T_{\text{p-grzałki}}$ are constant. After each experiment, the rail and the heater are cooled back to their initial temperatures.

The individual experiments continued for 30 minutes. Images of heated rails were recorded every 30 seconds to capture minimum temperature growths.

3 Distribution of Rail Temperatures in Induction Heating

A series of experiments were conducted on the heaters under discussion in the range of frequency f variations of the supply voltage (50 – 1000) Hz. Constant power of 60 W supplied to the heaters was maintained.

The experiments implied the inductors discussed in this paper failed. Temperature recorders showed that only heaters themselves became hot in both cases. Temperature growths ΔT of rail foot were below 3°C and were similar across the entire range of f variations.

Results of laboratory tests of rail heating by means of an oblong cup heater for the selected frequency $f = 650$ Hz are illustrated in Figure 4. Results of laboratory tests of rail heating by means of an oblong flat heater for the selected frequency $f = 650$ Hz are illustrated in Figure 5.

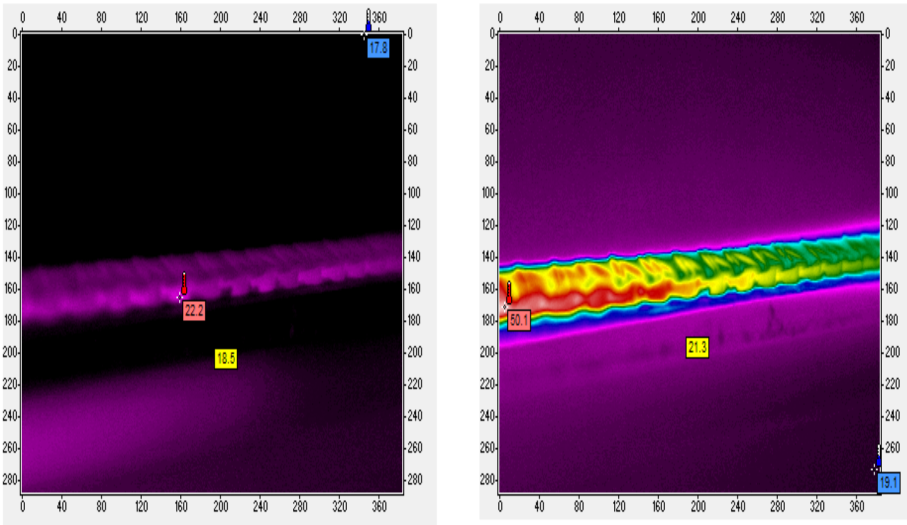

Fig. 4. Image from an infrared camera recording temperature growths ΔT across the rail foot after 30 mins of heating with an oblong cup heater (results of laboratory testing)

For the sake of comparison, Figure 6 illustrates temperature graphs in the rail foot heated with oblong : a) cup and b) flat heaters.

4 Conclusion

The oblong heaters presented in this paper fulfill requirements of resistance heater design in electric turnout heating (requirements of PKP PLK Polish railways) [7] in respect of their geometric dimensions.

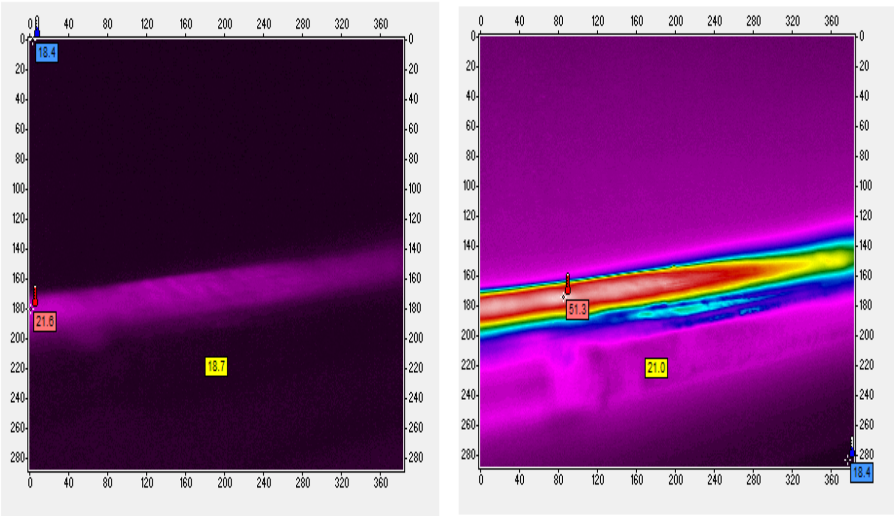

Fig. 5. Image from an infrared camera recording temperature growths ΔT across the rail foot after 30 mins of heating with an oblong flat heater (results of laboratory testing)

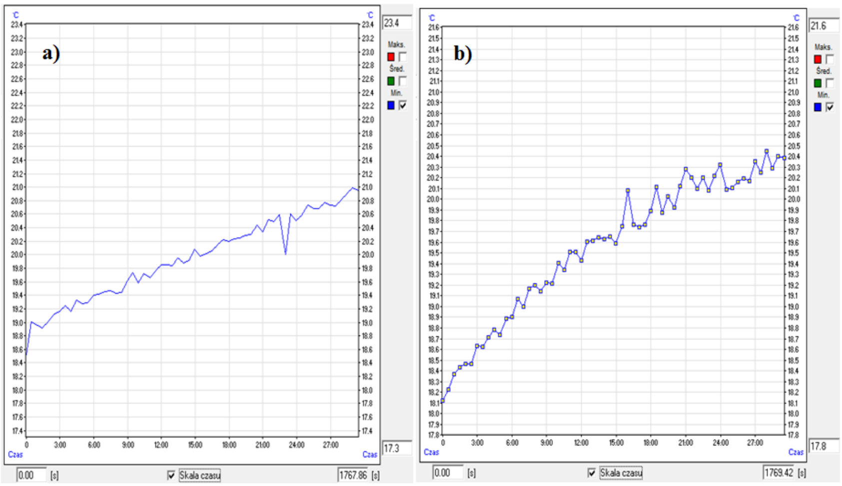

Fig. 6. Graphs of temperature growths ΔT across the rail foot after 30 mins of heating with an oblong a) cup heater and b) flat heater (results of laboratory testing)

Efficiency of rail heating with oblong cup and oblong flat heaters proved very low. Results of the laboratory testing imply that oblong heaters acting as inductors failed to provide a closed magnetic loop for the magnetic flux and the magnetic field they generated was dispersed as a result. The current caused heat to be released across the heater resistance only. The consequent temperature growth across the rail reached a mere few degrees and covered a small portion of the rail immediately adjacent to the heaters. The two design types of heaters presented in this paper will not be applied to induction heating of railroad turnouts, therefore.

Further research should focus on modifying design of inductors employed to heat rails as part of induction heating of railroad turnouts.

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