FACTA UNIVERSITATIS (NIŠ)
SER.: ELEC. ENERG. vol. 22, no. 2, August 2009, 175-182

Efficiency Of The 3-Phase System to Provide Energy Under Low Frequency Induction Heating of CWRs

Bogdan Miedzinski, Marcin Habrych, Zenon Okraszewski, Xin Wang, and Lj Xu

Abstract: In this paper the efficiency of heating of continuous welded rails (CWRs) under track laying when 3-phase low frequency supplying system is applied has been carefully considered. On the basis of computations confirmed by the investigated results, for different heaters location as well as different voltage phase shifts, the conclusions concerning proper selection of the structure of the energy supplying systems are formulated.

Keywords: 3-phase system, efficiency, low frequency induction heating.

1 Introduction

TO avoid dangerous stresses inside the rail body due to heavy weather conditions the laying of the rigid railway rail track must be performed under its specified thermal state. The rails are recommended to be welded and to fasten to a railroad tie only in a case if their medium temperature is equal to so called neutral value that in Europe is within 291K-303K depending on the country. In polish climatic zone the temperature for about 70% of days in the year is lower than the neutral one therefore, the rails heating usually is required. We have found that low frequency induction heating is much more effective and less hazardous with compare to this by means of propan-buthan heaters [1]. However, the heating efficiency of the rails is strongly related to many different factors including structural as well as environmental conditions [2].

Manuscript received on June 14, 2009.

B. Miedzinski, M. Habrych and Z. Okraszewski are with Wroclaw University of Technology, Institute of Electric Power Engineering, 50-370 Wroclaw, Poland (e-mail: bogdan.miedzinski@pwr.wroc.pl). X. Wang and L. Xu are with Beijing University of Post and Telecommunications, Research Lab. of Electric Contacts, Xi Tu Cheng Road 10#, Beijing, China, (e-mail: wangxin820117@gmail.com).

In this paper efficiency of heating of continuous welded rails (CWRs) under track laying when 3-phase low frequency systems is applied has been carefully investigated and considered. On the basis of the computations confirmed by investigated results the conclusions concerning proper selection of the heaters location over the rail as well as their way of power supply are formulated.

2 Analyzed Model of the Heater

The analyzed model of the inductive heater with the 3-phase energy delivery system is shown in Fig. 1.

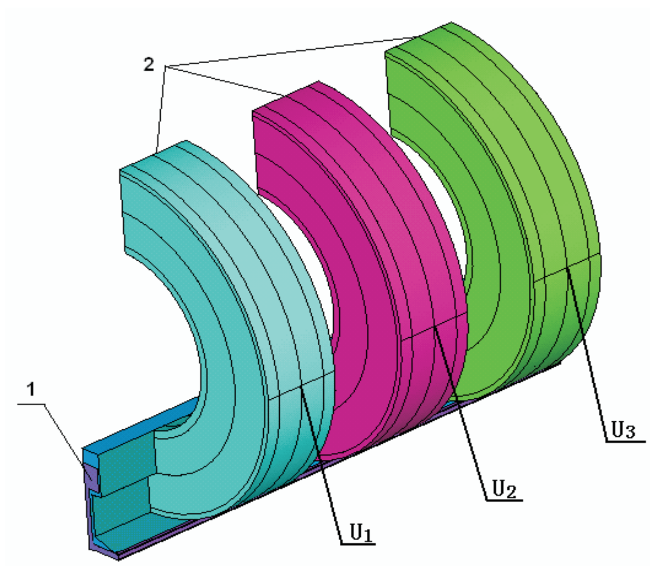

Fig. 1. The 3-heaters model for analysis (U_1, U_2, U_3 supplying 3-phase system); 1-railway rail being heated, 2-heaters located both on the head and web of the rail.

In order to simplify explanations in the text the respective indications U_1, U_2 and U_3 were used to consider not only different phase of the 3-phase system but also to label the particular heater element. Each heater has been made and assembled of the same electrical as well as magnetic materials, however of much higher resistivity with compare to the rail [1, 2]. Both 2-D and 3-D computations were performed by using two separate commercial FEM software packages (an indirect coupling model). The numerical solutions of 3-D coupled electro-magneto-thermal phenomena was approached by application of the Maxwell and Fourier-Kirchhoff formulas and their combination with thermal process equations due to eddy current losses [2–5]. The finite element mesh of the simulation model is presented in

Fig. 2 (a half of the completed physical model is taken under consideration due to symmetry). The simulations were performed for the stationary heaters however of two structures i.e. heating only the rails head or/and the head and web concurrently [1, 2]. The magnetic field energy was delivered to the rail body at 50 Hz. Both distance between particular heaters was varied as well as MMF direction and the voltage phase displacement.

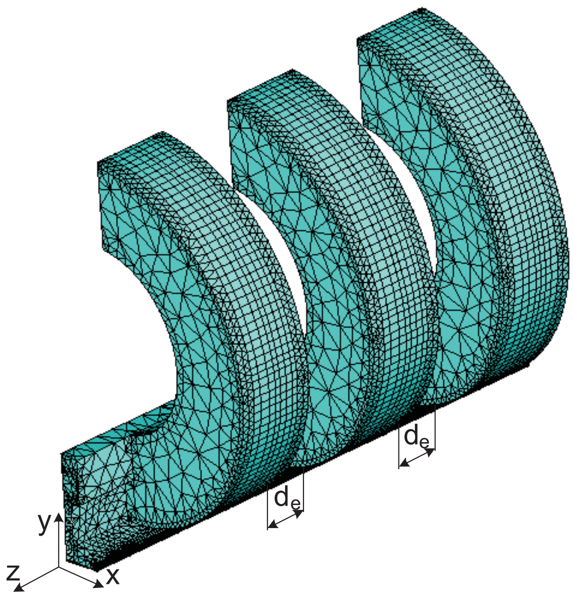

Fig. 2. The meshed model for analysis of the induction heating process when use the 3-heater system (de-distance between heaters).

3 Analysis and Discussion of Results

Thermal field distribution with time along both horizontal and longitudinal axis of the rail body under heating was evaluated with point of view of the proper selection of the low frequency heating strategy in practice.

3.1 Influence of distance between the heaters

In a case of multi-heater structure the heating efficiency is related to resultant magnetic field distribution therefore, it is sensitive, among others, to service position of the particular heater. It was found that for different distance (d_e) between each heater (see Fig. 2) the heat transfer result was quite different. The temperature measurements along the rail cross section (as in Fig. 3) have indicated that for the same supply conditions (the all heaters supplied from the same phase U_1) the most effective heating was observed for the distance de not higher than by about 50% with compare to the heater thickness ($d_e < 0.15$ m) what can be seen from Fig. 4. It seems to be obvious because with the increase in the distance between the heaters the heat is being gave up to environment in increased quantity. Therefore, taking into account technical problem of the heater system movement along the rail the de value should be fixed practically in range $0.2 < d_c/d_H < 2$.

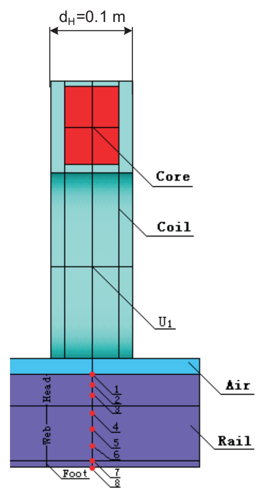

Fig. 3. Schematic for location of the temperature test point (1-8) along the y-axis in the medium cross section of the rail enclosed by the first heater (U_1) ($d_H = 0.1$m thickness of the heater).

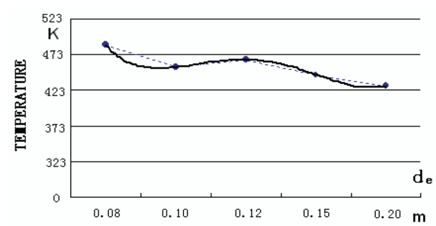

Fig. 4. Maximum temperature along the rail cross section versus distance d_e between heaters (50 Hz, heating time 100s, MMF=2500 A, head & web).

3.2 Influence of the phase displacement

When the heaters are supplied from various phases of the 3-phase system the heat generation is found to be also different. Table 1 notifies such the situation under simulation with respective labeling (111,,132).

As it can be compared from Fig. 5 Fig. 7 for the same value of MMF (2500A) the highest temperature was obtained for 213 mode of the power delivery system. While, for zero phase displacement (111 mode) the temperature distribution is the most uniform (see Fig. 5). However, taking into account both heating as well as cooling of the railway body under real conditions the most convenient seems to

Table 1. Notification of the phase displacement when supply particular heaters separately

Heater \ Sign	U_1	U_2	U_3
111	0°	0°	0°
123	0°	120°	240°
213	120°	0°	240°
132	0°	240°	120°

be the "213" mode that allows to get the highest heating efficiency. Therefore, for further considerations only the phase-angle setting mode "213" was taken into account.

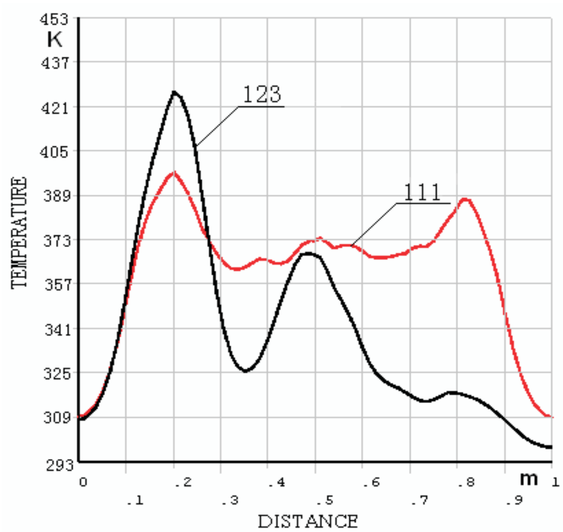

Fig. 5. Temperature distribution along z-axis of the rail for two different phase displacement modes: 111 and 123 respectively ($d_e = 0.2$m, MMF=2500 A, 50Hz, heating 100s, head & web).

3.3 Influence of MMF direction

Change of the MMF direction current flow is equivalent to changing the phase displacement of the 3-phase supplying voltage system. The best results were obtained for 213 setting mode however, at reversed direction of current generating magnetic field inside the last located heater (U_3). In this case U_1, U_2, U_3 constitutes the 3-phase system with phase-displacement equal 60°. Thus the resultant magnetic field produces the highest temperature inside the rail body with relatively uniform tem-

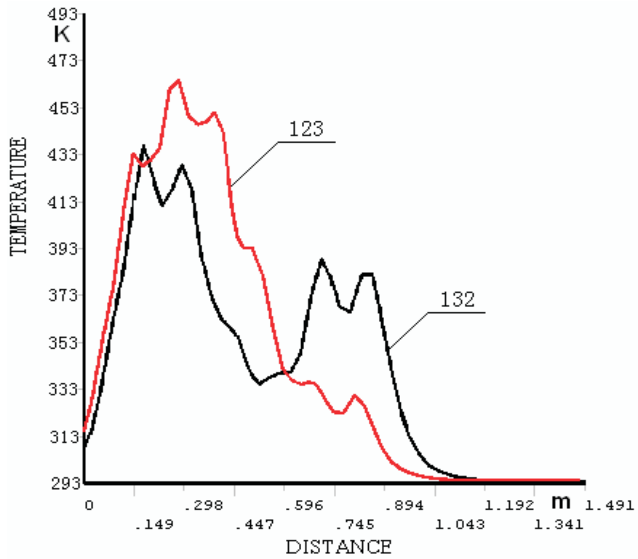

Fig. 6. Temperature distribution along *z*-axis of the rail for 123 and 132 phase displacement modes ($d_e = 0.12$m, MMF=2500 A, 50 Hz, heating 100s, head & web).

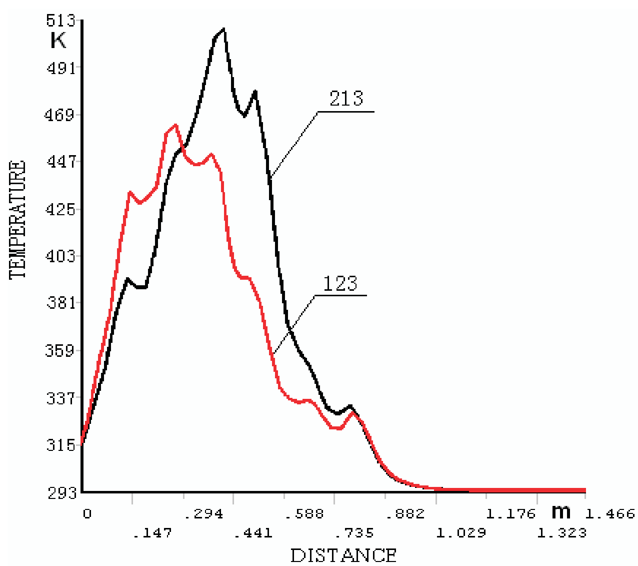

Fig. 7. Temperature distribution along *z*-axis of the rail for 123 and 213 phase displacement modes ($d_e = 0.12$m, MMF=2500 A, 50 Hz, heating 100s, head & web).

perature field distribution out of the heaters what can be compared from Fig. 8.

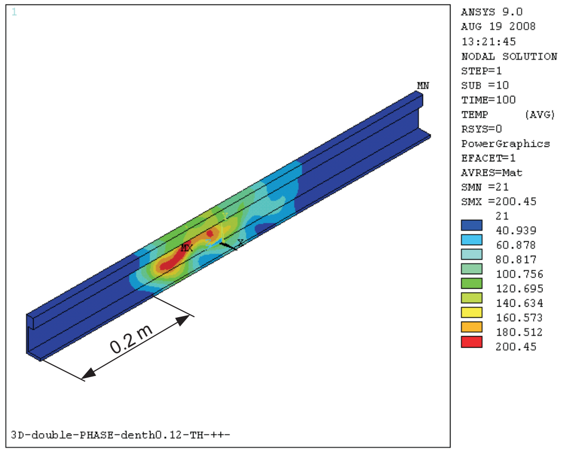

Fig. 8. Temperature field distribution inside the rail body for voltage setting with phase-displacement-equal to 60° ($d_e = 0.12$m, MMF=2500 A, 50 Hz, heating 100s, head & web).

4 Analysis and Discussion of Results

To compare the computations with the real ones respective investigations were carried out for especially developed physical model of the heater as illustrated in Fig. 9. It was found that the investigated results are in a good agreement with the theory if about the 3-phase delivery system efficiency.

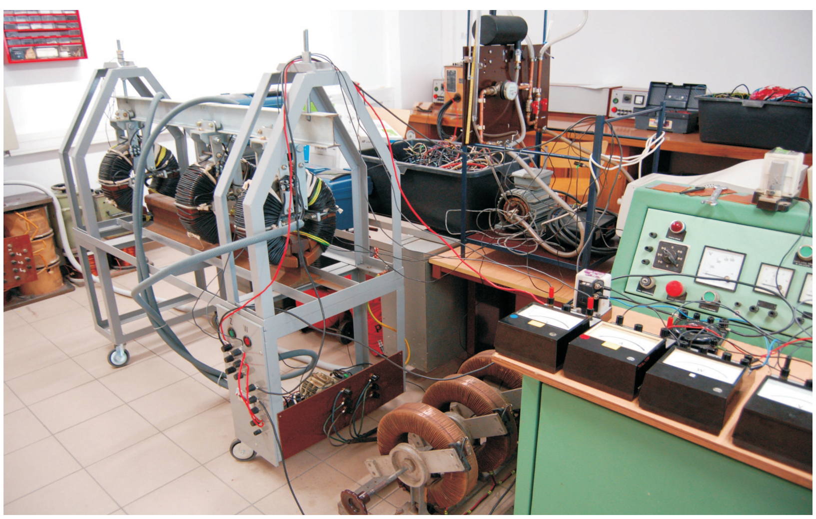

Fig. 9. View of the lab stand for testing of the low frequency induction heating of the railway rails.

5 Conclusions

Computations confirmed by the experimental results revealed that efficiency of the 3-phase heater is strongly related to location of particular heating elements each other over the rail as well as to phase displacement between voltage system delivering energy. The best results if about maximum temperature value and desired thermal field distribution under heating was obtained for the phase displacement between voltages equal to about 60° at the distance between particular heaters not higher than by about 100% with respect to the heater thickness.

References

[1] B. Miedzinski, Z. Okraszewski, A. Szymanski, and M. Kristiansen, "Low frequency inductive heating of a rigid track during track laying," in *Proc. 30th IAS Annual Meeting*, Orlando, Florida, USA, Oct. 8–12, 1995, pp. 1903–1909.

[2] B. Miedzinski, Z. Okraszewski, X. Wang, and L. Xu, "Approach to efficiency of the low frequency inductive heating of ferromagnetics," *Electronics and Electrical Engineering*, vol. 85, no. 5, pp. 3–7, 2008.

[3] R. L. Stoll, *The analysis of eddy currents*. Oxford: Clarendan Press, 1974.

[4] G. Strang and G. Fix, *An analysis of the finite element method*. Upper Saddle River, NJ 07458: Englewood Cliffs, Prentice-Hall, 1973.

[5] C. Hayashi, *Nonlinear oscillations in physical system*. New York: McGraw Hill, 1964.