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FEM MODELLING OF AN INDUCTION HEATING SYSTEM

ABSTRACT

The paper presents investigation of axisymmetrical induction heating system, consisting of two-layer disc-type inductor and heated detail. Two - dimensional coupled electromagnetic and temperature fields were analysed using FEM. The problem was solved as nonlinear and transient. The obtained numerical results have been compared to the experimental data for the magnetic flux and temperature distribution.

INTRODUCTION

Nowadays induction heating systems are widely used in the industry. Induction heating plays an important role in industrial heating. It can heat very accurately depths and surface areas in clean operating conditions with high power densities and short heat times. That is why they are of permanent interest to researchers in recent years [1-3].

The present paper deals with numerical and experimental investigation of an induction heating system. It consists of two-layer disc-type inductor and heated detail. The numerical models of the coupled electromagnetic and temperature fields are based on the finite element method (FEM) and electromagnetic and temperature distribution have been obtained using ANSYS 9.0 software package. The results were compared to the experimental data for the temperature distribution in the laboratory experimental setup.

The aim of the work is investigation of possibilities for creating adequate field models at some control points of the induction system. They can be used in the next work, concerning special requirements for temperature distribution in the heating detail. So it is a first step for future solving of the optimization problem.

INDUCTION SYSTEM DESCRIPTION

The principal geometry of the system is shown in Fig. 1. The inductor is two-layer, flat disc-type and multi-sectioned. The two layers are identical. The conductors are of rectangular cross-section.

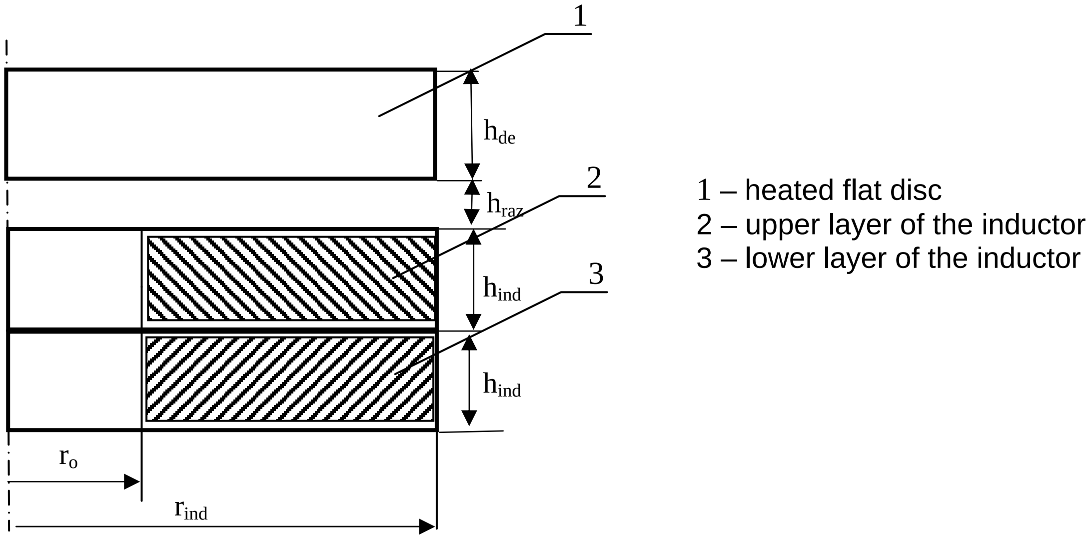

Fig. 1. Principal geometry of the induction system

The following notations are used for the Inductor:

- inner inductor radius r_0=0,03m is, the outer inductor radius r_{ind} =0,24m;
- height of each layer is h_{ind1}= h_{ind2}= h_{ind} 0,011m;
- distance between the inductor ad the detail is h_{raz}=0,003m;
- the inductor currents are at one and the same direction: upper current I_{up}=28 A and lower current I_{low}=36 A.
- current frequency is f =50 Hz.

The heated detail is a ferromagnetic disc of thickness h_{det}=0,003m. The temperature of ambient air isT_0=15^{0}C, the initial temperature of the heated detail is 27^{0}C.
The laboratory experimental setup is shown in Fig. 2.

Fig.2. Experimental setup

FIELD MODEL

Due to the axial symmetry of the geometry and to the cylindrical coordinates, the problem is considered as a two-dimensional one. So the numerical simulation of the heating process consists of analysis of two-dimensional electromagnetic problem coupled with transient thermal problem, taking into consideration the nonlinearities of the system (change of physical properties during the heating).

The electromagnetic problem is quasistationary and the field model with respect to the magnetic vector potential **A** is based on the equation:

$$j\omega\sigma\vec{A} + rot\left(\frac{1}{\mu} rot\vec{A}\right) = \vec{J} \qquad (1)$$

where ω is angular frequency, σ is electric conductivity, μ is magnetic permeability and *J* is current density.

The transient thermal field is modeled by:

$$\gamma.c\frac{\partial T}{\partial t} + div(-\lambda.gradT) = q \qquad (2)$$

where λ is thermal conductivity , *T* is temperature, γ is density, *c* is specific heat and *q* is power density. Equation (2) is solved under convection and radiation boundary condition.

The coupled problem is solved using indirect coupling of the quasistationary electromagnetic and transient thermal problem. The electromagnetic problem is solved in a domain consisting of the whole system and a wide buffer zone around it. The thermal problem is solved only in the heated detail.

RESULTS OF THE NUMERICAL SIMULATIONS

Two-dimensional numerical simulation of the coupled fields was carried out using FEM and ANSYS 9.0 software package [4].

The results are obtained for time period of 600 seconds. The following procedure was employed. The quasistationary electromagnetic problem was solved at every 10sec. taking into account the temperature dependence of the magnetic permeability and electric conductivity. As a result from the electromagnetic field analysis, the generated heat in the heated detail is obtained and used as heat source during the next 10 sec. The thermal problem was solved as nonlinear and temperature dependence of the thermal conductivity was taken into account.

The finite element mesh for the electromagnetic field problem is shown in Fig.3. The results from electromagnetic field analysis are shown in Fig. 4.

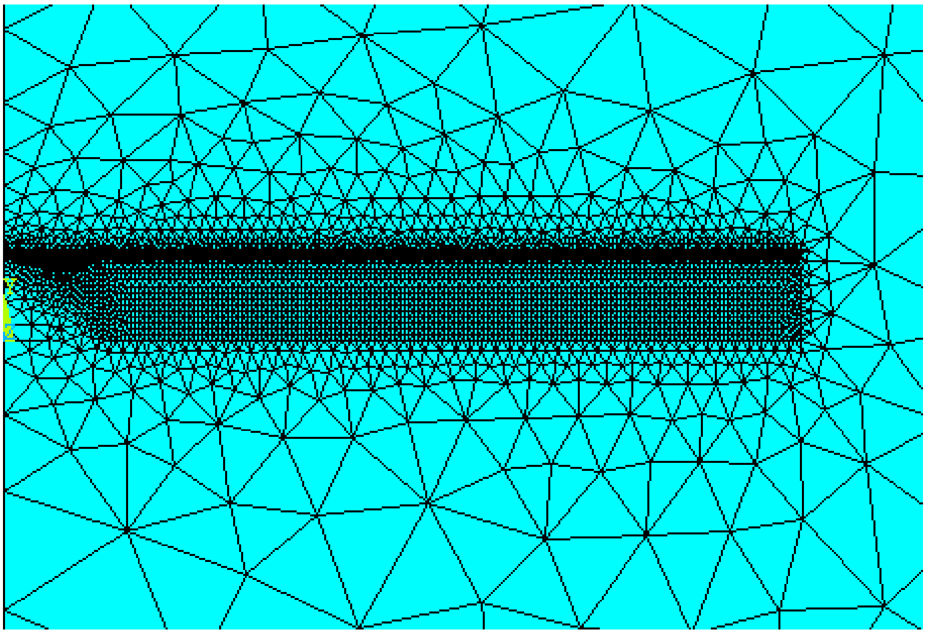

Fig. 3. FE mesh for the electromagnetic field problem

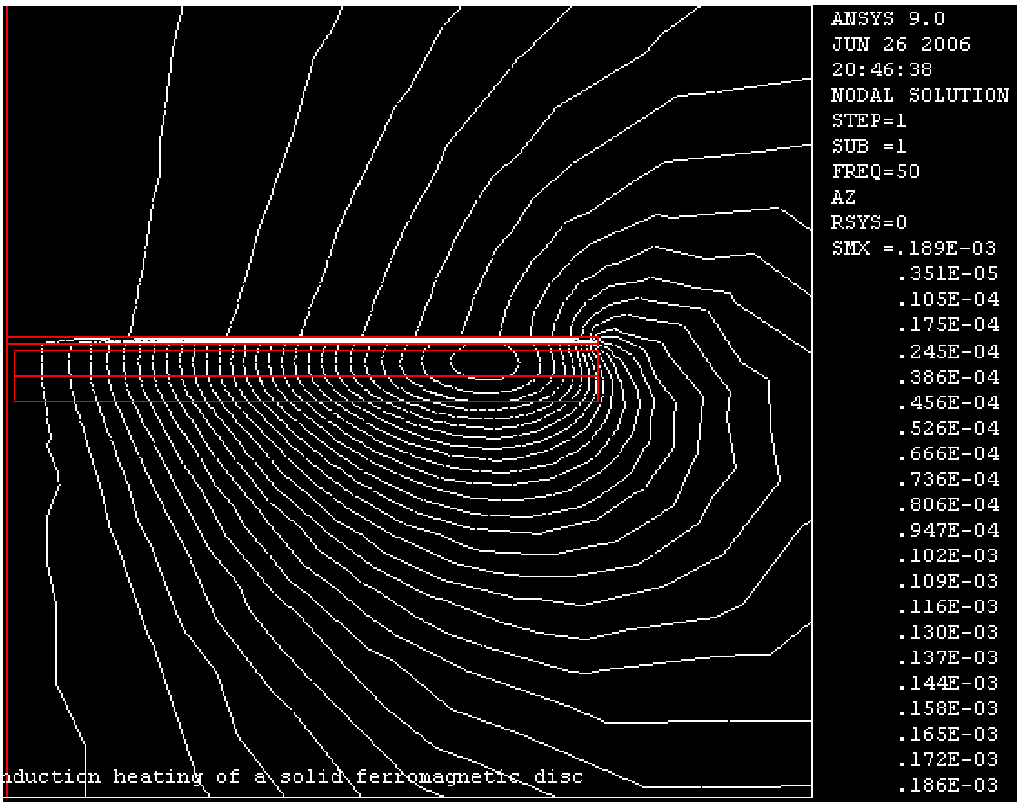

Fig. 4. Magnetic flux lins

For the investigated time period (600sec.) the point with maximal temperature was determined. It is the point of radius r= 0.15m and the temperature is 143^{0}C. This time was considered because this was the time in which experiment was carried out. The transient heating process in this point is shown in Fig.5. The temperature distribution in the heated disc in radial direction in time t=600sec is shown in Fig. 6.

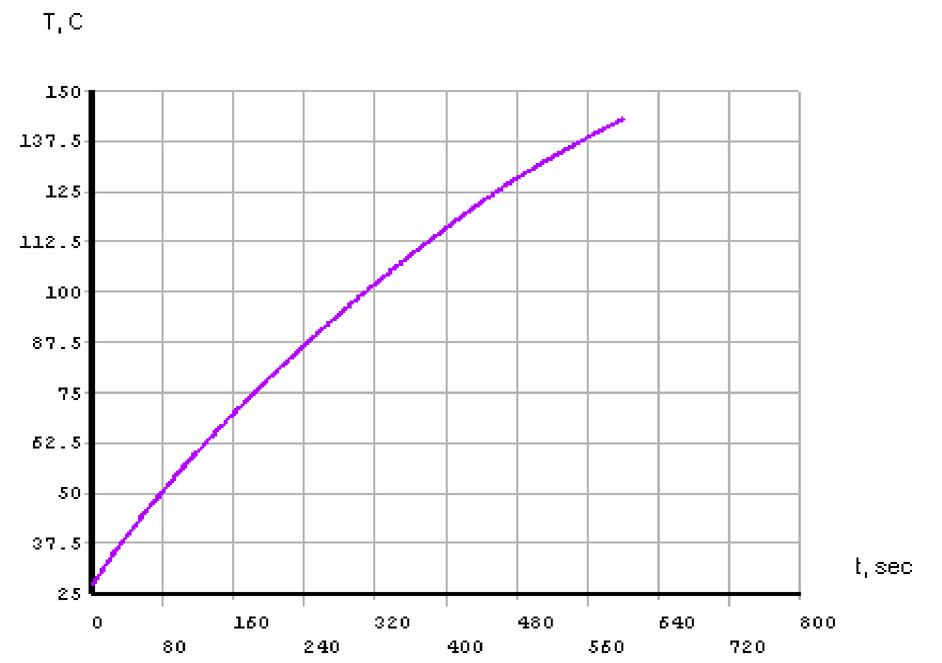

Fig. 5. Maximal temperature (point of radius r= 0.15m) – transient process

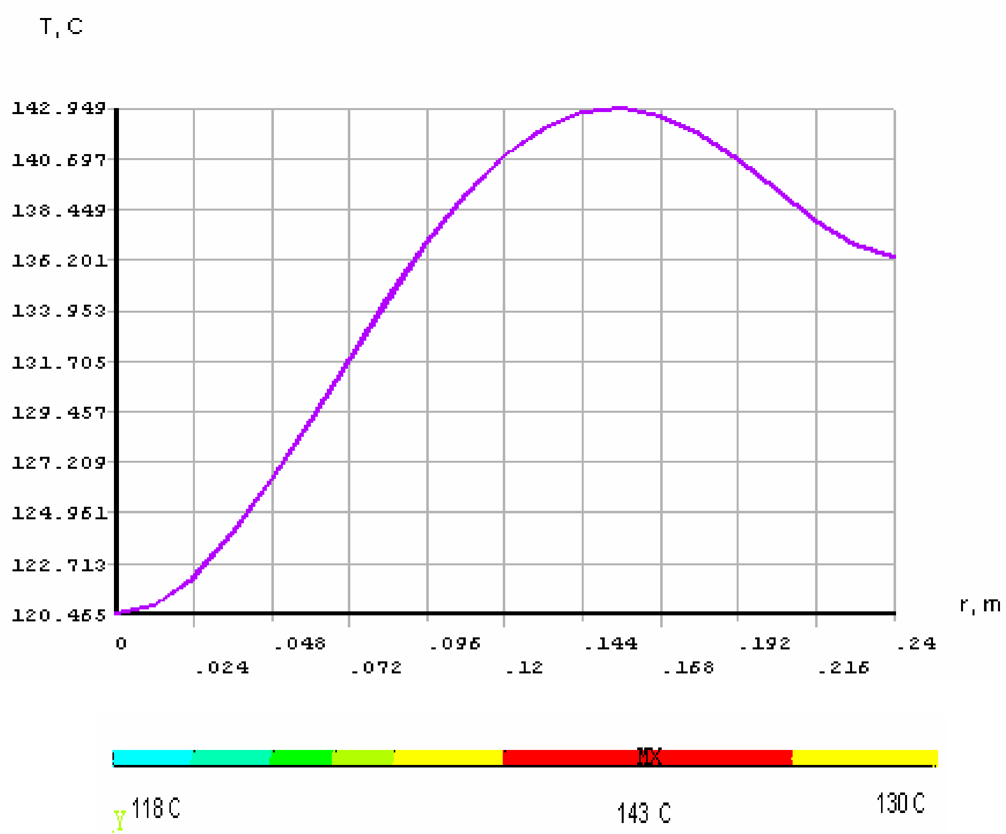

Fig. 6. Temperature distribution in radial direction at *t*= 600sec.

COMPARISON OF THE NUMERICAL AND EXPERIMENTAL RESULTS

The results obtained using the FEM model are compared to those obtained by experiment Temperature variations for the investigated period obtained numerically and by experiment are shown in Fig.7 for point with r= 0.06m and in Fig.8 for point with r= 0.15m. Relative error for point with r= 0.06m is shown in Fig. 9. The comparison between computation and experiment shows satisfactory agreement.

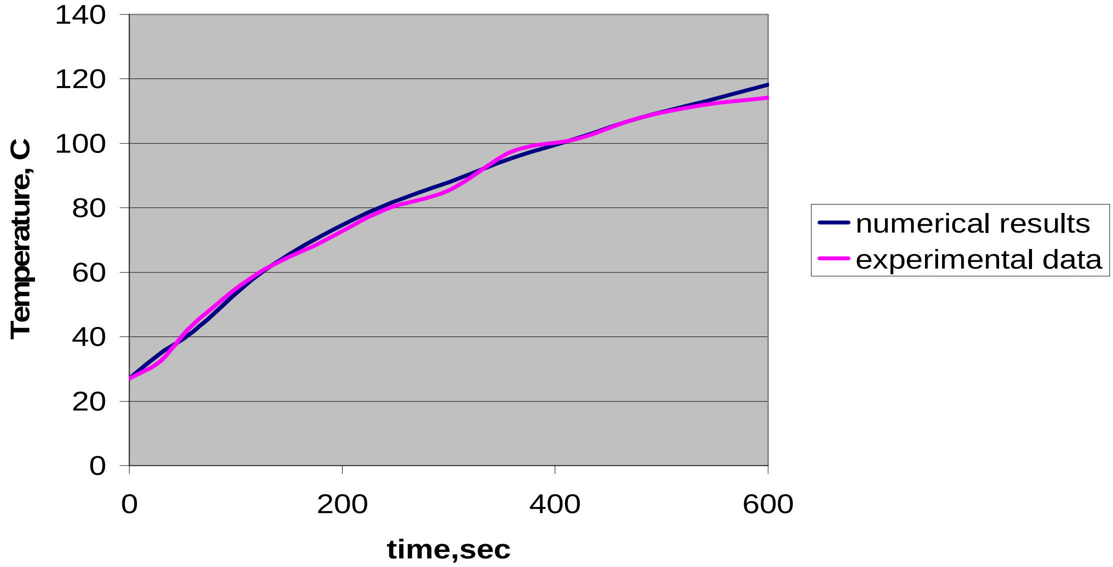

Fig. 7. Temperature variations for point with r= 0.06m.

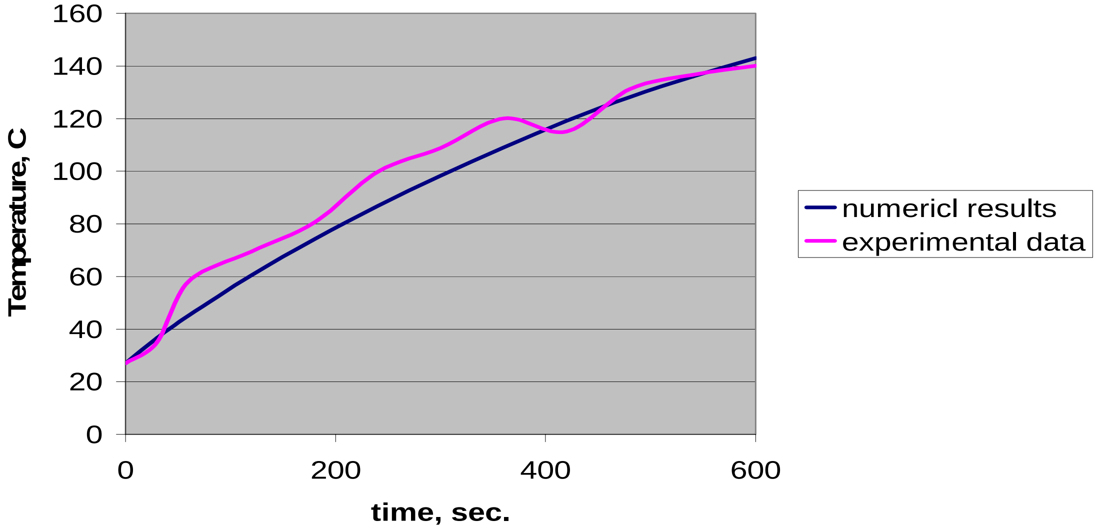

Fig. 8. Temperature variations for point with r= 0.15m.

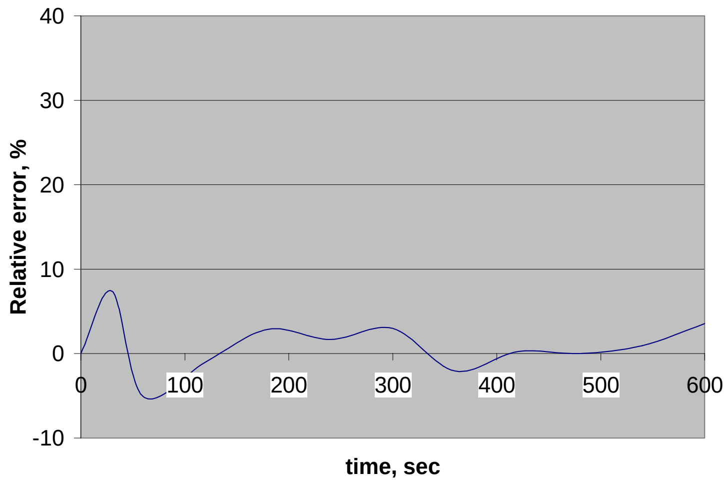

Fig. 9. Relative error for point with r= 0.06m

CONCLUSIONS

The results obtained using the FEM model are compared to experimental data for the transient temperature distribution. These results can be employed for further investigations concerning inverse and optimization problems when special requirements for temperature distribution in the heating detail are needed.

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