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DEMOUNTING OF SHAFT FLANGE WITH USING INDUCTION HEATING

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Abstract: This paper deals with an exemplary solution of one specific problem of an induction heating. It is partly determined by the means of the numerical method as a light-coupling problem. Numerical solution is calculated with the help of the professional programs (Fluent, QuickField). Results of the solution are discussed in the conclusion.

Keywords: light-coupling problem, finite element method, nodes, induction heating.

1. Introduction

The aim of this paper is a description of dismantling of the flange (connector) from the shaft of diesel generator with the output 11,6 MW (Fig. 1). During the operation of this equipment a turn occurred of the generator shaft towards the shaft driven by diesel aggregate (cca. by 30°). This turn was intolerable from the viewpoint of the function of the whole machinery and dismantling of the above-mentioned flange (connector) was necessary. This connector was pressed on the shaft while hot. That is why not only mechanic strength is necessary for the dismantling, but the same technology as for the assembly must be used, it is to bring thermal energy to the dismantled flange and in this way to lower the lubrication powers that are between the inner side of the flange and the outer side of the shaft in the point of contact of both materials.

As these are very large parts (shaft - 20 t, flange - 10 t), that are supposed to be used again, it is impossible, from the economic point of view, to cause a permanent damage to them during the dismantling (through plastic deformation). For that reason convention methods were not used for heating, but

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an inductive equipment. The advantage of this equipment designed for heating is the possibility of relatively exact calculation of parameters of heating regarding the permanent damage of the material.

In order to get inductive heating, an inductor was reeled on the flange of the diesel generator. Through this inductor exciting current I_{exc} of different value and net frequency 50Hz. Values of exciting current I_{exc} and time intervals of the influence of exciting current I_{exc} are given in Table 1.

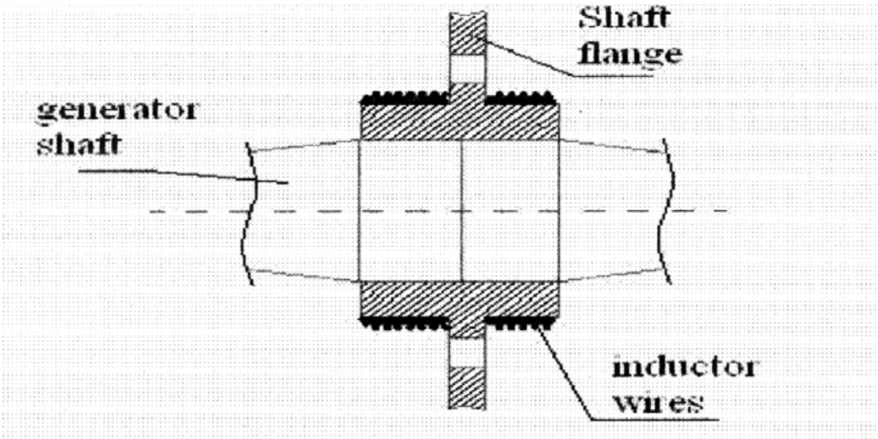

Fig.1. Implementation of inductor for induction heating

	Current in inductor [A]	No of turns	Time of heating[min]
1.	1380	28+36	2
2.	1110	28+36	4
3.	1072	28+36	1

Table 1.

2. Numerical solution of the problem

Numerical solution is done using two various professional programs. The program equipment QuickField is not able to calculate the non-stationary thermal field that exists in the given application of inductive heating. Electromagnetic field is calculated by the program QuickField and thermal field by the program Fluent. As entering data for the program Fluent for calculation of non-stationary thermal field with inner source of heat the discharge data for electromagnetic field calculated by QuickField are used.

Calculated losses in line generated by induced currents are used as the inner source of heat of non-stationary thermal field. The problem is approached to as weakly conjugated problem.

2.1. Simplified model for solution

Because of a complicated shape of the shaft fledge the authors decided to use, when constructing 2D model, a simplified shape of the cartridge (see Fig. 2). The Inductor is considered without insulation materials as joint with diameter that corresponds with the diameter of the real number of turns used for heating.

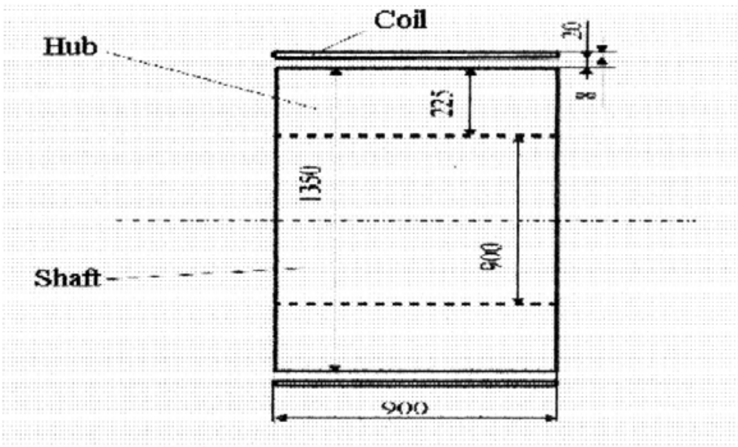

Fig. 2. Simplified model of shaft and fledge

2.2 Numerical model for program QUICKFIELD

Because of rotating symmetrical arrangement along axis z and axial symmetry of the problem along axis r it is possible to solve it only in 1 quarter of model from (Fig.2). For numerical solution of electromagnetic field using QUICKFIELD the authors constructed a numerical model (Fig.3). For numerical calculation it is necessary to recalculate the value of the intensity of the exciting current I_{1ef} so that this intensity is in harmony with a numerical model (see Fig.3). Calculated values are given in Table 2.

	I_{1ef} [A]	turns	$I_{1ef\text{-}oblast}$ [A]	$I_{1max\text{-}oblast}$ [A]	I_{1maxO2}[A]
1.	1 380	64	88 320	124 903	62 451
2.	1 110	64	71 040	100 465	50 232
3.	1 072	64	68 608	97 026	48 513

Table 2. Calculated values of exciting current

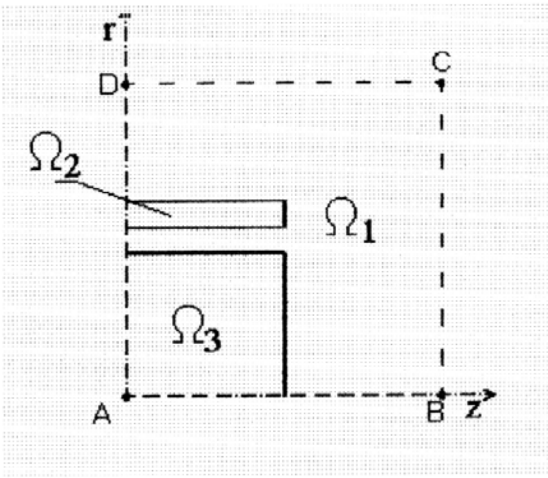

Fig. 3. –Numerical model – QuickField

where

$I_{1\,ef}$ current in the inductor of the real arrangement [A];

$I_{1\,ef-area}$ current in spare inductor [A] from Fig.2.;

$I_{1\,maxO\,2}$ current in the inductor in area Ω_2 from Fig. 3.

In particular areas Ω_1, Ω_2 and Ω_3 these equations are valid:

Ω_1: $$\mathrm{rot}\,\mathrm{rot}\,\mathbf{A} = 0 \tag{1}$$

Ω_2: $$\mathrm{rot}\,\mathrm{rot}\,\mathbf{A} - \gamma_1 \frac{\partial \mathbf{A}}{\partial t} = \mu_0\, \mathbf{J_b}(t) \tag{2}$$

Ω_3: $$\mathrm{rot}\frac{1}{\mu_k}\mathrm{rot}\ \mathbf{A} = \gamma_2 \frac{\partial \mathbf{A}}{\partial t} \tag{3}$$

γ_1 specific electric conductance of the inductor [S/m];

γ_2 MEDIUM value of specific electric conductance of heated material [S/m];

μ_k medium value of relative permeability of heated material;

$\mathbf{J_b}(t)$ exiting current in the inductor [A];

Ω_1 area of surrounding air;

Ω_2 area of inductor;

Ω_3 area of heated material.

boundary conditions :

A-B: $$\mathbf{B_r} = 0 \ \Rightarrow\ \frac{\partial \mathbf{A_\alpha}}{\partial z} = 0 \tag{4}$$

To the symmetry along axis r

B-C, C-D: $$B_r, B_z = 0 \ \Rightarrow\ A_\alpha = 0 \tag{5}$$

In a sufficiently big difference from the inductor

D-A: $$A_\alpha = 0 \tag{6}$$

To the antisymmetry along axis z where

$\vec{\mathbf{B}} = \vec{\mathbf{r}}B_r + \vec{\mathbf{z}}B_z$

$\vec{\mathbf{A}} = \vec{\mathbf{r}}.0 + \vec{\mathbf{z}}.0 + \vec{\boldsymbol{\alpha}}_0.A_\alpha$.

Conditions for the boundary of two environments inside areas Ω_1, Ω_2 *are*

$$\Omega_3: \frac{1}{\mu_i}\frac{\partial A_{\alpha i}}{\partial n_{ij}} = \frac{1}{\mu_j}\frac{\partial A_{\alpha j}}{\partial n_{ij}} \qquad (7)$$

2.3. Numerical calculation of electromagnetic field and its results

Values of losses in line in a charge calculated using QUICKFIELD are given in Table 3.

heating	sP_{21} [W]	heating[min]
1.	2 341 440	2
2.	1 514 840	4
3.	1 412 920	1

Table 3. Amount of losses in line

where is

sP_{21} value of losses in line (induced heat) in a charge [W]

2.4. Numerical calculation of thermal field and its results (prg. FLUENT)

The program enables both stationary and non-stationary analysis of 2D and 3D problems with following high quality visualisation of results. THE FLUENT program solves stationary and non-stationary Navier-Stokes equations using the method of finite volumes. When calculating heat transfer energy equations are solved as well.

Similar to QUICKFIELD also the FLUENT program needs the necessary information that specifies the given problem. The model and the net of the model are created using the GAMBIT program, which is a volume modeller and generator of nets of finite volumes that is not a part of FLUENT. The model created with the GAMBIT program is then transferred to FLUENT. In the FLUENT program it is necessary to specify what problem it is and to define the material constants, initial and boundary conditions of the solved program. The dependence in time of the surface temperature of the fledge is given in the following graph: "Calculated values (surface temperature).

3. Discussion of the results

Based on the calculation of the distribution of the magnetic field losses in material were calculated using QuickField. The values of the surface temperature of the heated material are calculated. Non-stationary thermal field was calculated using numerical method. For comparison of the results of mathematical models with measured values surface temperatures calculated with FLUENT are available. These are given in a graph (Fig.4). In the graph, there are also the courses of measured surface temperatures. Temperature in row 1 corresponds with the surface temperature of the fledge calculated using Fluent with the previous calculation of magnetic field using QuickField.

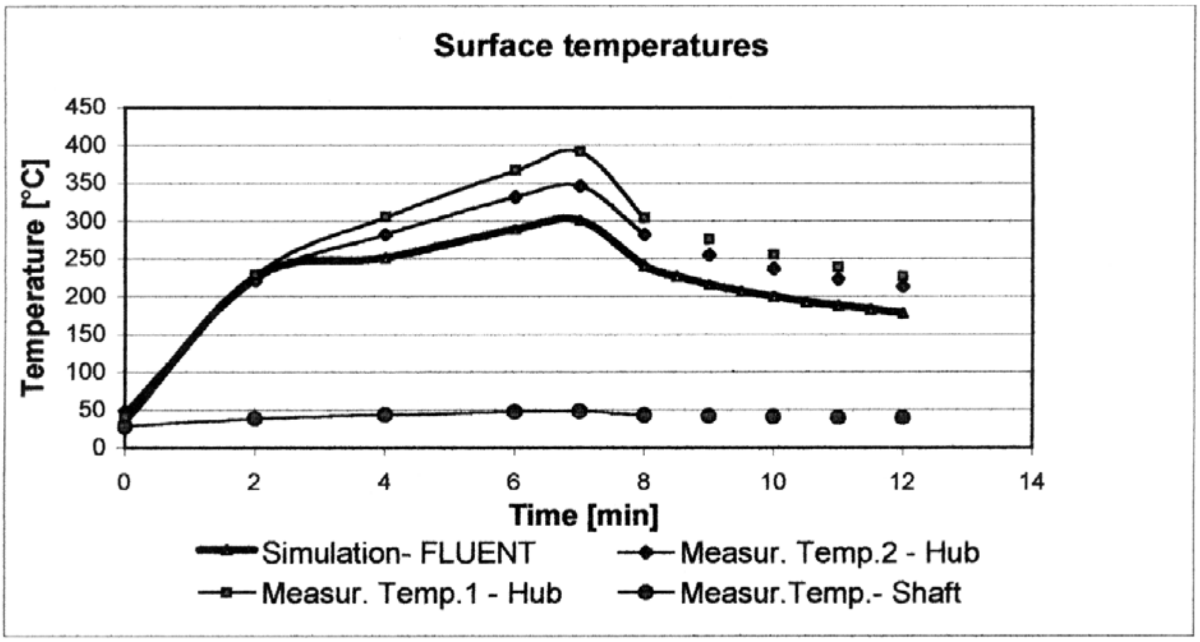

Fig. 4. Surface temperatures

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