ABOUT INDUCTION HARDENING METHOD OF GEAR USED IN A CONVEYOR

Cheregi Gabriel*, Burca Adrian, Codău Anca Teodora*****

* University of Oradea, Faculty of Environmental Protection, 26 Gen. Magheru St, 410048, Oradea, Romania, e-mail: grcheregi@yahoo.com
** University of Oradea, Faculty of Electrotechnics and Informatics, 5 Universităţii St., 410087, Oradea, Romania, e-mail: aburca@uoradea.ro
*** "Dimitrie Cantemir" Secondary School, 2A, Sextil Puşcariu St., Oradea, Romania, e-mail: teodoracodau@uoradea.ro

Abstract

This paper proposes induction hardening method of gear used in a conveyor. The heating analysisin case of treat piece needs solution with thermal diffusion problems coupled with eddy currents problem. Therefore the experiments number in designing process can be decreased for a better knowledge of the process can be obtained.

Key words: electromagnetic field coupled with thermal, numerical simulation.

INTRODUCTION

In the latest time the induction hardening method has been developed. The numeric analysis is coupled with thermal diffusion. The methods can be used for all kinds of geometry types. They can consider the change of both the electromagnetic and thermal parameters according to temperature. Close to Curie point, the B-H relation very dependend on temperature, passing from iron-magnetic environment form to air. Regarding to this reason, the eddy's current problems and thermal diffusion are strongly coupled in the Curie point zone. All numerical methods warn a kind of instability when is solving the problem. Branded programs, adopt the linear pattern (Cingoski, 1996), where the B-H relation is linear, the magnetic permeability is adjusting according to the highest effective value of the magnetic induction (Cheregi, Arion, 2010). The pattern allows adopting the sinusoidal regime and the images too for the sizes of the electromagnetic field and its equations. The results are acceptable for the specialists. Another refined method, such as "rough force" (see the FLUX package) or "harmonious balance" (Doppel, 1996) is a big time and memory consumer and it doesn't lead to a better accurate solution.

The recommended solutions are analysed with FLUX-2D package programme.

MATERIAL AND METHODS

In the case of electromagnetic problem we have a parallel – plane structure. The magnetic field problem can be reduced to the determination of a potential vector with a single component, which verifies an similar equation with that of the scalar potential:

$$-\operatorname{div}(\nu \operatorname{grad} A)+\sigma\frac{\partial A}{\partial t}=C\cdot J_0. \qquad (1)$$

We wrote $\nu=\frac{1}{\mu}$ and we considered $\boldsymbol{J}_0 = \mathrm{k}J_0$. The constants values C, which can be different on disjoining conducting domain, which the results on global current assessment on these sub-domains. The Dirichlet boundary condition for A comes from the imposed boundary conditions to normal element of magnetic induction.

$$A = g_A \qquad (2)$$

The Neumann boundary conditions for A results from the imposed boundary condition to tangential component of H:

$$-\nu\frac{\partial A}{\partial n}=f \qquad (3)$$

The thermal diffusion field is describe by equation:

$$-\operatorname{div}\lambda\operatorname{grad}T+c\frac{\partial T}{\partial t}=p \qquad (9)$$

Where:
c is volume thermal capacity,
λ is thermal conductibility
p volume power density who transform himself from electromagnetic form in heat.

To equation we add the boundary condition:

$$-\lambda\frac{\partial T}{\partial n}=\alpha(T-T_e) \qquad (10)$$

the, initial condition for temperature is: $T(0)=T_{in}$.

Time discretisation of equation (10) its doing through Crank-Nicholson technique, and space discretisation through finite element method (Leuca et al., 2005).

The coupled of thermal diffusion problems with eddy currents is the main problem. The material parameters from eddy currents problem (B-H characteristic and resistivity) depend from temperature, in time material parameters from thermal problem depend from the result of eddy currents problem (power density) and temperature (thermal capacity and thermal conductibility) (Leuca et al., 2002; Leuca, 1997). Each adopt time steps for thermal problem, it return to eddy currents and diffusion problem. If the correction is not significant, we go to the next time step. If its signalize instability in time, then the time step must reduce.

RESULTS AND DISCUSSION

The numerical simulation allows to determining accurately the relationship between the frequencies used, the power density and the desired treatment depth.

The optimal frequency can be estimated by the penetration depth of induced currents. The process consists in performing a single hardening at 8 kHz using an inductor as shown in Figure 1.

The inductor is dimensioned in order to assure a distribution of the currents in the piece which implies the optimal heat treatment.

The magnetic flux density depencence with the magnetic field strength and temperature of the steel is shown in Figure 2 for circular conductor.

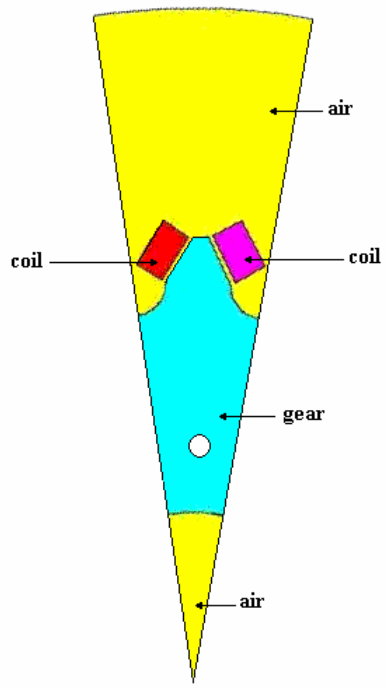

Fig. 1. The model of gear used in a conveyor

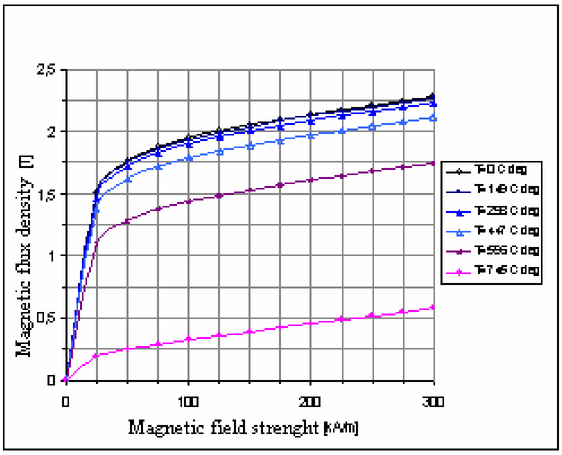

Fig. 2. The magnetic flux density depencence with the magnetic field strength and temperature of the steel

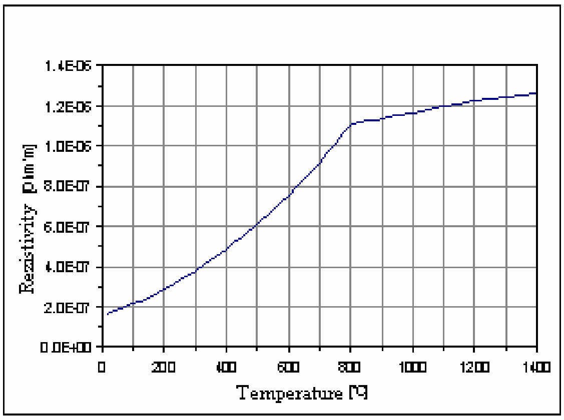

Fig. 3. The rezistivity dependence with the temperature of the steel

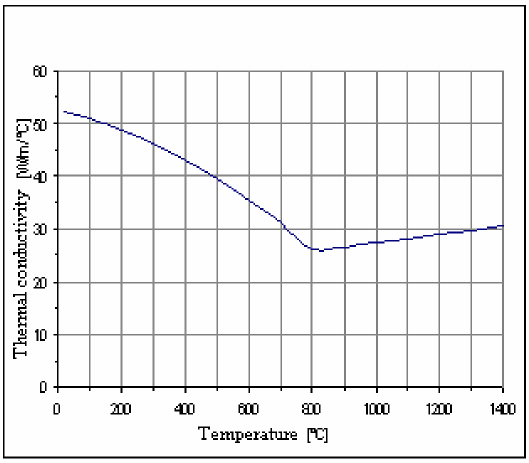

Fig. 4. The thermal conductivity depencence with the temperature of the steel

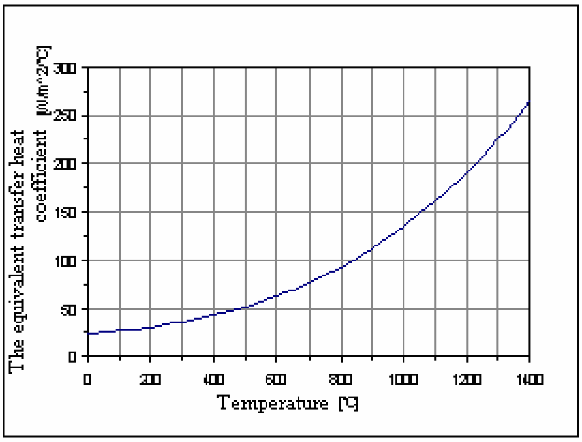

Fig. 5. The equivalent transfer heat coefficient dependence with the temperature

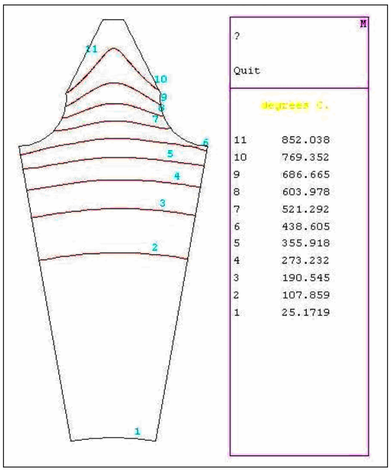

Fig. 6. Thermal field distribution into the tooth of the conveyor gear at time 21.28 sec

CONCLUSIONS

The numeric simulation of superficial hardening process is a complex problem, where are resolve simultaneous two field non-linear problems one of eddy currents and thermal diffusion. The non-linear problems of eddy currents is provide from non-linear relation of **B-H**, in time the non-linear of thermal problem provide from dependence with temperature of thermal parameters (Leuca et al., 2007; Burca, Cheregi, 2012).

The parameters are: thermal conductibility, thermal capacity, thermal transfer coefficient on surface.

The coupled of two problems result from strong dependence of relation **B-H** with temperature, in electromagnetic field problem and thermal field source, given by Joule lost, in thermal diffusion problem.

The advantage of this method is results from the possibility to adopt the sinusoidal regime and complex image, the numeric form of field equation leading to one algebric equation system with complex coefficient.

In this case of the two coupled field, the problem is solve with time discretisation procedure, where at each time step, it is make the iterative correction of electromagnetic and thermal parameters.

REFERENCES

1. Arion M., Cheregi G., 2008, “About the analisys of simultaneousinduction hardening method of pinions with rectangular coil”, Journal of electrical and electronics engineering, University of Oradea.
2. Arion M., Leuca T., Hathazi F.I., Soproni V.D., Molnar C., Cheregi G., 2012, “Aspects Regarding the Numerical Computation of the Eddy Current Problem within the Electromagnetic Induction Processes of Thin Planes”, Journal of electrical and electronics engineering, University of Oradea, Vol. 5, no. 2, pp. 17-20.
3. Burca A., Cheregi G., 2012, “Numerical Modeling of Induction Hardening System of Gears”, Journal of electrical and electron. eng., Univ.of Oradea, Vol.5, no.1, pp. 23-26.
4. Cheregi G.R., 2006, “Contributions on the numerical analysis of the heating process through induction in the thermal treatments issues,” doctoral thesis.
5. Cheregi G., Arion M., 2008, “About the analisys of simultaneous induction hardening method of pinions with circular coil”, J. of el. and electr.eng., Univ.of Oradea, pp.26-29.
6. Cheregi G., Leuca T., Arion M., 2008, “About numerical analisys of electromagnetic field induce in gear wheels during hardening process”, Journal of electrical and electronics engineering, University of Oradea, pp. 22-25.
7. Cheregi G., Arion M., 2009, “About the analisys of simultaneous induction hardening method of disk used at suspense harrow in agriculture with circular coil”, Journal of electrical and electronics engineering, University of Oradea, Vol. 2, no. 2, pp. 17-20.
8. Cheregi G., Arion M., 2010, “About the analisys of simultaneous induction hardening method of disk used at suspense harrow in agriculture with rectangular coil”, Journal of electrical and electronics engineering, University of Oradea, Vol. 3, no. 2, pp. 47-50.
9. Cingoski V., 1996, "Analysis of magneto-thermal coupled problems involving moving eddy-current conductors", IEEE Transactions on Magnetics, vol.32, pp. 1042-1046.
10. Doppel K., 1996, "Finite element method for calculating power frequency 2D electromagnetic field distributions in ferromagnetic materials", IEEE Transactions on Magnetics, vol.32, pp. 792-796.
11. Hantila F. et al., 2001, “The numeric computation of eddy currents”, Ed. ICPE, Buc.
12. Leuca T., 1997, "Numerical modelling energy optimization of the electromagnetic and thermal coupled fields in the induction heating process of the cylindrical half-finished products", Internat. symposium on non-linear electromagnetic systems, Braunschweig.
13. Leuca T., Cranganu-Cretu B., Arion M., Tarcau G., 2002, "Numerical modelling of industrial processing by electromagnetic induction of ferromagnetic parts", 10th Internat. IGTE Symposium on Numerical Field Calcul. in Electrical Eng., Graz, Austria.
14. Leuca T., Arion M., Cheregi G., 2005, ”Dual Frequency Simulation of the Electromagnetic Induction Process in Gear Wheels”, Anal. Univ. din Oradea, pp. 36-39.
15. Leuca T., Arion M., Cheregi G., Horge I., 2007, “About numerical computation of electromagnetic field in ferromagnetic bodies”, Analele Univ. din Oradea, Fascicula Electrotehnică, pp. 11-14.