Numerical Modeling and the Technological Process of cleating at a Frequency of 500 Hz

Claudia Olimpia STASAC, Dorel Anton HOBLE

University of Oradea, Department of EMUEE,
Faculty of Electrical Engineering and Information Technology,
410087 Oradea, Romania, e-mail: claudiastasac@yahoo.com

Abstract *- The paper refers to a technology of achieving bimetallic combination by processing structure in an electromagnetic field of medium frequency.*

The numerical model used in this study is based on the finite element model and is destined to the study of heating by induction in volume of cyllindrical feromagnetic steel structure whose properties vary with temperature and suffer phase transformation across Curie point.

Keywords: *cleating, electromagnetic field, inductive heating, heating process bimetallic components*

I. INTRODUCTION

Cleating technology of two materials is based on the exterior structure heating up to 800° C, then the inductor feeding is stopped. The interior cyllindrical feeding is stopped. The interior cyllindrical structure is introduced, the transfer of heat towards the assembly interior being realized through thre phenomena of thermic conduction (Fig.1) [7].

Due to the expanding of the exterior structure, during the inductive heating process, its interior diameter will grow, allowing the introduction in this phase of an interior cyllindrical structure. At the cooling of the exterior structure, by thermic transfer towards the interior one, this is contracted, causing pressure to the interior one. Due to this fact, a pressure force of exterior structure to the interior one appears, which in the case of a well controlled process leads to the structural combination of the two materials.

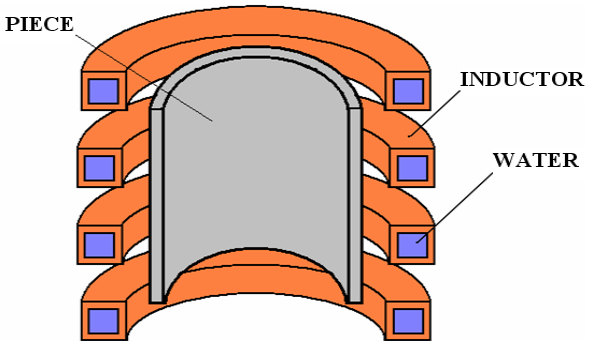


Fig. 1. Modeled structure

II. PRESENTATION OF THE STUDY CASE

For the study developed in this paper an assembly made up of two pieces of cylindrical shape, empty inside and coaxially assembled, the structure of the piece being presented below - Figure 2. The inside element is made up of brass and the exterior one of iron. Two materials were chosen, exterior and interior to allow the study to develop a subsequent development towards the combination of the hybrid structures, using the electromagnetic processing.

The technology of combination of the two materials is base on the structure heating towards the exterior structure up to a certain temperature, after hat the inductor energy supply is stopped, the transfer of the heating towards the assembly interior producing the thermal conduction phenomenon.

Due to the different expanding index a pressure force of the interior structure to the exterior structure appear which in the case of the well controlled process leads to the structural combination of the two materials.

Fig. 2. The piece to be processed

In the plan *r-z*, the domain of calculation of the problem, also out of symmetry reasons, is reduced at half of the section.

Having in mind the fact that the problem modeled shall comprise two stages, namely the heating of the ferro-magnetic cylinder in the inductor, followed by a stage of sending heat through a process of thermal conduction from the exterior cylinder towards the interior cylindrical structure, there was achieved a first geometry of study, ferro-magnetic cylinder inside the inductor. [1,2]

Taking into account these aspects, the geometry of the model studied is presented in figure 3.

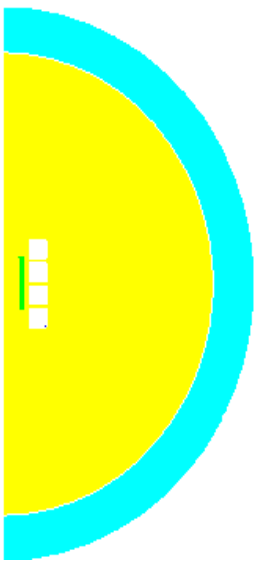


Fig. 3. Geometry of the calculation field

The calculation domain of the electromagnetic field represents but half of the physical model, because of the system symmetry.

The construction of a network of optimum discretization represents one of the essential stages in the correct solving of a problem of field, the accuracy of the results being strongly dependent on the way of making the network, [8].

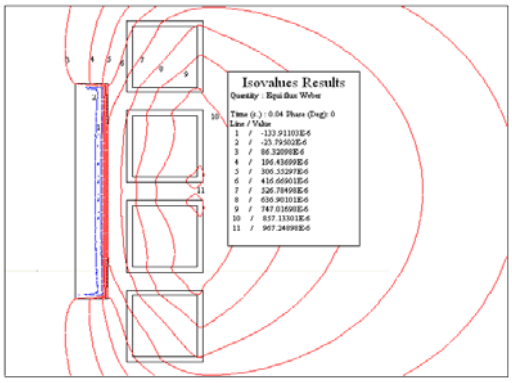
For the resolving of the problem through the Finite Elements Method, the calculation domain is made discrete in finite elements of triangular form. This discretization must be made in accordance with the way of developing the phenomena in the physical system in the sense of the pronounced and progressive of the discretization network in the respective areas and in the sense in which the gradient of the state size increases..

In order to satisfy the qualitative requirements, the triangular finite elements must have a form as close as possible to that of an equilateral triangle. It is a difficult thing especially when the calculation domain comprises regions with a large extension next to very thin regions. This shortcoming can be solved with the condition of increasing the finite elements number.

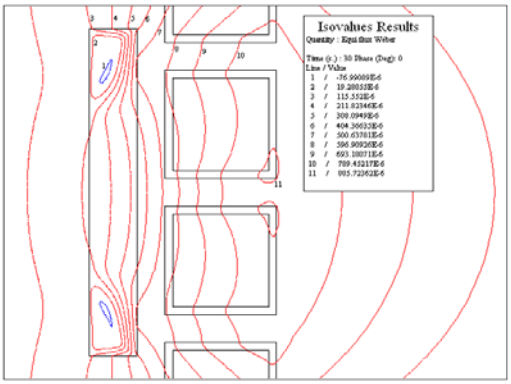
III. THE NUMERICAL MODELING

For the achievement of the numerical modeling, the modeling and simulation program FLUX 2D, and electricity density on inductor of 42 A/mm^2, and work frequency of 500 Hz.

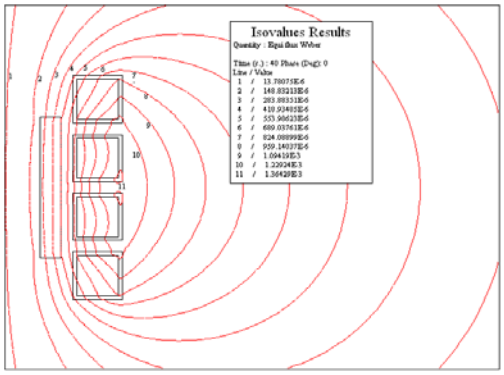
After numerical simulation, the repartition of the magnetic field lines in formed shape was studied, the simulation result being presented in figure 4 *a, b and c*.



a



b



c

Fig. 4. Magnetic field lines at 0,4 s and frequency 500 Hz (a), at 30 s and frequency 500 Hz (b) and at 40 s and frequency 500 Hz (c)

The distribution of the temperature field, in the heated piece, represents one of the most important parameters that were followed during the study. That is why we will present the results obtained after modeling and simulation of the heating process.[7]

To maintain the possibility of results comparison the time steps where analysis was made are 1s and 47s (fig. 5,6,7).

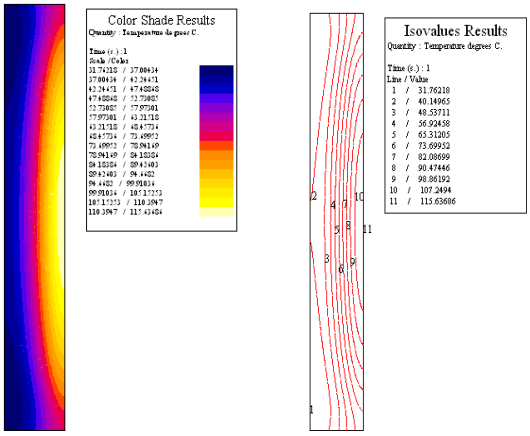


Fig. 5.

a. Distribution of thermic field at time moment 1 s and work frequency 500Hz

b. Distribution of thermic field lines at time moment 1 s and work frequency 500Hz

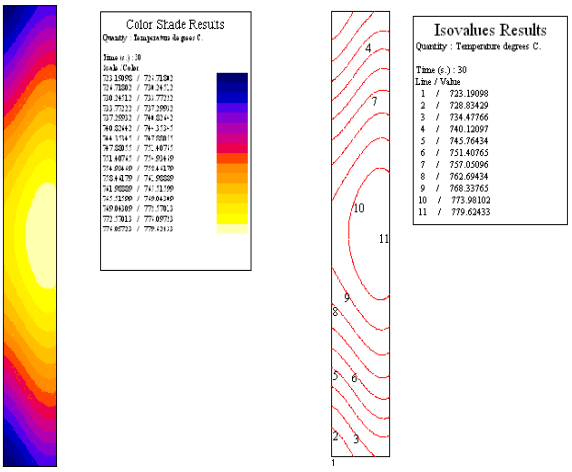


Fig. 6.

a. Distribution of thermic field at time moment 30 s and work frequency 500Hz

b. Distribution of thermic field lines at time moment 30 s and work frequency 500Hz

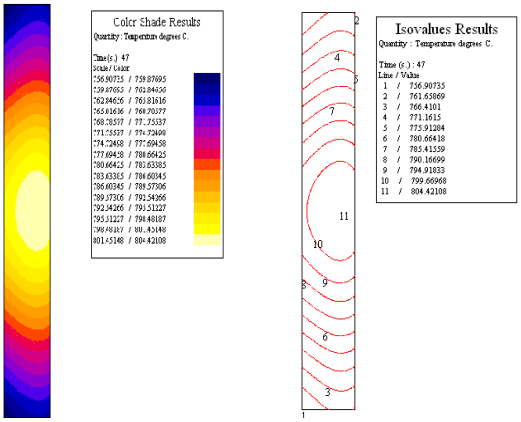


Fig. 7.

a. Distribution of thermic field at time moment 47 s and work frequency 500Hz

b. Distribution of thermic field lines at time moment 47 s and work frequency 500Hz

In this paper, the heating by turbionary currents and exterior piece expanding for achieving the diameters differences necessary for the cleating procedure is presented. The temperature field in this piece was obtained by solving the problems linked to quasi-stationary and thermal diffusion electromagnetic field.

The heating is made at a high enough temperature (803° C), so that the expanding leads to such a diameter difference that allows the introduction of the interior pipe in the exterior one, even if during the handling the temperature of the

exterior pipe decrease.[5,6]

The value of the *cleating* diameter is 46 s.

In this case one can notice that the average temperatures on median line and on the 2 lines in the vicinity of the spare part margins differ very little, although the depth of penetration is around 3 times smaller than in the case of the frequency of 50 Hz.

This is a consequence of the very good thermal conductibility of the spare part and of the fact that the heating time is pretty high.

In fig. 8 and 9 are traced the graphs of the average temperature, respectively of the exterior diameter, according to time.

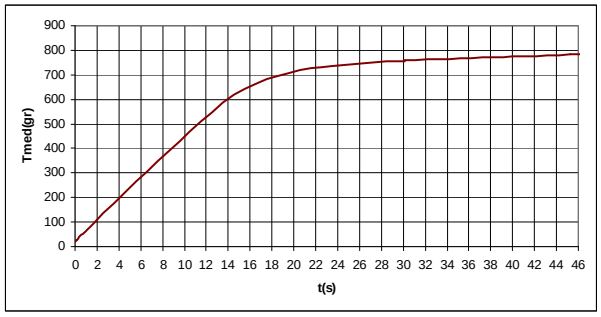


Fig. 8. Medium temperature in the piece

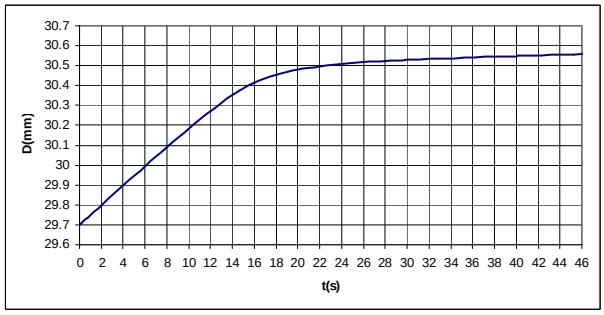


Fig. 9. Inside diameter of the exterior pipe

IV. CONCLUSIONS

As a conclusion of the study made, one can say that further to increasing the work frequency to the value of 500 Hz. There was obtained a considerable improving of the heating time, there being reached temperatures of 803^{o}C, in an interval of 47s.

The distribution of the thermal field is more uniform than in other cases, but it is noticed a decreased of the flux density in the piece towards thje end of the heating interval.

In order to make a more thorough study of the phenomenon of inductive heating it is recommended an analysis of the heating process, using a higher work frequency.

The above results show that the analysis proposed in this paper allows the adoption of the most convenient work frequency and values of the current density. The hypothesis that the frequency increases too much it is possible that the pellicles effect can be so pronounced that is a short time after the current appliance the temperature in certain areas of the piece increase a lot, the average temperature remaining insufficient to achieve the cleating diameter.

The mechanic combination through thermal process are often used in practical applications that is why the research of the heating process by metal pieces induction imposed for the improving of the phenomena of electromagnetic conversion and distribution of the electromagnetic field, linked to the thermal one in the structures subjected to heating.

REFERENCES

[1]. B o u r h i s, J.C., *Chauffage de billettes par inducteur multicouche : Du prototype a la premiere reference industrielle*. Les cahiers de l ingenier, No 62 , 1996;

[2]. H o b l e, D. , S t a ş a c, C., *Study about the inductive heating of a cylindrical workpiece, used torsioned inductor*. Proceeding of HIS-01 , Padua, Italy 2001;

[3]. H o b l e, D., *Numerical modeling and experimental validation of a inductive heating process with a doublelayer inductor*. The 10th International IGTE Symposyum on Numerical Field Calculation in Electrical Engineering, Graz, Austria, 2002;

[4]. H o b l e, D. , S t a ş a c, C., *Study about the increasing of the heating efficiency of the coaxial bimetallic workpieces*. Proceeding of International Conference of Central European Energy, Efficiency and Renewable Energy Sources – Prague, 2003;

[5]. L e u c a, T., *Câmpul electromagnetic şi termic cuplat. Curenţi turbionari*, Editura Mediamira, Cluj Napoca, 1996;

6]. M a g h i a r, T., L e u c a, T., H ă n ţ i l ă, I., F., *Analiza numerică a proceselor de încălzire prin curenţi turbionari,* Editura Universităţii din Oradea, Oradea, 2001;

[7]. S t a ş a c, C. O., H o b l e, D. A., *Modelling of the electromagnetic field in bimetallic components*, Journal of Electrical and Electronics Engineering, Oradea, 2008, pp. 134-136;

[8]. S t a ş a c, C. O., H o b l e, D. A., *"The study of modelling inductive heating utilization the joining technique of "fretaj",* Journal of Electrical and Electronics Engineering, Oradea, 2008, pp. 137-139;

[9]. * * * CEDRAT, *Flux 2D*, version 8.1 "CEDRAT, MEYLAN France ".