INCREASING THE ENERGY EFFICIENCY INDUCTORS FOR INDUCTIVE HEATING BY ADOPTING MODERN CONSTRUCTION SOLUTIONS AND MATERIALS

Dorel Anton Hoble[1] Claudia Olimpia Stasac[2],
[1] University of Oradea, , dhoble@uorade.ro
[2] University of Oradea claudiastasac@yahoo.com

ABSTRACT: This paper attempts to study the utilisation of the magnetic field concentrators in the industrial heating process. The magnetic field concentrators used for this study were modelled with the proper parameters of the magnetodielectrics (MDM) materials. For the modelling of the phenomena, the FLUX2D software was used.
KEYWORDS: inductive heating, magnetic field concentrators, numerical modelling, FLUX2D software.

1. INTRODUCTION

In the industrial heating process the inductive heating is a modern procedure, who is characterized by great efficiency[1,2,4,6]. The modern desing procedure It is great advantage makes the studies regarding the increasing of the electric efficiency be very useful, as well as the decrease of the energetic consumption.

2. THEORETICAL PROBLEM

If we consider an inductive coil around a work piece, shown in picture number 1, the equivalent magnetic circuit is shown in picture number 2.

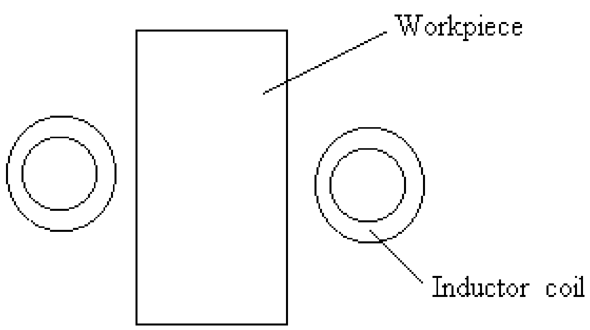

Fig.1 The theoretical study model

The Ohm`s law, applied to this magnetic circuit is:

$$N\ I = R_m \times \Phi_I$$

The magnetic reluctance is made of two parallel magnetic reluctance, R_{mw} of the work piece and R_{mg} of the air gap, inseried with a magnetic reluctance R_{mo} of the medium behind the inductive coil.

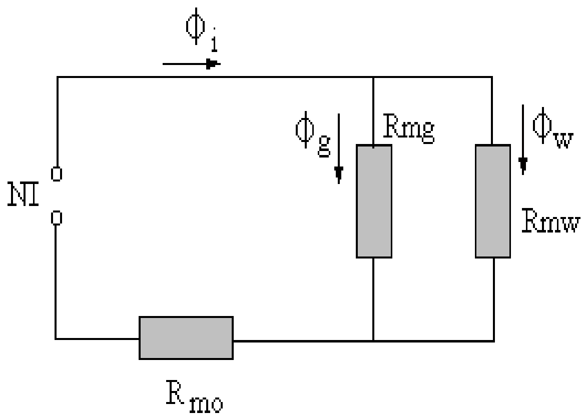

Fig.2 The equivalent magnetic circuit

For the decreasing the energetic losses, the reduction of the magnetic reluctance R_{mo} , could be a good solution. We can obtain this, by using a magnetic field concentrator.

One of the modern materials, used for the magnetic field concentrators is the magnetodielectric materials (MDM) [7,11,12].

The paper shows an inductive heating process of a cylindrical work piece with Φ_I=50mm. introduced in an inductor with six coils with Φ_I=60mm. The study was made using FLUX2D software [5,10].

Two cases of the disposal of the coils are study and shown in picture number 3, and 4.[8,9].

For symmetrical reasons, the study area has been halfened.

The electrical equivalent circuit used for the simulation of the inductor function is shown in picture number 5.

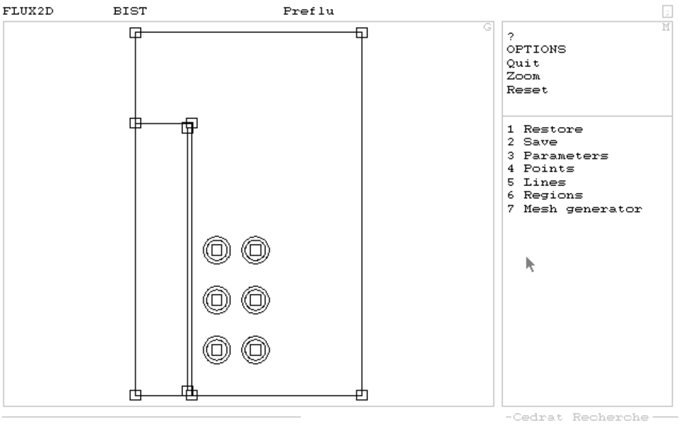

Fig.3 The first disposal of the coils

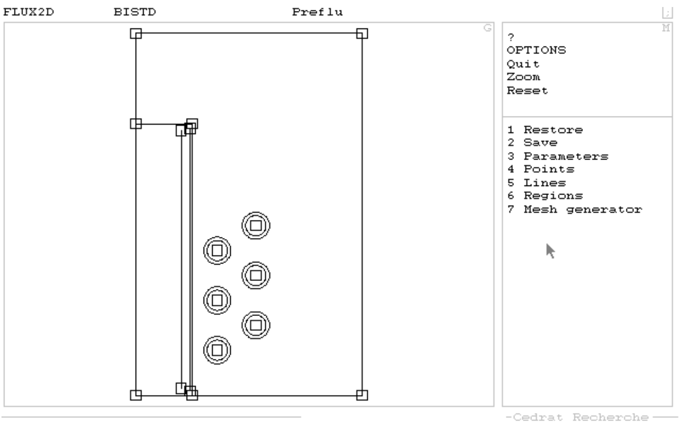

Fig.4 The second disposal of the coils

The supplying electrical voltage of the inductor is 40V.

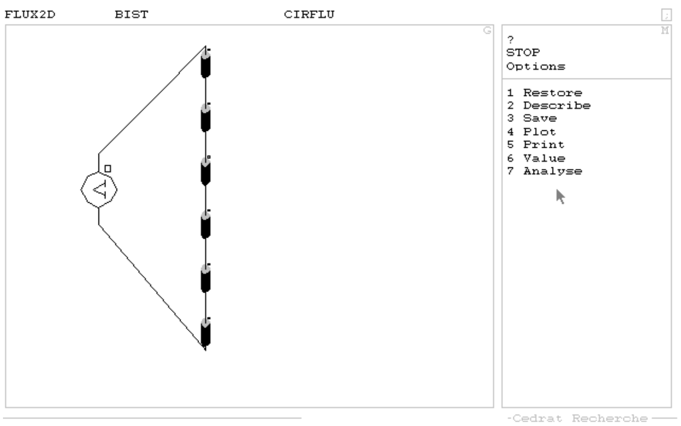

Fig.5 The electrical equivalent circuit

For this two disposes cases of the inductor`s coils with magnetodielectric field concentrator, the repartition of the electric field and the power density induced in work piece, was analyzed.

The repartition of the electric field in the first case of study is shown in picture number 6, without magnetic field concentrator, and in picture number 7 with magnetic field concentrator.

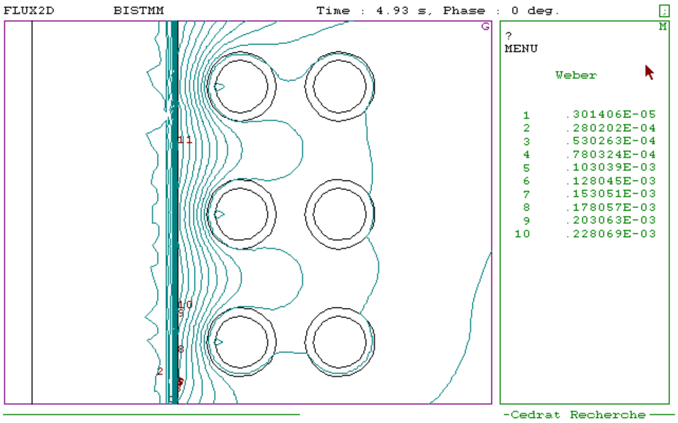

Fig.6 The repartition of the electric field in the first case of study

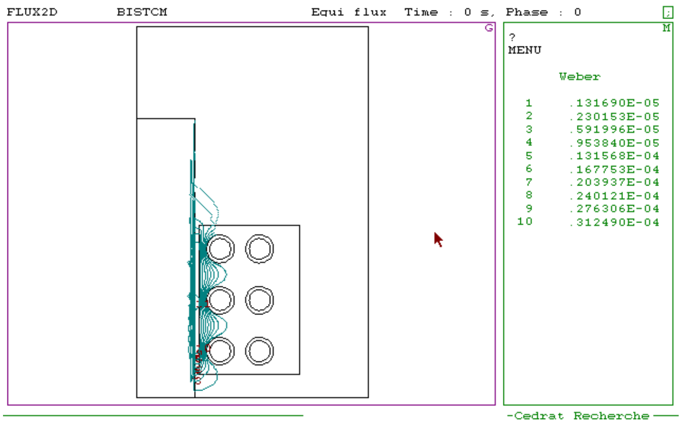

Fig.7 The repartition of the electric field with magnetic field concentrator

Analysing the value of the flux in these two cases, it is possible to see a higher value in the utilisation of the magnetic field concentrator case. Similarly the utilisation of the second variant of the coil disposes without using the magnetic field concentrator was analysed.

The results of modelling are shown in picture number 8, and 9.

As in the first case of disposing, in the second case of disposing we can notice an advantage when the magnetodielectric field concentrator. The maxim value of the flux is $0,524635.10^{-4}$ Wb in the case of utilisation of the field concentrator, compared to the maxim value of the flux $0,335723.10^{-4}$ Wb, when the magnetic field concentrator is not used.

The next step of the study is to analyse the value of the power density induced in the work piece when the magnetic field concentrator is used. The results of the modelling are shown in picture number 10, and 11.

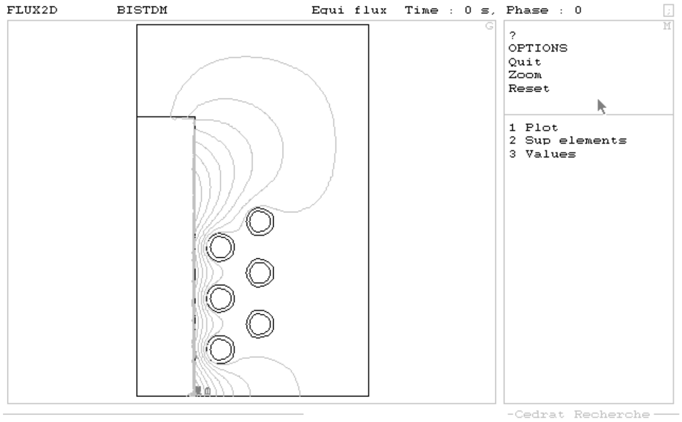

Fig.8 The repartition of the electric field in the second case of study, without using the magnetic field concentrator

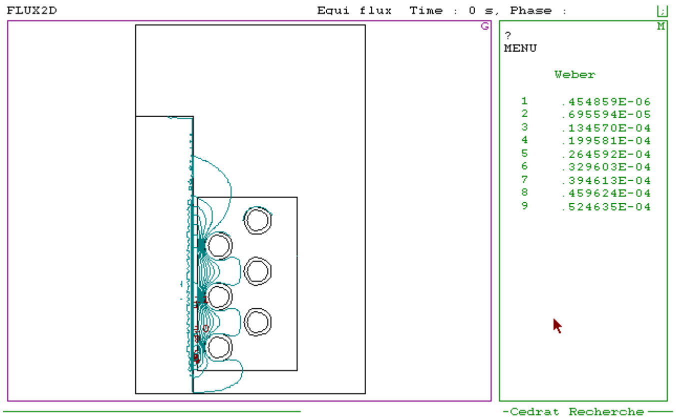

Fig.9 The repartition of the electric field in the second case of study, using the magnetic field

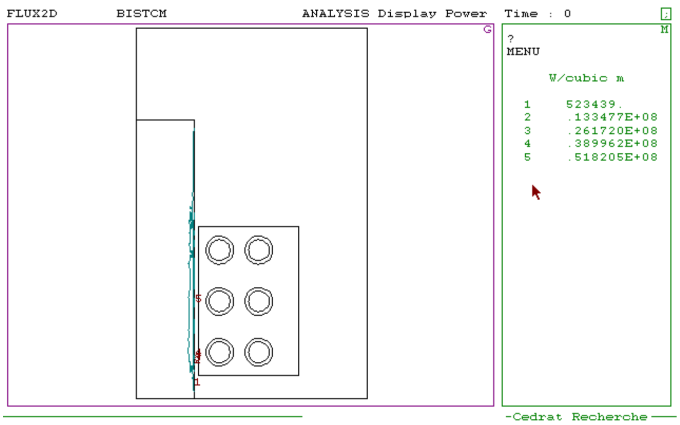

Fig.10 The value of the power density induced in the work piece, when the magnetic field concentrator is used, in the first type of coil dispose.

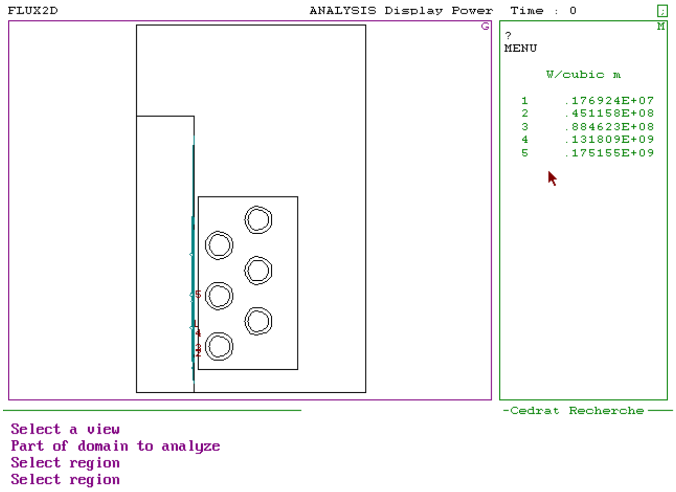

Fig.11 The value of the power density induced in the work piece, when the magnetic field concentrator is used, in the second type of coil dispose.

Analysing the maxim value of the induced power, it we can notice an increasing of this, in the second variant of the disposing of the coils. The maxim value in the first case is 0,518205.10 ^{8} ^{W}/m^{3}, and in the second case is 0,175155.10 ^{9}W/m^{3}.

3. EXPERIMENTAL DETERMINATIONS

Based on the analysis of theoretical performed, it was made two experimental inductors models, based on the results of numerical otimization, one of them an double layer inductor with the coils displaced and an double layer inductor with the coils displaced who have a field concentrator made by magnetodielectric material.

The experimental models were tested on a heating inductive instalation with working frequency of 2500Hz and with voltage and current parameters identical to those used in the numerical modeling.

The temperature measuring of the processed workpiece , it was made by an infrared temperature measurement device, connected to a computer system, whose image is shown in picture number 12.

In the first step of the experimental determination was performed an heating process with the inductor, with the arrangement of the coils as in the modeling shown in picture number 4 .

In picture number 13, it is show the experimental inductor during the heating process. The measurement results, of the temperature variation in the heating process is shown in figure 14.

Fig.12 The infrared temperature measurement device

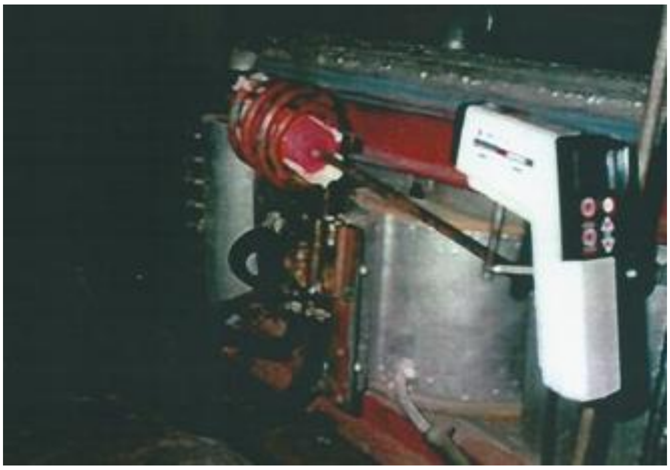

Fig.13 The heating process with the double layers inductor

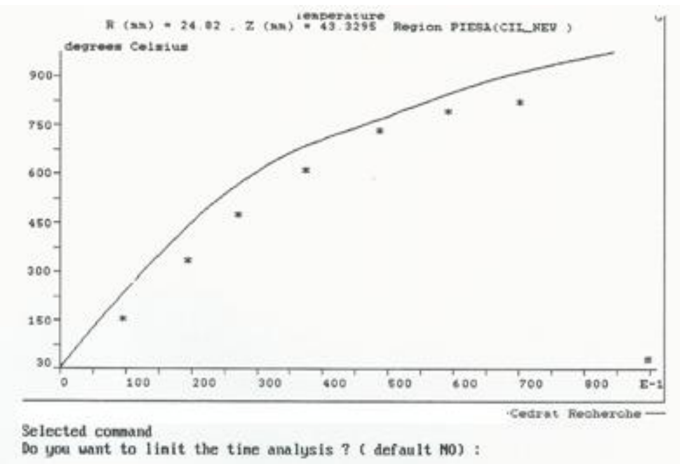

Fig.14 The variation of temperature during the heating process for the two-layer inductor

In the picture above, the solid line presents the variation of temperature on a point on the workpiece surface processed results obtained by numerical modeling and with (***) points are presented experimental values who was obtained.

In the second step of experimental process, it was warming the workpiece, using an inductor with field concentrator made by magnetodielectric material. The next picture show the warming process for this case.

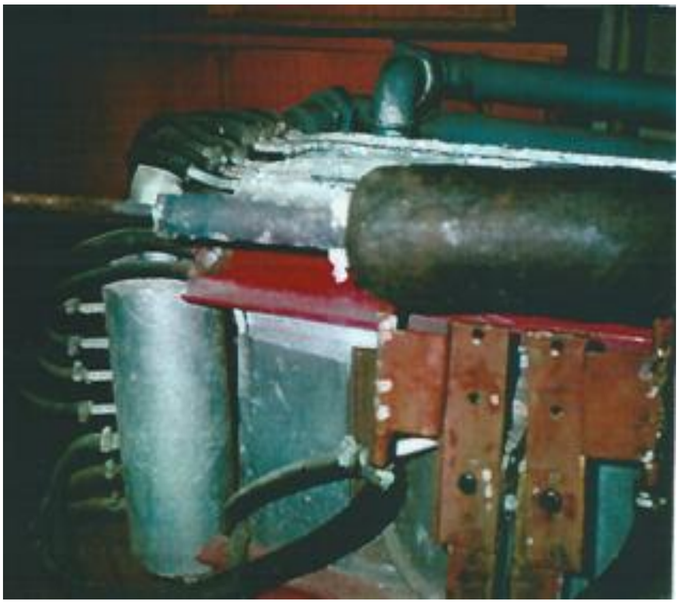

Fig.15 The heating process with the double layers inductor, and magnetodielectric field concentrator

The image below present with the solid line, the temperature variation on a point on the workpiece surface, results obtained by numerical modeling, and with (***) are marked the experimental values obtained in the heating process.

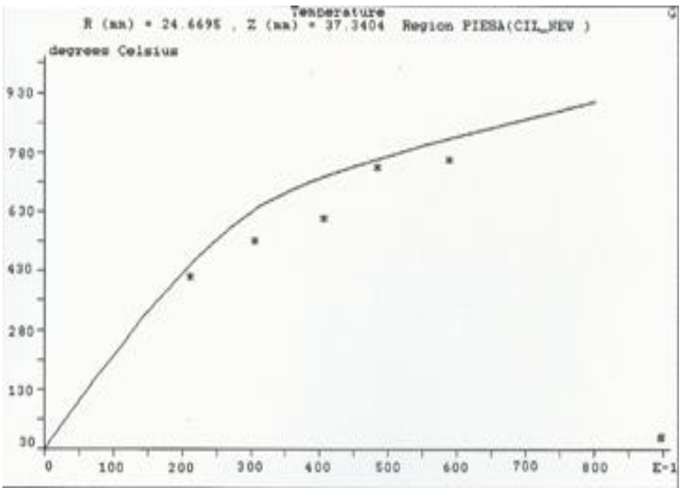

Fig.16 The variation of temperature during the heating process when the inductor is made with field concentrator.

4. CONCLUSIONS

In conclusions, analysing the value that was obtained by modelling, we can notice an advantage when using the magnetodielectric field concentrators.

Analysing the maxim value of the density power is one can notice an increase of this in the coils disposing shown in Fig.4 , and we consider that this last variant is the best approach for our research.

5. REFERENCES

1. Hoble Dorel Anton, *Materiale pentru inginerie electric şi electronică*, Editura Universităţii din Oradea, ISBN 978-606-10-1171-1, Oradea, 2013;
2. Livia Bandici, Dorel Anton Hoble, Ştefan Nagy, *Tehnologii innovative în procesarea materialelor,* Editura Universităţii din Oradea, ISBN 978-606-10-0472-0, Oradea, 2011;
3. Petru V. Noţingher, *Materiale pentru electrotehnică*, Editura POLITEHNICA Press, București, 2005;
4. Dorel Anton Hoble, Livia Bandici, Ştefan Nagy, *Sisteme performante de procesare electrotermică a materialelor,* Editura Universităţii din Oradea, ISBN 978-606-10-0767-7, Oradea, 2012;
5. Florin Ciuprina, Tiberiu Tudorache. *Utilizarea Flux3D pentru analiza dielectricilor*, Editura matrix Rom Bucureşti 2006.
6. L.Bandici , D.A.Hoble „ Utilizari ale Energiei Electrice” ISBN (10)973-759-118-6 ISBN (13) 978-973-759-118-0 Editura Universităţii Oradea – 2006
7. D.Hoble, M.A. Silaghi**, -** *Dielectric Material*, Editura INTECH, 2012, ISBN 978-953-51-0764-4, Session 2., Chapter 4, Novi Sad, Croatia
8. J.C.Bourhis – “Chauffage de billettes par inducteur multicouche : Du prototype a la premiere reference industrielle”-Les cahiers de l’ingenierie N^{o} 62 decembre 1996
9. A.E.Sluhotkii , S.E.Riskin –“Inductoare pentru încălzirea electrică” – E.T.Bucureşti 1982
10. V.Fireţeanu , A.Tudorache –“Numerical modeling and optimisation of induction heating processes” – 8th International IGTE Symposium 1998-Graz , Austria
11. Claudia Olimpia Staşac, *Tehnologia îmbinărilor nedemontabile utilizînd metode inductive*, Editura Universităţi din Oradea, 2010;
12. T.Maghiar , D. Hoble –“A comparative study about utilisation of monolayer and bilayer inductor used in electrical heating , performed by numerical simulation using the finite element method” – 8th International IGTE Symposium 1998-Graz , Austria