THERMAL FIELD ANALYSIS IN MICROWAVE SINTERING PROCESS OF BARIUM FERRITES FOR PING-PONG TABLE'S SENSOR

Sorin Savu[1], Gabriel Mangra[1], Ion Ciupitu[1], Danut Savu[1], Nicolae Gherasim[2]

[1]University of Craiova, Faculty of the Engineering and Management of the Technological Systems
Calugareni Street no. 1, Drobeta Turnu Severin 220327, Romania

[2]BRAINS Ltd. Year 1848 Street no. 75, Craiova 200541, Romania

Abstract

The performance of a tennis player is given not only from his training, but also by the play conditions during his training and in challenger tours. The paper presents some studies on the thermal field evolution in materials which are sintered in microwave field to obtain hard cores for inductive sensors used to establish the inclination of a table for ping-pong players.

Key words: *microwave heating, thermal field, nanostructured sensor*

1. INTRODUCTION

The play conditions in an official game are represented by the managing issues and sport issues. Regarding to the second issue, the researches have showed that even a small inclination of a ping-pong table can create an advantage or disadvantage for one of the players. In figure one is presented the trajectory of a ball when the table is correctly positioned.

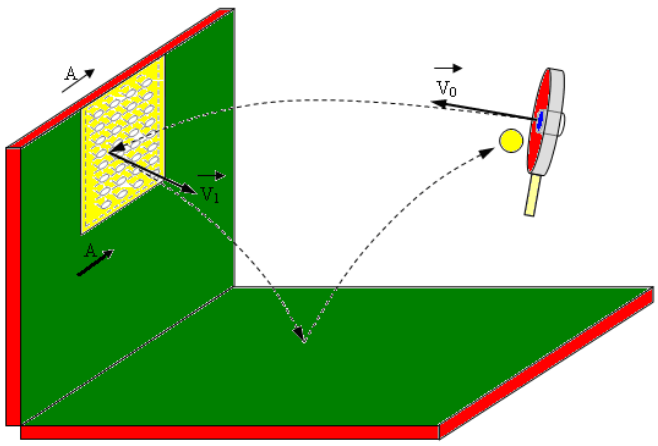


Fig. 1. The influence of the relative position of the ping-pong table under the player performances [3]

The paper propose a research about the elaboration of new generation of nanostructured inductive sensors using a new heating procedures such is the one direction microwave field. The paper presents an analytical and experimental thermal field evolution from inside to outside of the sample and the advantages and disadvantages of the microwave heating process.

2. MICROWAVE HEATING AND EXPERIMENTAL DEVICE

The dielectric heating (DH) process which contain the microwave heating (MW) and radio-frequency heating (RF) is based on the alternative transformation of the electromagnetic field energy into thermal energy in materials with unequal electric charges in molecules called polar materials (dielectric materials). In the high frequency alternative electromagnetic field the dipole axis of the polar molecules follows a permanently rotational movement and magnetic orientation thus their poles to instantly follow the field direction which is changing up to billion changes per second (10^9 changes/sec). In figure 2 is presented the orientation of the dipoles with the electrical field orientation.

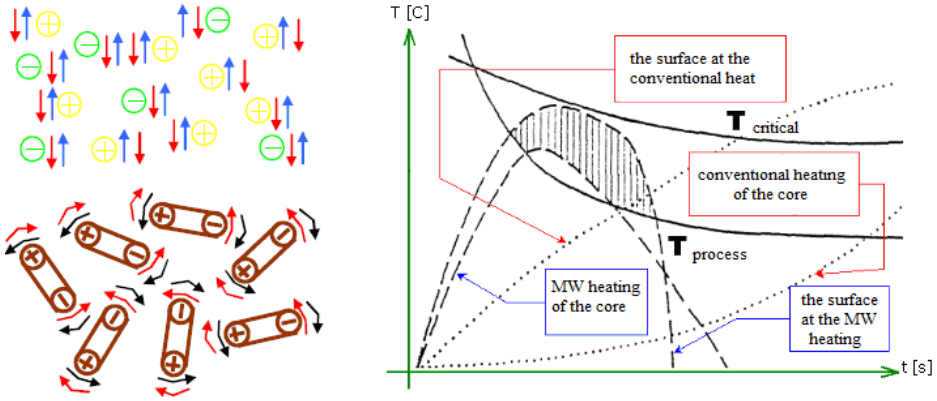


Fig. 2. The heating mechanism of the dielectric materials in microwave field

In this moment, two different phenomena are used: intermolecular friction induced by the intermolecular attraction forces and hysteresis between the action field and electrical answer induced, caused by the inertial effect, according to the electrical charges, mass and the shape of the molecules. Because of the action methods the microwave heating will assure a quick heat of the materials. [1].

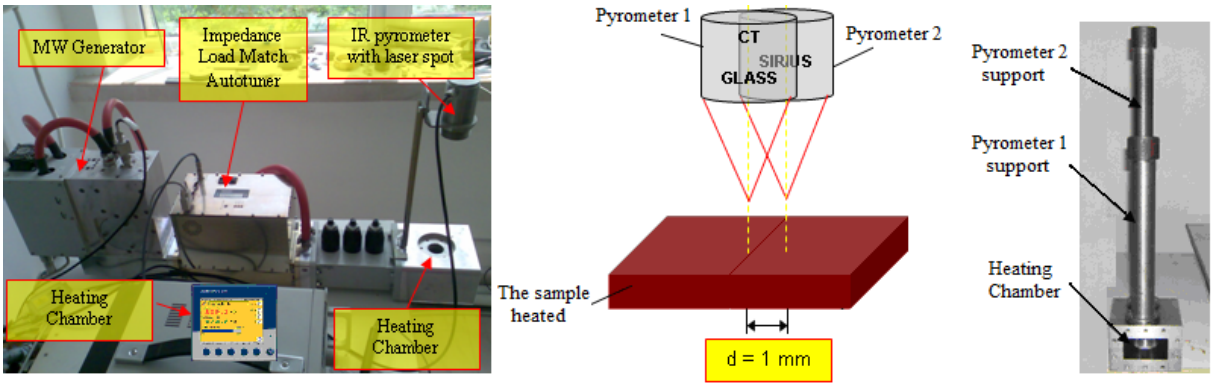


Fig. 3. The experimental device and experimental procedures

In the experiments it has been used a microwave generator controlled by a matching load impedance auto-tuner and a temperature regulator with two channels for temperatures acquisitions the entire

system being presented in figure 3. The principle of the measurement method to analyze the thermal field consists in the measurement of the temperatures in the same time in two points starting from the centre of the sample. The temperatures have been measured with two IR pyrometers with laser spot with the measurement range [250^0 – 1600^0 C] [4]. During the experimental procedures it have been used a controlling system for the injected power in the range [0 – 600 W], and the distance between the laser spots of the two pyrometers described previously is 1 mm. The emissivity of the material has been setup to 95% this setting being characteristic to the ferrites materials; the material heated being the barium ferrite type W [2].

3. THEORETICAL MODEL FOR THERMAL FIELD EVOLUTION INSIDE THE MATERIAL

In the next rows it will be presented a theoretical model for the thermal field evolution inside the material. Starting from the thermal conductivity law, a custom math model has been elaborated for the shape of the sample as follow:

$$T(r,t)=\frac{P}{\lambda \cdot S}\cdot\left(r_{S^2}+4\cdot a\cdot b_b\right) \quad (1)$$

where:

$$b_b=\frac{\alpha \cdot P}{\lambda \cdot S} \quad (2)$$

where:

- b_b – the coefficient of the dissipated heat from inside to outside
- α – the coefficient for linear transfer of the heat
- P – electromagnetic power injected in the sample
- S – the area of the sample

In the first stage it have been evaluated the equation (1) for few injected power values (relevant values from experimentally point of view). For the barium ferrite has been considered the next coefficients which are characteristics to the ceramics:

- Density: ρ = 4,2865 g/cc
- Diffusivity: a = 12,0 mm^2/s
- Specific heat: c = 0,70768 J/g x ^0C
- Coefficient of the heat transferred from inside to outside: α = 24,0 W/m x ^0K

The shape of the sample has been established to be cylinder with 20 mm diameter and a height up to 20 mm. The computational evaluation for the thermal field using the mathematical model previously presented has generated some theoretical values presented in table 1.

Table 1. Theoretical evaluation of the thermal field inside the material

No	MW Injected Power [W]	Temperature [^{0}C]
1	0	0
2	200	301
3	250	380
4	300	459

4. EXPERIMENTAL RESULTS OF THE PROCEDURES AND COMPARATIVE ANALYSIS

The experimental procedure consists in the increasing of an electromagnetic power in the material from 0 W up to 600 W. The temperatures have been recorded by moving the samples from the centre where the first pyrometer focuses his laser spot. The gap of the movement has been 1 mm (figure 3). The recorded values want to show two different aspects: the values of the temperatures according with the movement of the sample and the values of the temperatures according with injected power. Figure 4 shows a snapshot of the heating of the sample, according the impedance and recording the temperatures.

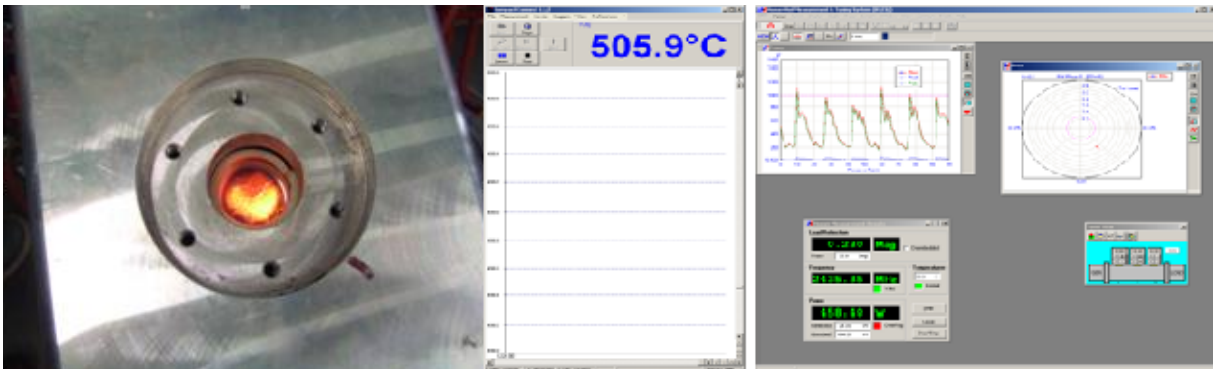


Fig. 4. The microwave heating process

In table 2 are presented the recorded values of the temperature in the first case:

Table 2. The temperatures recorded by the pyrometers according with the movement of the sample

No.	d [mm]	$T_{pyrometer\ 1\ CT\ GLASS}$ [^{0}C]	$T_{pyrometer\ 2\ SIRIUS}$ [^{0}C]
1	Pyrometer 1 = 0 Pyrometer 2 = 1	700	695
2	Pyrometer 1 = 1 Pyrometer 2 = 2	691	682
3	Pyrometer 1 = 2 Pyrometer 2 = 3	684	677
4	Pyrometer 1 = 3 Pyrometer 2 = 4	678	670
5	Pyrometer 1 = 4 Pyrometer 2 = 5	668	661
6	Pyrometer 1 = 5 Pyrometer 2 = 6	658	657
7	Pyrometer 1 = 6 Pyrometer 2 = 7	650	644
8	Pyrometer 1 = 7 Pyrometer 2 = 8	642	631
9	Pyrometer 1 = 8 Pyrometer 2 = 9	632	624
10	Pyrometer 1 = 9 Pyrometer 2 = 10	618	611

The second stage of the research has consisted in the utilization of specific procedures of the STATISTICA software. It have been generated multiple plots using the series of the temperature presented in table 2. The graphs are presented in figure 5 as follow and represent the evolution of the temperatures depending to the distance from the centre of the sample to the edge:

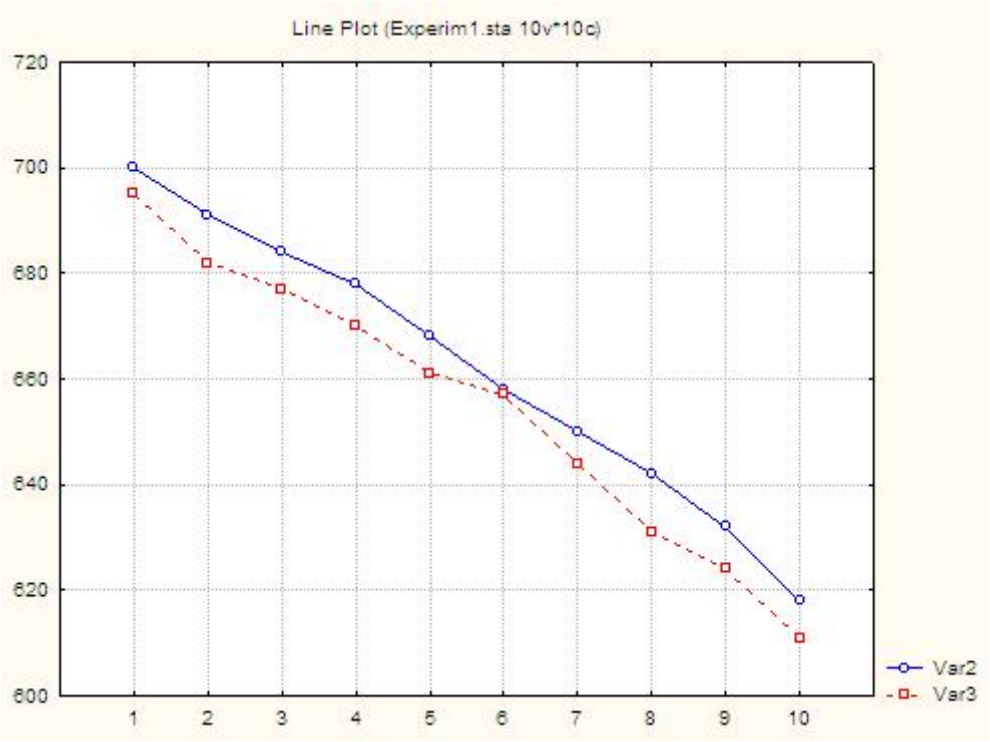


Fig. 5. Evolution of the thermal field inside the materials recorded by the pyrometers

In this graph the series „**Var2**" represent the temperature evolution recorded by the CT Glass pyrometer and the series „**Var3**" represent the temperature evolution recorded by the SIRIUS pyrometer.

In table 3 are presented the temperatures recorded according to injected power to obtain the temperature up to 700^0 C.

Table 3 The electromagnetic power injected in sample

No.	Injected Power [W]	Temperature in centre of the sample [° C]
1	0	0
2	200	347
3	250	425
4	300	700

In figure 6 are presented the values obtained using the theoretical model and the experimental results for a comparative analysis regarding to the evolution of the thermal field. The series presented are: "**Var2**" – the temperatures recorded in the centre of sample until de temperature become 700^0 C and "**Var3**" – the temperature evaluated using theoretical model.

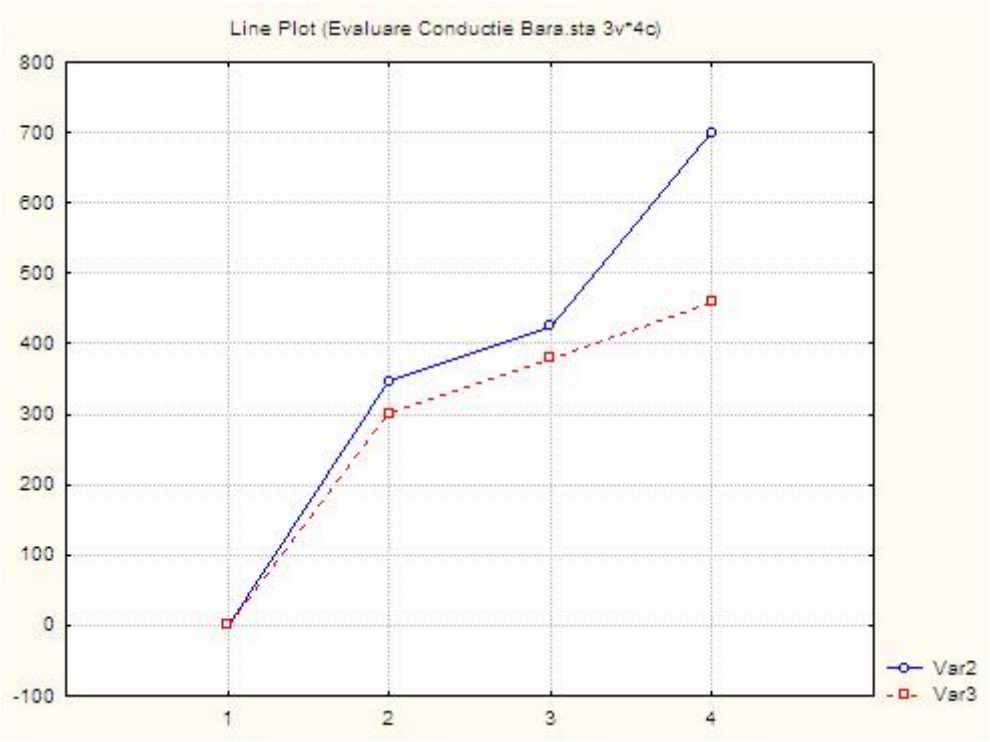


Fig. 6 The comparative analysis between the theoretical model and experimental procedure

5. CONCLUSIONS

- The theoretical math model maintain the temperature evolution tendencies until 400^0 C when the experiments have leaded to a suddenly increase of the temperature because the level of the absorbance of the microwave is changing and the ceramics will became more absorbent which will lead to a superior volume heating
- In the case of measurement of the temperatures inside the material using the two pyrometers it is showed the volume thermal phenomena by the temperature levels, thus the measured temperature using CT GLASS pyrometer is bigger than the temperature measured with SIRIUS pyrometer because the microwave heating is a volume heating from inside the material to the edge.
- In the case of the heating using microwave of the ceramics materials it can be observed o suddenly cool of the samples which have been heated this fact being a disadvantage of the heating process compare with the classical heating where the thermal crashes of the oven with electrical resistance is bigger than the microwave oven

REFERENCES

1. Moşanu A. – Theoretical and experimental contributions regarding to drying process of the cherry using microwave, PhD thesis, Chisinau, Moldova

2. Savu S.V., N. Gherasim, A. Filipciuc, C. Paraschiv, C. Mitran – Microwaves – thermal source for welding and ecological destroy of the medical waste, International conference Innovative technologies for joining advanced materials - tima08 June, 12-13, 2008, Timişoara, Romania.

3. Mangra G.I., Savu S.V., I.D. Savu - Inductive sensor with sintered magnetic core to evaluate the performances of the table tennis players, The 4th Int. Conf. on PM, p.93, ISBN 978 – 973 – 53 – 0097 – 5.

4. W.R. Tinga – Rapid high temperature measurement of microwave dielectric properties, Mat.Res.Soc.Proceedings.

5. Savu, S., Birdeanu, V., Dehelean, D., Savu, I.D., "Development of a nanostructured sensor for the laser-arc welding process", Welding in the World, 2007, vol. 51, SPI, pag. 75-82, UK (ISSN 0043-2288).

6. Savu, I.D., Savu, S., "Flow rate nanosensor for shielding gas welding systems", Proceedings of the 1st South-East European Welding Congress, 24-26 May 2006, Timisoara, Romania (ISBN 978-973-8359-42-0)