THE OPTIMIZATION OF THE PROCESSING OF DIELECTRIC MATERIALS IN A MICROWAVE FIELD

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Abstract*— The paper contains results obtained in the domain of the processing of the dielectric materials a microwave field. It has a character of applicative research, the results obtained being of practical use, with the main purpose to optimize the functioning of some heating devices in a microwave

***Keywords:* Electromagnetic field, optimization, microwaves, dielectrics**

I. INTRODUCTION

The heating of a dielectric can be due also to some effects of direct conduction, because of, for example, the redistribution on small conduction areas of the electric loads under the influence of the electric field. The last case is more frequent for the heterogeneous materials (mixtures) [1].

Comparatively to the classical heating processes, whose disadvantages are due to the no uniformity of the heating and the big duration in time which is necessary for the reaching of a certain temperature, microwave heating creates in the material reverse thermal gradients, heating developing in the material from its interior to the exterior.

This effect of heating of the dielectric material is due on the one hand to the polarization of the particles loaded in the material by the high frequency electric field, and on the other hand to the Joule effect, due to the conduction of the free loads under the action of the electric field [2].

The electric polarization is a phenomenon at molecular level determined by the different positioning of the centres of the positive and negative electric load of the molecule, thus realizing an electric dipole characterized by an electric moment.

A characteristic of the dielectric materials is the capacity to store electric energy.

The polarization of orientation and that of no homogeneity, together with the effect of the electric conduction are considered dominant mechanisms of the dielectric heating in the frequency band of the microwaves [3].

The polarization of a dielectric material can be permanent $\mathbf{P_p}$, or temporary $\mathbf{P_t}$, the temporary polarization can be induced by the electric field.

Because of the phenomenon of electric polarization, the electric field in the bodies cannot be characterized only with the help of the measure **E** and so we define the electric induction, **D**, a physical measure which depends on the electric flux produced by the electric loads and polarizations:

$$\mathbf{D} = \varepsilon_0 \mathbf{E} + \mathbf{P_t}(E) + \mathbf{P_p} \qquad (1)$$

The relation (1), is a general law of state of the electromagnetic field, valid in each point in the field and at each moment. The temporary polarization characterizes the dielectric materials and depending on the dependence between **E** and $\mathbf{P_t}$, these can be divided into isotropic and no isotropic dielectric materials, linear or nonlinear, with or without histerezis [3], [4].

II. THE PROPAGATION OF THE ELECTROMAGNETIC FIELD IN MICROWAVE SYSTEMS

An electromagnetic system functions at resonance if in a harmonious regime the reactive power received by the system is null.

The systems with resonant microwaves are part of the category of devices used in the heating of the dielectric materials in a microwave field [2].

These are enclosures with metalic walls, conductors, feeded through one or more wave guides.

The sizes of the microwave systems are large in comparison to the wave guide we used. The number of modes that can appear in comparison with the wave length depends generally on the volume of the system and the working frequency.

In the practical realization of the microwave systems there appear problems regarding the choice of the form Îand of the sizes, so that the heating is uniform, fast and not destroy the qualities of the processed material.

There are cases in which in the cavity we introduce auxiliary devices able to perturb the field, and, when it is possible, the body exposed to heating can start moving.

At resonance, the behaviour of a system is purely resistive, from the point of view of the alimentation source there takes place an exact compensation of the electric energy with the magnetic one in the interior of the system, and the contribution of active power supplied by the source is compensated by the consumption of active power in the dissipative elements of the system. At different resonance frequencies, over the resistive behaviour we add a reactive behaviour determined by the lack of balance between the average electric energy and the average magnetic energy in the system, in the oscilating process maintained by the source.

Generally, the study of the microwave systems is approached in the hypothesis of the absence of the losses on the boundary, admiting that the walls are made of a material „perfect E" type. If there is nevertheless some losses in the conductive walls, these will be small enough, in order not to affect significantly the distribution of the electromagnetic field.

III. THE TRANSFER PHENOMENON OF THE ELECTROMAGNETIC FIELD

The drying in a microwave field of the dielectric materials offers the possibility of the growth of the evaporation speed and the optimization of the entire drying process. The energy of the microwaves is absorbed in the volume of the solid body and gives birth to a heat source in the whole material. The existence of such a volumetric heat source allows the transfer of energy in the body of the solid and modifies the phisical characteristics of the drying.

The coupling of the electromagnetic field with the thermal one and the mass problems implies the knowledge of the dependence of the properties of the dielectric material on temperature and moisture [4], [5].

The most difficult aspect regarding the transfer phenomenon of the electromagnetic field is represented by the fact that the electromagnetic field, thermal field and mass problems are coupled between them.

So, having the effective values of the intensity of the electric field obtained for an initial value of the permittivity, we determine the volume density of the losses with the relation:

$$p = \omega \cdot \varepsilon' \cdot E_{eff}^2 \cdot tg\delta \qquad (2)$$

where ε' (the dielectric constant) and tgδ (the tangent of the angle of losses), depend on the moisutre (maybe also on the temperature).

By integrating the volume power of the dielectric material considered, we obtain the active power and the average power, on basis of the relaions:

$$P_{act} = \int_{\Omega} \omega\, \varepsilon_0\, \varepsilon''\, E^2 dv \qquad (3)$$

$$P_{med} = \frac{P_{act}}{V} \qquad (4)$$

We determine the deviation of the power form the average value and the relative deviation. These measurements describe the uniform or no uniform distribution of the losses in the dielectric.

$$Ab.\,medie = \frac{1}{V}\int_{\Omega} \left| \omega\, \varepsilon_0\, \varepsilon'' E^2 - P_{med} \right| dv \qquad (5)$$

$$Ab.rel = \frac{Ab.\,medie}{\mathbf{P_{med}}} \qquad (6)$$

The equation system obtained of the spatial division by the method of the finite differences, at each time step, is solved by iterative Gauss-Seidel methods. It is the most efficient method of solving taking into account that in the case of the thermal diffusion the matrix of the system is strictly diagonal dominant and contains only 7 no null elements in line.

IV. NUMERICAL RESULTS

If in the case of the radio-frequency applicators we can approximate a regime of the electromagnetic field of electric type, in the microwaves applicators we take into account the non stationary regime of the electromagnetic field.

Because of this, the state of the distribution of the field in the action space of the microwave applicators leads to the elaboration of more toilsome mathematical methods [5].

The considered applicator has the geometrical shape of the dielectric to be processed, it is an applicator with a stationary electromagnetic field (figure 1.). There will be reflections towards the metallic walls and the points of maximum and minimum of the electric and magnetic fields will be stationary, that is they will keep a fixed position towards the reference system of the applicator. As a consequence, we tried to obtain a profile of the electromagnetic field as uniform as possible on the surface of the processed dielectrics, which determines a very uniform drying of these dielectrics.

If in the interior of the applicator we introduce more dielectrics having the same moisture, the same dielectric constants, the placing of the wave guide and implicitly of the microwave generator to be made so that the electromagnetic field is in a parallel plane with the dielectric. In the case when the dielectrics are superposed, the electromagnetic field is recommended to be in a perpendicular plane with the dielectrics.

In figure 2 it is shown the distribution of the electric field in complex measurements on the surface of the dielectrics, in the case when the electromagnetic wave is placed in a plane parallel with the dielectrics.

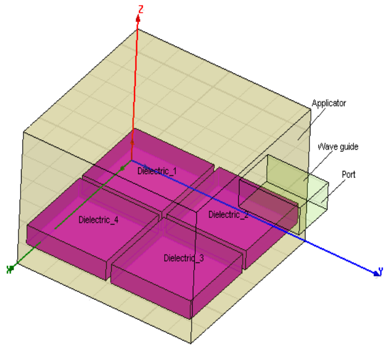

Fig 1. The geometry of the applicator

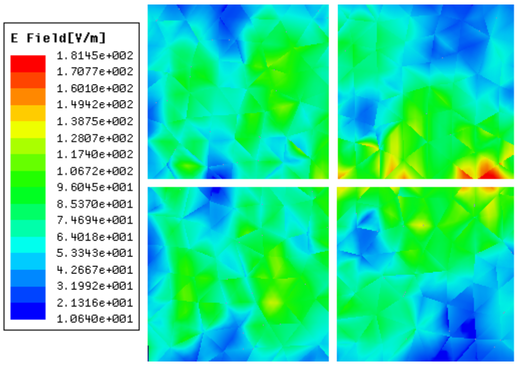

Fig. 2. The distribution of the electric field in complex measurements on the surface of the dielectrics, the electromagnetic wave is placed in a plane parallel with the dielectrics

The analysis of the electromagnetic field offers a founding of the division network with tetrahedral elements, with self refinement in the areas with big variations of permittivity.
This analysis is efficient, but it supposes the exact knowledge of the dielectric and thermal properties of the material that is to be processed, as well as the dependence of these properties on the temperature.
In fig. 3., 4 we present the distribution of the electric field in complex measurements on the surface of the dielectrics, in the case in which the electromagnetic wave is placed in a perpendicular plan on the surface of the dielectric, the dielectrics being superposed.

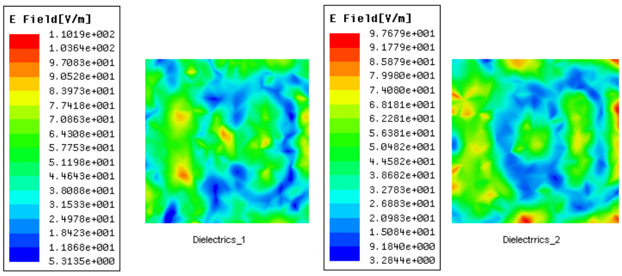

Fig.3. The distribution of the electric field in complex measurements on the surface of the dielectrics 1 and 2

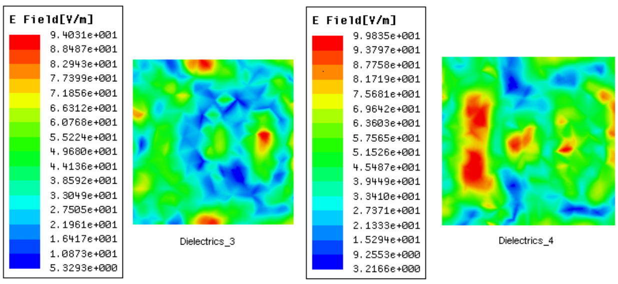

Fig.4. The distribution of the electric field in complex measurements on the surface of the dielectrics 3 and 4

Because the majority of the materials have dielectric and thermal properties which depend on temperature, we took into account the coupling between the electric field and the thermal one, meaning that once we changed the temperature, the dielectric properties of the heated material also change and thus the distribution of the electric fiend in its interior changes.

III. CONCLUSIONS

The paper shows an analysis of the influence of the electromagnetic field on dielectrics placed in the interior of a microwave applicator.
This analysis is efficient, but implies the exat knowledge of the dielectric and thermal properties of the material which is to be processed, as well as the dependence of these properties on temperature.
The main problem which appears is represented by the homogeneity of the field and implicitly of the temperature in the material.

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