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A STUDY OF ELECTROMAGNETIC PROPERTIES OF FIBER FABRIC BASED FILLED EPOXY COMPOSITES

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ABSTRACT

Electric and magnetic properties of laminate carbon fiber fabric based epoxy composites are investigated through experimental techniques. Various concentrations of powder fillers were used in order to change the basic properties of standard composite. Also effects of an electric or a magnetic external field over the mentioned properties are investigated. Characterizing the reaction of the sample to an electromagnetic wave the electric capacitance and the electric inductance of samples are investigated both across the reinforcement and at the surfaces of samples.

KEYWORDS: Laminate Composite, Ferrite, CNT, Electromagnetic Properties, Resonance Frequency.

1. Introduction

Assuming that a composite material is a complex structure it is obvious that it is hard to describe all its properties in terms of its parts properties. The electromagnetic properties of the composite depend not only on the electromagnetic properties of the components but on the quality and nature of the interface between the components and its electromagnetic properties [1]. There are many researches about the interdependencies between components and there are also many purposed models which describe the macroscopic electromagnetic properties of composites in terms of constitutes' properties. A new field of development was opened regarding the controlled electromagnetic properties. One question is, for example, if it is possible that a composite material can be, at the same time, a metamaterial [2]. Powders are used as fillers in order to obtain bi-components composites. There is no structural order in such a filled composite, the most important aim being the uniform distribution of particles in matrix. The powders can be dielectric as talc, clay or ferrites, can be magnetic active as ferrite, can be electric active as CNT or carbon nano-fibers. All these powders have effects over the electromagnetic properties of the composite [3].

There exist many models regarding the mathematic description of electromagnetic properties of the bi-component composites [4], [5]. Also there are studies regarding the bounds of models [6].

Obviously the electromagnetic properties of the filled polymer composite are depending on the arrangement of the filler's particles in the polymer structure. If there is no structural order then there is no anisotropy of electromagnetic properties. Anisotropy is present if the filler's particles are arranged in polymer's structure [7], [8], [9].

The design problem of a composite with given electromagnetic properties is of high complexity [10]. Taking into account that not only the electromagnetic properties are important but also the mechanical and thermal properties the problem becomes almost impossible. The aim of this research is to analyze the electromagnetic effects of the powders presence in the polymeric matrix of a composite.

2. Samples

Samples used for this study were described already in the first part of this research [11]. There are two types of samples, one filled with magnetic active powder (ferrites) the other one filled with electric active powder (CNT).

3. Measurements

Measurements were performed in order to determine the electric capacitance and the electric impedance both across the reinforcement and at the surface of the plates.

For these measurements it had been used an experimental setup described by [12]. This arrangement is made in order to determine the electric capacitance and, subsequently the electric permittivity. The method is based on the use of a measuring cell (three electrodes) and an apparatus able to measure electric capacitance and electric inductance. The measuring cell is also described in [11]. Using a *RLC-meter* it is possible to record also the quality factor and the dielectric loss. With those we have: $\varepsilon = \frac{C_V d}{S}$ where C_V is the read value of capacitance, $S = \pi r^2$ and d is the sample's thickness (all the dimensions are according the I.S.). Also the L_V value of electric inductance was recorded. Based on the observation that the standard method allows the determination of surface resistivity as it was recorded, also, C_S and L_S characterizing from the electromagnetic point of view the surface of the sample [13]. All the values of above mentioned parameters are results of an average of over 20 measured values. It is necessary to mention that electric capacitance and the electric inductance are for a cylinder with sample's thickness as height and a circular disk of r radius as base, L_S and C_S correspond to a circular sector between r_1 and r_2 [11]. It was also tested a method for magnetic permeability determination based on a theoretical application [14]. Unfortunately the method's efficiency is restricted to low frequencies of measurement.

4. Results

In the last period there are more and more interests in tailoring the composites in order to satisfy various electromagnetic requirements (shielding, electromagnetic response to electromagnetic waves action). In the next section we present the results of electric permittivity measurements [15].

It is expected a decrease of electric permittivity of CNT filled epoxy with the concentration of CNT because they have high electric conductance. At macroscopic level it is present in a decrease of electric capacitance, C_V [16]. Filling the epoxy with ferrites it is expected that L_V will increase. The samples used for this study are not only of filled polymer but also they are reinforced with parallel sheets of carbon fiber fabric and the presence of reinforcement has its effects on measured C_V and L_V. It can be said that C_V and L_V are characterizing a four component composite [11] while C_S and L_S are characterizing a bi-component composite (filled epoxy). Because their electric or magnetic sensitivity it is expected that values of C_V, L_V, C_S, L_S to be dependent on external fields applied during the formation of samples. Figure 1 present the variations of electric permittivity, in F/m, of the carbon fiber fabric based CNT filled epoxy matrix laminate composites and its variation with external electric field and the figure 2 the variations of the electric permittivity, in F/m, of the same structure with ferrite filled epoxy.

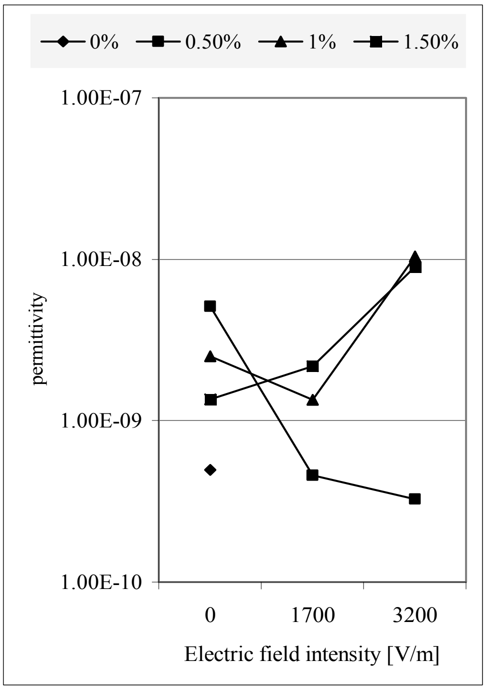

Fig. 1. *Electric permittivity of samples CNT filled epoxy in external electric field.*

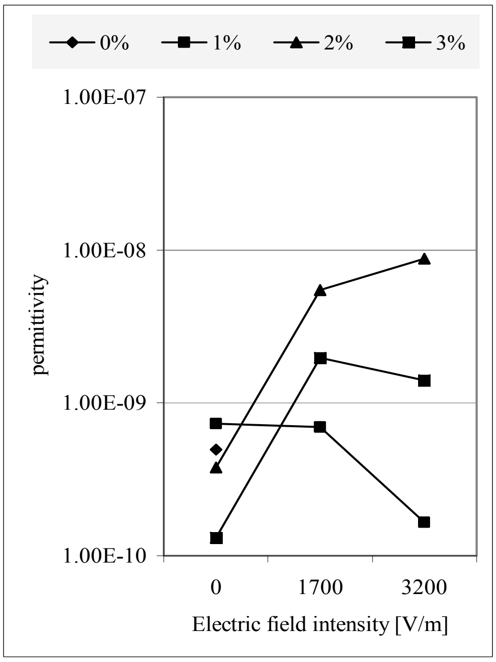

Fig. 2. *Electric permittivity of samples Ferrite filled epoxy in external electric field.*

The figure 3 present the variations of electric permittivity, in F/m, of the carbon fiber fabric based CNT filled epoxy matrix laminate composites and its variation with external magnetic field and the figure 4 the electric permittivity, in F/m, of the same structure with ferrite filled epoxy.

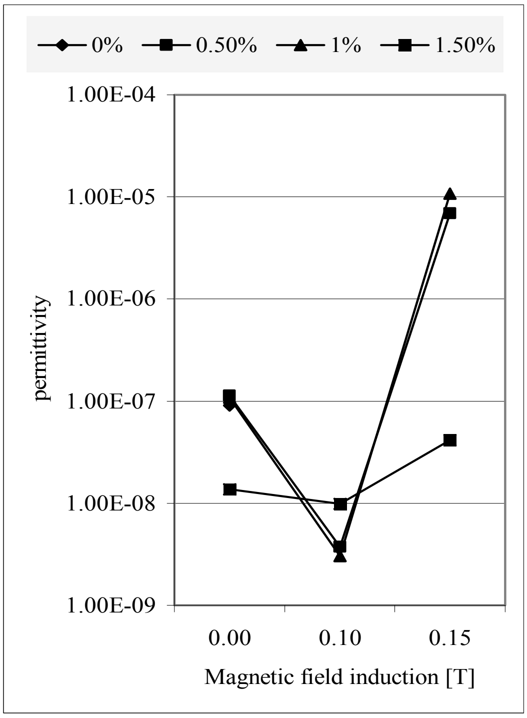

Fig. 3. *Electric permittivity of samples CNT filled epoxy in external magnetic field.*

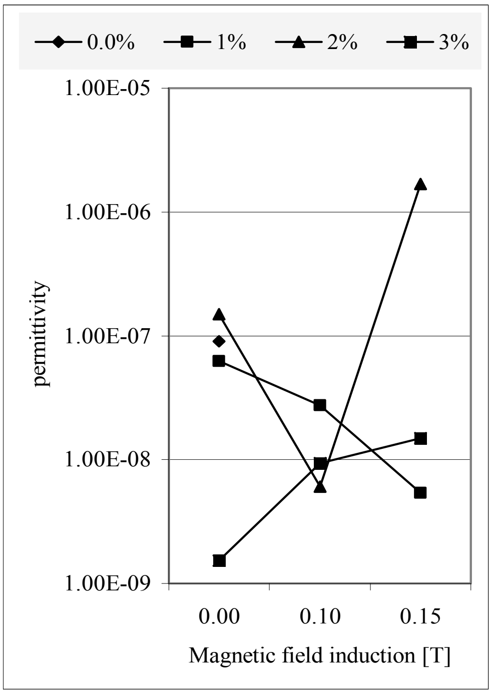

Fig. 4. *Electric permittivity of samples Ferrite filled epoxy in external magnetic field.*

The last aspect we want to emphasis is about the resonance frequency of the composite. This parameter is hard to model even for simple composites such as random distributed fiber composites or powder filled composites [17], [18]. There is a model (extremely simple to use) the mixed rule. In this section we will present calculated resonance frequencies based on L_V and C_V measurement through the cell method. The frequency, in rad/s is given by the simple relation: $f_0 = 1/\sqrt{LC}$.

Perhaps, the best way to characterize the samples from the electromagnetic point of view is to show the electric permittivity and the magnetic permeability of each sample. Figure 5 presents the resonance frequencies for CNT filled epoxy matrix laminate with 13 sheets of reinforcement in electric field. It can be noticed that there is a strong influence of the external electric field over the resonance frequency. This may be explained through the filler's alignment. In our opinion the triple point in the right part of diagram is very important because it can be used as starting point for a concentration-electric field equivalence in order to optimize the forming of such composites. From the future experiences point of view we also present the resonance frequencies for ferrite filled epoxy matrix composites. Figure 6 presents the resonance frequencies for Ferrite filled epoxy matrix laminate with 13 sheets of reinforcement in electric field.

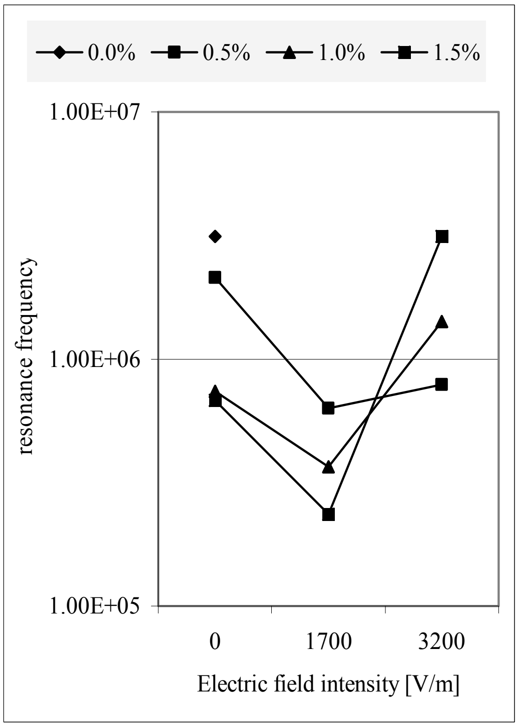

Fig. 5. *Resonance frequencies of the CNT filled epoxy samples formed in external electric field.*

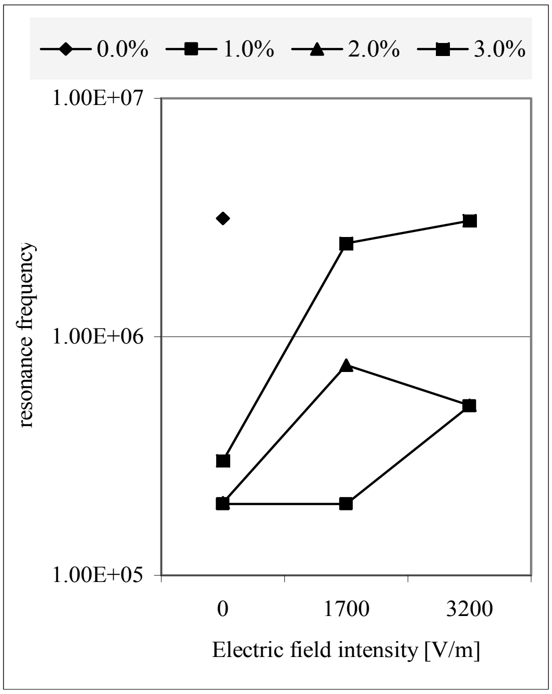

__Fig. 6.__ Resonance frequencies of the Ferrite filled epoxy samples formed in external electric field.

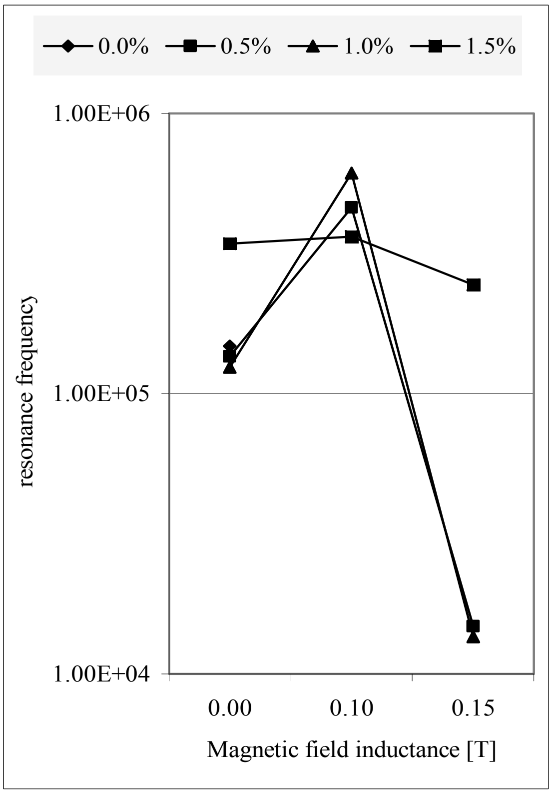

__Fig. 7.__ Resonance frequencies of the CNT filled epoxy samples formed in external magnetic field.

Figure 7 - the resonance frequencies for CNT filled epoxy matrix laminate with 15 sheets of reinforcement in magnetic field and the figure 8 the resonance frequencies for Ferrite filled epoxy matrix laminate with 15 sheets of reinforcement in magnetic field.

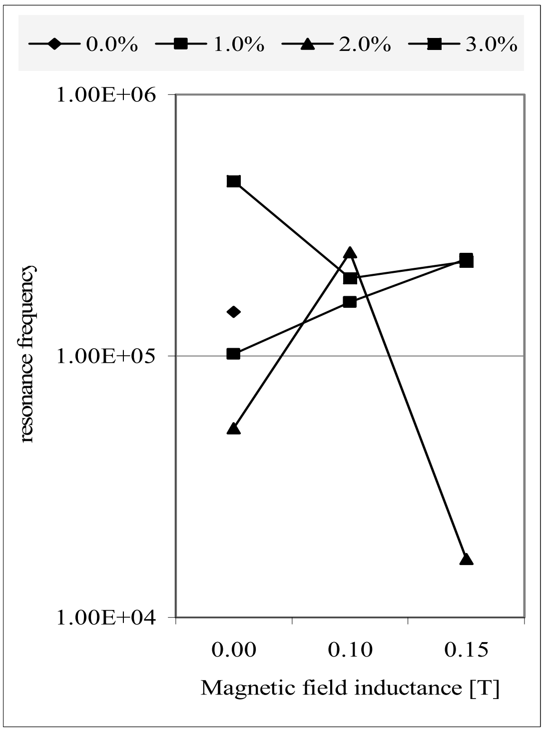

__Fig. 8.__ Resonance frequencies of the Ferrite filled epoxy samples formed in external magnetic field.

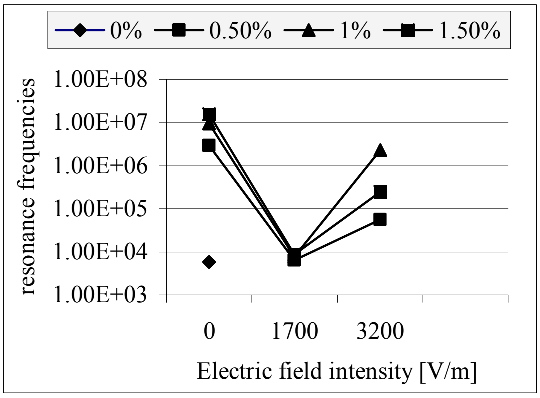

__Fig. 9.__ Resonance frequencies of the CNT filled epoxy samples formed in external electric field – surface.

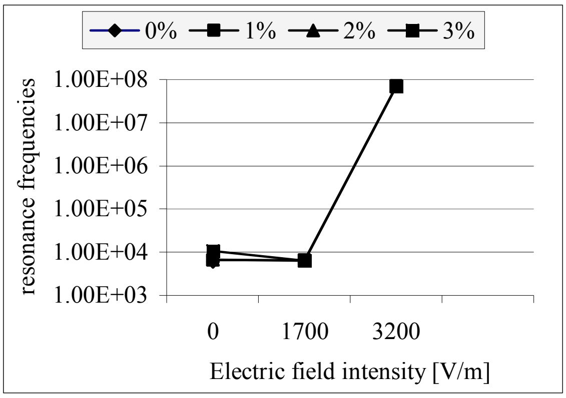

Fig. 10. *Resonance frequencies of the Ferrite filled epoxy samples formed in external electric field – surface.*

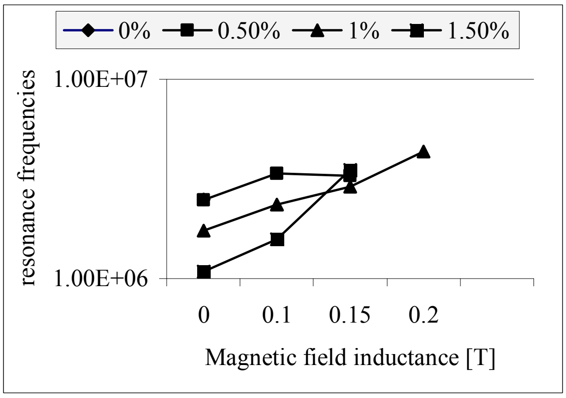

Fig. 11. *Resonance frequencies of the CNT filled epoxy samples formed in external magnetic field – surface.*

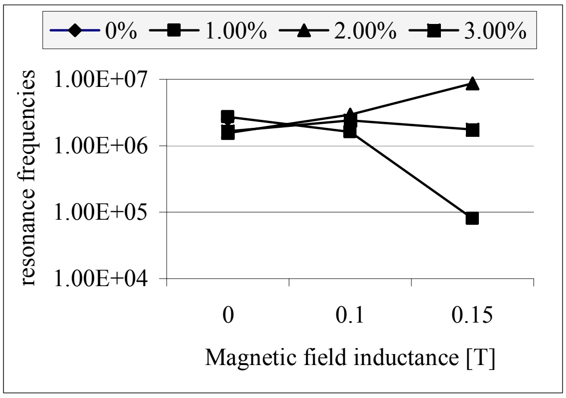

Fig. 12. *Resonance frequencies of the Ferrite filled epoxy samples formed in external magnetic field – surface.*

Figures 9, 10, 11 and 12 are respectively corresponding to figures 5, 6, 7, and 8 but show the resonance frequencies for the surfaces of the samples.

5. Conclusions

The above presented results allow the consideration that it is possible to form a composite based on a certain geometry of reinforcement (fiber fabric) using various types of filled polymers. It is clear that presented results are just a part of an exhaustive characterization of samples. Mechanical, thermal and thermomechanical analysis are necessary.

Another aspect to be taken into account is the fact that because of the fillers and of the reinforcement such a composite material is frequency sensitive *i.e.* the electric and electromagnetic properties depend on the frequency of measuring signal. More, it is necessary to determine the above parameters through other methods, including electromagnetic waves based methods.

The study of mechanical and thermal properties will allow us to make the right decision about the best reinforcement, best geometry of the reinforcement, best fillers' concentrations for a given application. Based on our results we intend to start verifying some models regarding electric and electromagnetic properties of complex composites.

It is possible to design the electromagnetic properties of reinforced composites by using filled polymers as matrix. This design is useful regarding the response of the material under the action of a certain electromagnetic wave. This could be the starting point of a study regarding multi-component composites as metamaterials.

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