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ELECTRIC AND ELECTROMAGNETIC PROPERTIES OF FIBER FABRIC BASED FILLED EPOXY COMPOSITES

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ABSTRACT

Electric and magnetic properties of laminate 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. Two types of fiber fabric were used in order to evaluate the effect of reinforcement. Various types of filled epoxy were also used in order to identify the effects

KEYWORDS: Laminate Composite, Ferrite, CNT, Electric Properties, Electromagnetic properties.

1. Introduction

It is known that properties of a composite are depending on properties of its parts. There are many models purposed for mathematical description of those properties but frequently they are designed for two components composites [1], [2], [3]. It is not the aim of this work to establish a mathematical model but, at least, it is possible to qualitatively measure the effects of a reinforcement or another, the effects of a filler or another.

It is the goal of this study to identify the effects of reinforcement type and of the matrix type. It was one of the problems that the epoxy resin is not adherent to the carbon fiber so the composite’s integrity is affected. One solution was to prepare the carbon fiber fabric by deposing a thin film of PNB rubber [4]. Another solution is to use a mixed aramide-carbon fabric which presents the advantage of lower price and because of kevlar’s presence the mechanical properties are improved [5], [6].

Kevlar fibers are dielectric while carbon fibers have high electric conductivity so the mixed fabric is actually a superposition of two nets. In such conditions the composite’s properties have to be effect of two behaviors. Nowadays the bi- component composites are mostly studied especially the filled polymer composites [7]. The cited paper is an excellent review of actual orientations and results in the domain of filled polymer composites and emphasizes the importance of filler dimensions and shapes bringing in attention the importance of interface.

The design of a composite is a very difficult task if just mechanical properties are emphasized [8], [9], [10]. When the electromagnetic or thermal properties are taken into account the problem is practically unsolvable. It is the aim of this work to empirically determine electric and electromagnetic parameters which characterize the composite.

One answer seek in this work is about if it is possible to establish the electromagnetic properties of composites by using various reinforcements and various filled epoxy resin layers at various depths in the composite.

2. Samples

The samples were realized by a technique described in [11]. In order to identify the effects of reinforcement over composite’s electric and electromagnetic properties two types of samples were formed. Both types of samples have reinforcements of 13 sheets of simple type of fiber fabric. The mixed fabric is realized of alternate Kevlar and carbon fibers.

For each type of reinforcement four types of matrix were realized by using filled epoxy resin in various setups. As was described in above mentioned study, the samples were realized through layer-by-layer method. In this case the matrix was realized, each time, by using the same concentration of various fillers (CNT, Ferrite, Talc) but even the filled resin was used in layers. In fact, the samples are named with four characters the first one denoting the type of reinforcement (K for Kevlar-carbon fiber fabric and C for carbon fiber fabric). The other three characters are denoting the epoxy's filler (C for CNT, F for ferrite, T for talc). Assuming the symmetry of reinforcement reported to medial plane there were used, for example, three layers of Ferrite filled epoxy (external layers), three layers of CNT filled epoxy (middle layers) and two of Talc filled epoxy (intermediate layers). So, the structure of the sample from the matrix point of view is 3F-2T-3C-2T-3F and for carbon fiber fabric reinforcement the sample is CFTC. In the C-type samples there are alternate 0 degrees 45 degrees sheets of reinforcements wile in K-type of samples all sheets are placed such as fill and yarn are parallel.

3. Measurements

Measurements were performed in order to determine the electric conductivity across and along reinforcement and at the surface of samples [12]. Also measurements were carried out for electromagnetic properties determination [13]. The experimental arrangements were described in [11].

4. Results

It is expected that alternating the filled epoxy layers used for formatting the composite surface and bulk the electromagnetic properties to be modified.

The across resistivity $\rho_V\,[\Omega m]$ is determined by measuring the electric resistance at low frequency.

The across resistivity is evaluated in orthogonal direction to reinforcement and is depending on the type of reinforcement and on the type of filler. It is expected that small amounts of CNT to improve the electric conductivity. Figure 1 shows the across resistivity and it can be noticed that the two types of reinforcement are leading to almost the same resistivity of composite when CNT is used as filler. Also it can be seen the effect of carbon fiber reinforcement over the across conductivity.

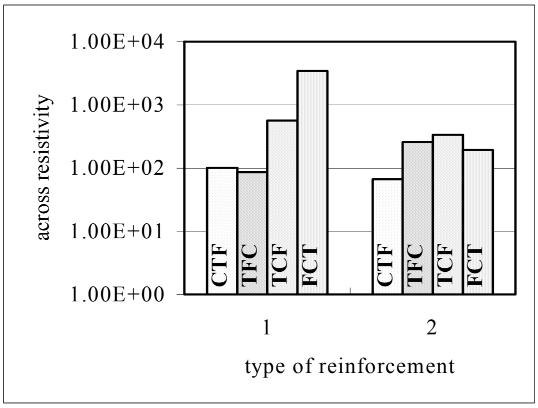

***Figure 1**. The across resistivity of samples 1. K-Type; 2. C-Type.*

Figure 2 shows the surface resistivity $\rho_S\,[\Omega]$ of the samples evaluated through measurement of a circular sector at the surface of sample. The surface resistivity has to depend on the type of filler and can be noticed that the smallest value is reached when CNT is used as filler.

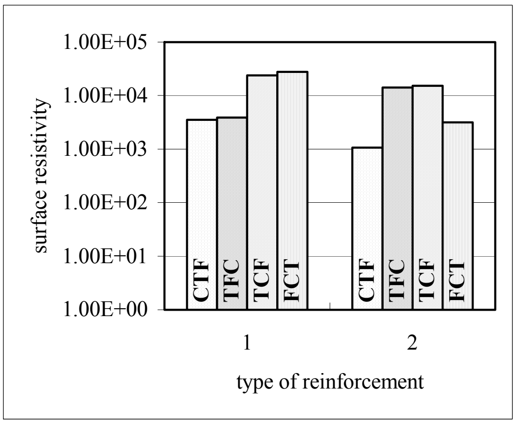

***Figure 2.** The surface resistivity of samples 1 – K – Type; 2 – C – Type.*

Figure 3 represents the along resistivity $\rho_L\,[\Omega m]$ evaluated through the van der Pauw method and is strongly dependent on the reinforcement's type and position. It can be noticed that in the case of carbon fiber fabric all the four values are respectively smaller than the values in the case of kevlar-carbon fiber fabric. An explanation for this situation is not only the presence of carbon fibers but also the geometry of reinforcement. In the case of C-Type samples the anisotropy is reduced.

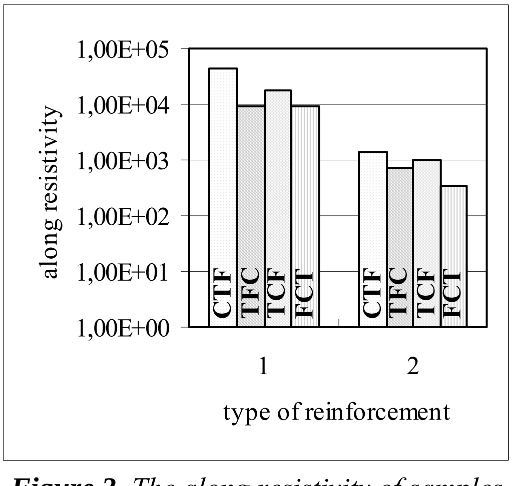

***Figure 3.** The along resistivity of samples 1. K-Type; 2. C-Type.*

The concentration of fillers is also important to final properties of the composite. It is known that relatively high concentrations of CNT are producing an increasing of resistivity [14]. Maybe the optimal solution is to fill the epoxy with a mixture of powders in certain concentrations in order to obtain certain macroscopic electric properties. From this point of view it is necessary to analyze the electric properties through other more sensitive methods. Because the dimensions of the filler’s particles it is expected that electric and electromagnetic properties to be field dependent so all the measurements has to be carried out at more then one frequency. Regarding the electromagnetic properties of a composite there is important to specify the electric permittivity and the magnetic permeability. However measurement of electric permittivity is a much easier task than measuring magnetic permeability.

Figure 4 shows the electric permittivities $\varepsilon[F/m]$ of the samples and it can be seen that the talc transforms the epoxy in a high dielectric. It is also important to notice that the position of resin layers determines the electromagnetic properties.

Another aspect of high interest is the electromagnetic shielding of a material. From this point of view in this study measurements were carried out for electric capacitance and magnetic inductance of the samples.

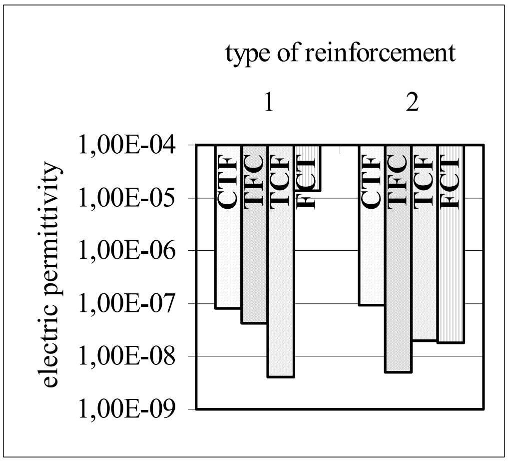

Figure 4. *The electric permittivity of samples 1. K-Type; 2. C-Type.*

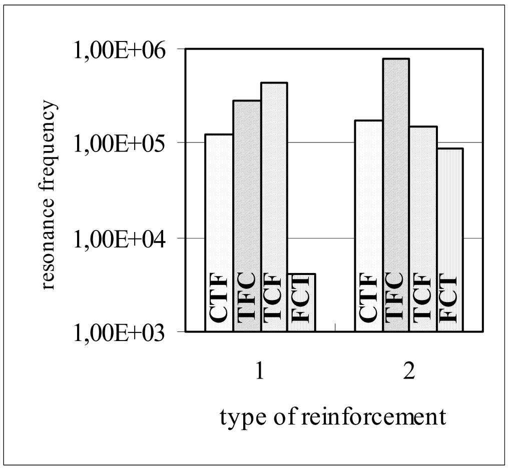

Figure 5. *The resonance frequencies of samples 1. K-Type; 2. C-Type.*

Figure 5 shows the resonance frequencies of the samples. The measurements for bulk capacitance and bulk inductance were performed at low frequency so, there is possible that at high frequency the results to be different because of the field sensitivity of the samples.

5. Conclusions

For special applications seems to be possible to arrange the filled resin such as the external layers of the composite to have high conductivity while the core of it to have strong dielectric or magnetic properties. The resistivities of K-type samples are susceptible to be improved in the case of the same architecture as C-type samples. It seems to be possible a combination of fillers with certain amounts which could ensure optimal electromagnetic properties for the multi-component composite material. There is a great advantage in the case of multi-component composite namely the area of interfaces is increasing if the fillers are nanosized. Mean time in the case of microsized particles’ presence the material fails.

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