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RESEARCH

Tribological and Electrical Properties of Filled Epoxy Reinforced Composites

The main goal of this study is to identify the ways in which it is possible to intervene in order to improve the electromagnetic, thermal, thermo-mechanical and mechanical properties of composite materials. One of the cheapest methods is to fill the polymer with various powders. This study's approach is a trail and error one because the fillers' influences are not very well known despite the multitude of world wide carried out studies. Plates of fabric reinforced ferrite filled epoxy were formed. Electrical conductivity and abrasive behavior were investigated using recommended methods. The focus were on indentifying the influence of ferrite's concentration. Some changes in composites' properties may be noticed both regarding the electrical conductivity and wear resistance.

Keywords: *epoxy, carbon fiber fabric, ferrite, electrical conductivity, wear resistance.*

1. INTRODUCTION

Both for engineers and physicists a new challenge arose in last years: how to improve the electro-magnetic properties of a composite. The necessity of metal replacement in aircraft and spacecraft application requires not only excellent mechanical properties but also good electro-magnetic properties. More, it seems to be possible to obtain composite materials having electro-magnetic properties better than metals ones.

There are many solutions for solving the problem. The most common is to fill the polymer with various powders. An excellent review of this method which emphasizes also the importance of the interface was recently published [1]. Interesting is the fact that usually studies are focused on bi-composites. Obviously the properties of a filled composite are different from ones of a reinforced composite. There are many models describing bi-component's properties but they are complex and limited [2, 3, 4]. The problem of designing a composite material is a complex one because all of mechanical, thermal, electro-magnetic, tribological, wear and chemical properties have to be taken into account [5, 6].

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On one hand, the reinforcement is ensuring good mechanical properties and another hand the filler is ensuring good electromagnetic properties. From this point of view a composite able to replace a metal has to be, a least, a tri-component one.

Many studies demonstrate that the main role in determining the composite's properties is played by the interface fiber-polymer or/and filler's particles-polymer. This is one reason for which, at least, the accent has to be put on designing the interface, at first, and then designing the composite [7, 8, 9].

Electromagnetic and mechanical properties of composites, as manifestations at the external changes, have to be averaged manifestations of the components. This is just a "trail and error" approach viewed as a starting point both for further studies and decision making in forming a composite with certain properties [10]. The aim of this study is to present some empirical results in order to help the manufacturers in decision making of forming a special composite.

2. MATERIALS

Plates of three components composites with a 4 mm thickness and 120 mm x 250 mm as planar dimensions were formed in glass moulds (Figure 1.). As basic matrix for composite was used the bi-component epoxy resin EPIPHEN 4020 and it was used in order to obtain the reference sample. The reinforcement is realized from 15 sheets of carbon fiber fabric with an arrangement of alternate 0 and 45 degrees sheets. The orientation of reinforcement sheets is been given relatively to the sample's edges:

0 degrees means that the yarn and the fill of the fabric are parallel to the length and the width of the sample and 45 degrees means that the yarn and the fill of the fabric are oriented at 45 degrees relatively to the same dimensions of the sample.

The forming of samples were made using a combined method, first a “layer-by-layer” adding of resin imbued sheets of reinforcement. After the mould was closed the excess of resin was extracted through application of a mechanical effort, then the mould was introduced in a rubber bag. The air and other gases from the bag were removed using a small vacuum pump in order to avoid the gas intrusions in the sample.

The dimensions of composite plates were imposed by the necessity to full characterize the material. Electric and dielectric measurements require a large plate of composite while the mechanical tests require standard recommended samples. Regarding the mechanical samples they were cut using a high pressure water jet machine in order to avoid the properties’ changes at the edges. Figure 2. shows a plate from which the mechanical tests samples were cut.

Figure 1. The glass mould

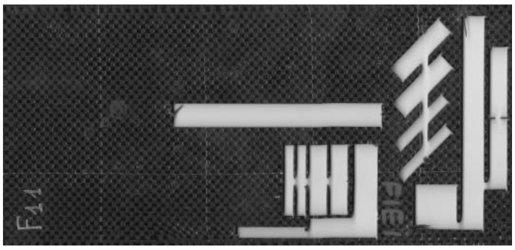

Figure 2. Composite plate

3. MEASUREMENTS

Measurements were performed in order to determine the electric conductivity of each sample, across (perpendicular on) the reinforcement plan, along the reinforcement, and at surface. The evaluation of electrical conductivity is conditioned by the electrical resistivity measurement. The van der Pauw technique (Figure 3.) was used in order to determine the longitudinal resistivity [11] while the cell method [12] was used to measure the across and surface resistivity (Figure 4.).

A pin-on-disk type apparatus was employed for the determination of wear of the filled polymer composites under consideration. A Multi-Specimen Test System from UMT – CETR was adapted to be used to evaluate wear resistance of composite samples [13, 14]. Specimens of 32 mm x 8 mm x 4mm where the friction surface is 8 mm x 4mm and the sheets of reinforcement are parallel to the abrasive disk radius (perpendicular on tangential velocity). Three different loads were used for each type of material and for each load three different speeds were set. Meantime a temperature analysis was made using a ThermoVision A20M camera from Flir Systems. The temperature values were recorded for each load, speed and material combination.

Figure 3. Experimental arrangement for longitudinal conductivity determination. Van der Pauw technique.

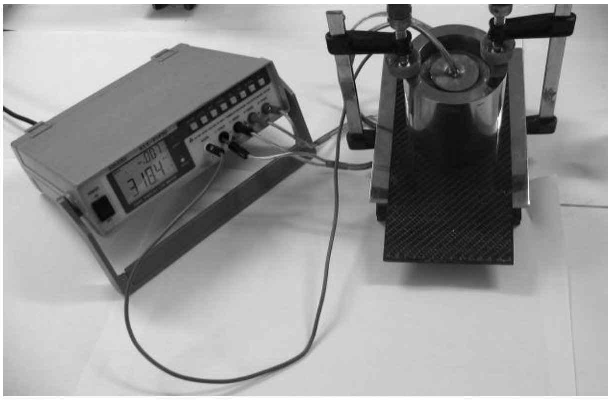

Figure 4. Experimental arrangement for across and surface resistivity measurement. Cell technique.

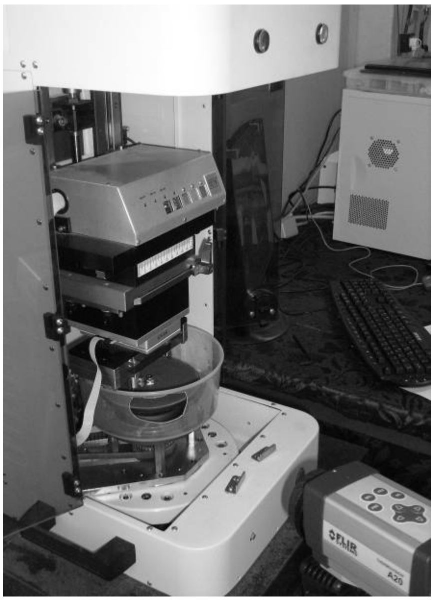

Figure 5. The experimental setup for wear resistance

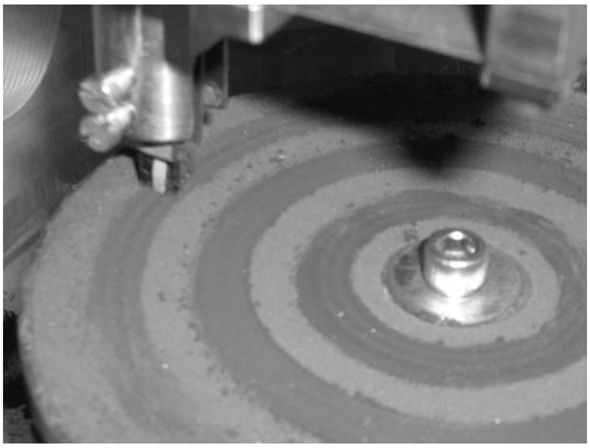

Figure 6. The sample position on the abrasive disk

Figure 5. shows the experimental setup for wear resistance evaluation. Figure 6. shows the wear sample and the three traces corresponding to the three speeds. The rotation frequency was kept at 120 rot/min while the three radius values were 2.0 cm, 3.5 cm and 5.0 cm, corresponding to the 0.252 m/s, 0.439 m/s and 0.628 m/s values of speed. The abrasive disk is made from abrasive paper P 150 and the loads were 1.0 N, 1.5 N and 2.0 N.

4. RESULTS

As expected, in the case of along electrical conductivity – Figure 7., (evaluated in plane of the reinforcement) the results are closed because the main contribution is given by the electrical conductivity of carbon fibers differences are given by the ferrite presence. The across resistivity decrease when ferrite's concentration increases. In the case of surface conductivity the results are influenced by the surface quality (Figures 8 and 9).

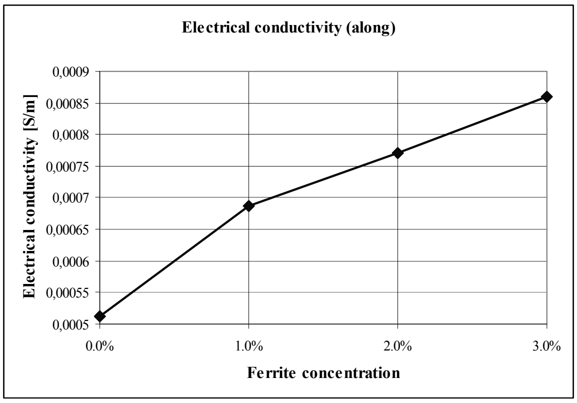

Figure 7. Electrical conductivity evaluated parallel to the reinforcement

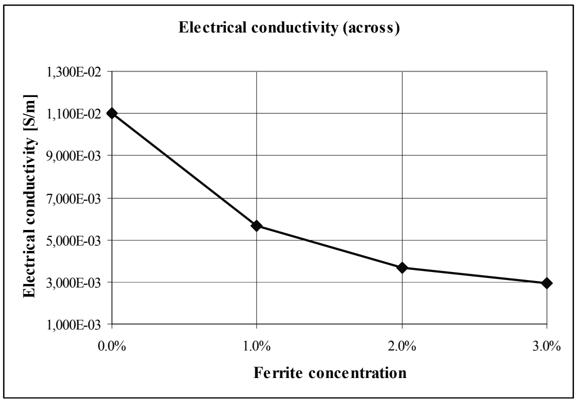

Figure 8. Bulk electrical conductivity (across)

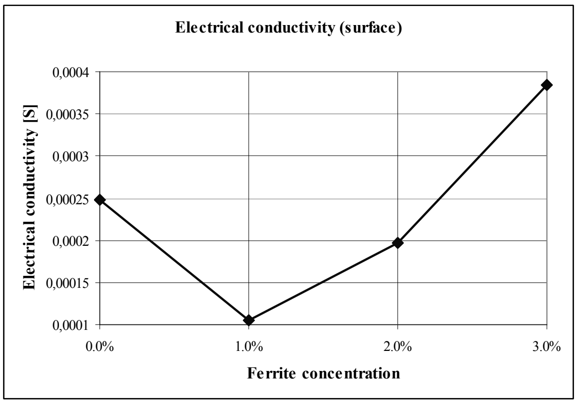

Figure 9. Surface electrical conductivity

The wear resistance is evaluated on the basis of:

$$R_w = \frac{F_n S_d}{\Delta W / \rho} \tag{1}$$

Where: F_n is the normal load [N], S_d is the sliding distance [m], ΔW is the weight loss [kg] and ρ is the composite's density [14]. The wear resistance's dependence on the normal load is showed in Figure 10 – 12. The sliding distances are evaluated on the basis of above mentioned values for rotation frequency and radius. The measurement time was for each test of 180 s.

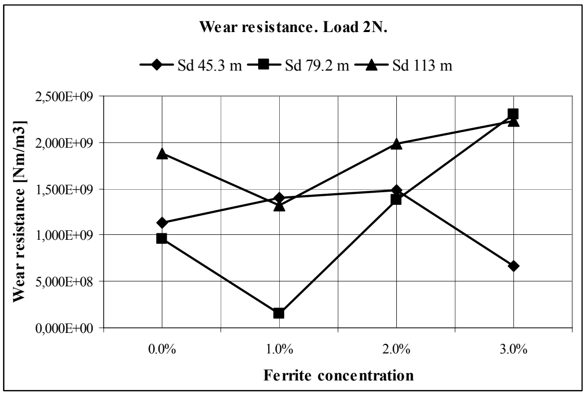

Figure 10. Wear resistance at 2 N normal load

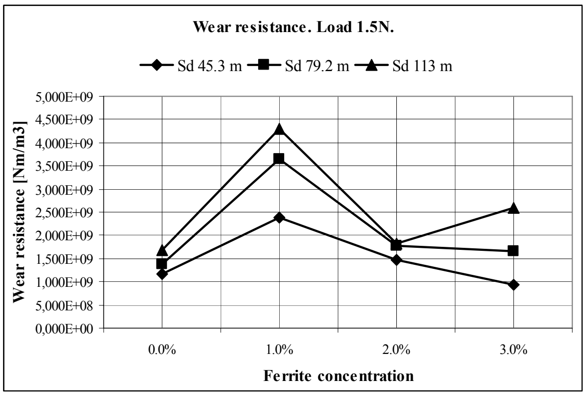

Figure 11. Wear resistance at 1.5 N normal load

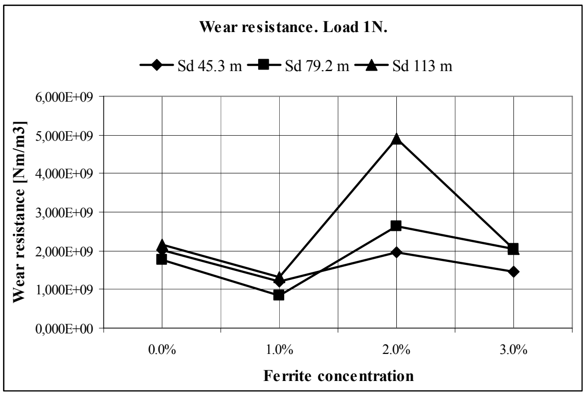

Figure 12. Wear resistance at 1 N normal load

5. CONCLUSION

In the case of studied composites the ferrite is increasing the wear resistance of the material. As it may be noticed when the normal load increases the wear resistance is higher when the ferrite concentration is higher. Also regarding electrical conductivity it seems that high concentrations of ferrite lead to high values of surface conductivity and the electrical conductivity in the reinforcement plane.

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

The study of mechanical and thermal properties will allow manufacturers to make the right decision about the best reinforcement, best geometry of the reinforcement, best fillers' concentration for a given application. Based on these results it is possible to start verifying some models regarding electric and electromagnetic properties of complex composites.

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