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SOME MECHANICAL PROPERTIES OF REINFORCED FILLED EPOXY COMPOSITES

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Abstract: *The multi-component composites could represent the cheapest solution when controllable properties are required. In order to establish the right amount of filler it is necessary to analyze not only the electro-magnetic and mechanical properties but also, the thermal ones. The filler presence in the matrix produces discontinuities at the fibre-matrix interface with consequences regarding mechanical properties. Using a single filler it is possible to improve one or two properties electrical and thermal conductivity for instance and mean time to induce a decrease of other properties as bending strength, shock resistance etc. Using polymer layers with relatively high electrical conductivity as external layers of laminate and magnetic particles filled polymer as core layers.*
Key words: *fibre fabric, epoxy, fillers, stratified composite*

1. INTRODUCTION

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. If the fillers' particles are arranged into the polymer volume is possible to change the electro-magnetic behavior of the obtained composite making this one to act as a meta-material (Caloz & Itoh, 2006, Leskova et al., 2007).

More and more studies regarding the use of fabrics to form composites were developed recently but as in case of fibers the problem of polymer adhesion is very important. Also, in the case of carbon, aramide, and glass fiber the fabrics are highly instable when they are manipulated during the technological processes. Using certain types of fabrics it seems to be possible to obtain laminate-like materials with different properties in different layers (Vasiliev & Morozov 2001). In any case, the mechanical, thermal and physical properties of formed materials depend on quality of interface between components (Yu et al., 2006, Karkkainen et al., 2007).

It is possible to use fiber fabric in such applications with the advantage of filling the polymer with various powders to increase mechanical, thermal or electromagnetic qualities of the composite. This study is about using fiber fabrics in order to form layered composites with filled epoxy matrix and to investigate the influence of reinforcement's architecture on some of the final properties of formed multi-component composites.

Assuming that a composite material is a complex structure it is obvious that is hard to describe all its properties in terms of its parts properties. The properties of the composite depend not only on the properties of the components but on quality and nature of the interface between the components and its properties. There are many studies regarding the influence of certain fillers on the properties of a particulate composite, regarding the influence of the reinforcement on the properties of a fibrous composite etc but generally these studies refer to a class of properties like thermal, or electrical, or electro-magnetic. It is obviously that changing the standard receipt of a composite its properties are modified. For example filling the polymer matrix of a reinforced composite not only the electro-magnetic properties will be affected but also the mechanical properties, due to the way in which the polymeric bonds are changed by the presence of the filler's particles. One question is how long it may be increased the filler's concentration such as basic mechanical properties to remain unchanged (or with negligible modifications).

2. MATERIALS

Two types of fabric were used during this study; first type is simple fabric made of untwisted tows of carbon fibers while the second is a simple fabric made of alternating untwisted tows of carbon and aramide fibers. From the beginning the two fabrics were choose because of the intrinsic properties of fibers (electromagnetic and mechanical in the case of carbon fiber, shock and thermal in the case of aramide fiber). Two problems had to be solved before use them to form reinforced composites: their stability – because during the cutting the tows are slipping one on each other leading to structural defects of fabric with consequences in mechanical properties of the composite; the second problem is about the low epoxy adhesion to the two types of fiber which leads to discontinuities at the interface level with consequences in all the composite's properties.

The fabrics treatment has two phases: a chemical one meant to increase the specific area of fibers and to ensure the matrix adhesion consists in treatment with 50% hypochlorite aqueous solution and then with 20% NaOH aqueous solution; the second phase meant to stabilize the tows consists in covering the fabrics with o thin film of PNB rubber and then with a thin film of epoxy. Both the rubber solution and polymer's components solutions were filled with small amounts of clay and carbon black in order to enlarge the specific area of the fabrics and to improve the electrical behavior of materials.

The matrix of reinforced composites consists of epoxy resin filled with equal amounts of Clay and Talc (5%, weight ratio). The two powders were dispersed in the first component of the epoxy Epiphen system (RE 4020) and then the right amount of second epoxy system's component (DE 4020) was added. The named epoxy system has a 45 minutes gel time so the mixture was mechanically homogenized for 15 minutes before molding.

The forming technique is a layer-by-layer one. Each piece of fabric is imbued with filled pre-polymer and then placed into a mould. After all the reinforcements are placed the mould is closed and gases are extracted using the rubber bag technique. The materials are extracted after 24 hours at room temperature.

For this study ten materials were formed in order to point out the influence of reinforcements on final properties of formed materials. For each formed material the reinforcement consist in eight sheets of fabric but they are different through order and orientation. The reinforcement sheets were cut parallel to yarn and fill of the fabric (0^o) or at 45^o reported to the yarn and fill of the fabric (45^o). The two types of fabrics are denoted as C, for carbon fiber fabric or K for mixed fabric such as each reinforcement's sheet may be described as C(0^o), C(45^o), K(0^o) or K(45^o). The reinforcement's structure of each material is presented in Table 1-2.

	Reinforcement structure A
1	C(0°) C(45°) K(0°) K(45°) K(45°) K(0°) C(45°) C(0°)
2	C(0°) C(45°) C(45°) K(0°) K(45°) K(0°) C(45°) C(0°)
3	C(0°) C(45°) C(0°) K(45°) K(0°) C(45°) K(45 °) C(0°)
4	C(0°) C(45 °) C(45°) C(0°) C(0°) C(45°) C(45 °) C(0°)
5	C(0°) C(45 °) C(45°) C(0°) C(0°) C(45°) C(45 °) C(0°)

Tab. 1. Reinforcement structure

	Reinforcement structure B
1	K(0°) K(45°) C(0°) C(45°) C(45°) C(0°) K(45°) K(0°)
2	K(0°) K(45°) K(45°) C(0°) C(45°) C(0°) K(45°) K(0°)
3	K(0°) K(45°) K(0°) C(45°) C(0°) K(45°) C(45 °) K(0°)
4	K(0°) K(45 °) K(45°) K(0°) K(0°) K(45°) K(45 °) K(0°)
5	K(0°) K(45 °) K(45°) K(0°) K(0°) K(45°) K(45 °) K(0°)

Tab. 2. Reinforcement structure

3. MEASUREMENTS AND RESULTS

Bending standard tests were performed for each material using a M350-5AT testing machine from *Testometric*. For each material samples were extracted using a high pressure water jet machine. Due to the forming technique it is expected that bending properties will be different when the sample is loaded from the first reinforcement sheet and from the last one. As it was mentioned before the gel time of the epoxy system is about 45 minutes, but for molding just 20 to 25 minutes are available. To mold a material 15 minutes are necessary but first reinforcement layer will be imbued with a low viscosity pre-polymer while for the last ones the viscosity will increase leading to poor polymer bonds.

The bending tests were performed both loading the samples from the first molded layer (d) and from the last molded layer (i) and the results are shown in Fig. 1 – 3. Three parameters were evaluated for the formed materials bending strength, bending modulus and inter-laminar shear strength.

It might be noticed that the highest values in the case of A type are reached for the material with carbon fiber fabric while in the case of B type in the same situation the lowest values are reached. An explanation could consist in the fact that in the first material all the interfaces are between carbon fiber and epoxy while for the second material the amount of aramide fiber is the highest leading equal ratios of interfaces.

The inter-laminar share stress at break is evaluated (Gay et al. 2003) in mid-plane of the sample. Generally it might be said that this parameter is evaluated between the fourth and the fifth reinforcement layers and as a consequence the highest value is for carbon fiber fabric reinforcement due to the presence of the same type of interface polymer-fiber (Marur, 2004). It might be imagined that the evaluation take place inside the polymer matrix (the sample mid-plane is immersed in filled polymer) as well as in the alternate reinforced materials which explains the same behavior for these materials.

The lowering of inter-laminar shear stress at break in the case of alternate reinforcement is due to the fact that each time the parameter is evaluated inside a polymer layer between two reinforcement sheets with different orientation (0° and 45°).

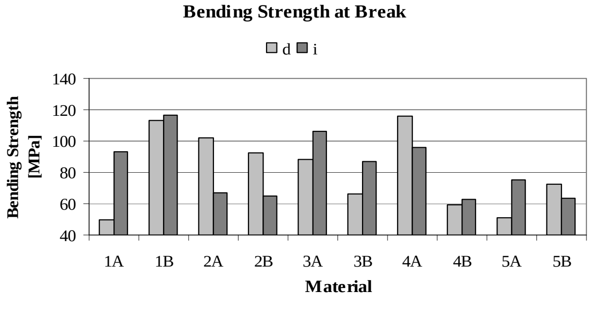

Fig. 1. Bending Strength at Break for stratified composites

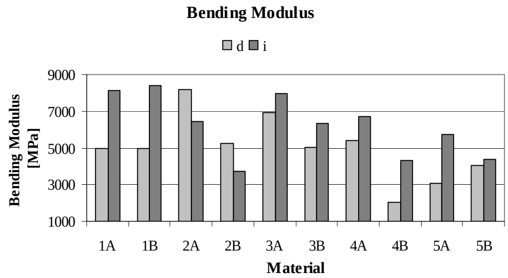

Fig. 2. Bending Modulus for stratified composites

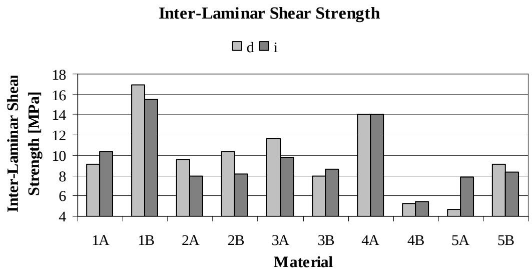

Fig. 3. Inter-Laminar Shear Stress for stratified composites

4. CONCLUSION

The use of fabrics to form stratified composites seems to be the best way to design and control composites properties. For this study just two fillers had been used to change the basic properties of polymer matrix and their amounts were relatively large. For further studies other fillers will be used to change electric or magnetic properties of the formed composites. The forming technique allows obtaining of laminated like composites without inter-laminar bonding problems due to the fact that the polymer chains are not only between laminae but also through them.

5. ACKNOWLEDGEMENTS

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