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SOME PHYSICAL PROPERTIES OF FABRIC LAMINAE

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Abstract: *The fibre fabrics are more and more used to form reinforced composites not only due to their low costs but also due of their properties which allow complicated sinuous surfaces. Even their mechanical properties are little bit reduced form the ones of orthotropic materials their advantages are resides in special physical properties. This study is about electrical characterization laminae with epoxy matrix and plain woven fabric.*
Key words: *fibre fabric, epoxy, thermal properties, electrical conductivity, filers*

1. INTRODUCTION

It is well known that, in the case of reinforced composites, spatially arrangements of fibers lead to better mechanical properties of formed composite materials irrespectively of matrix nature. Because the usual fibers have no lateral filaments they are hardly to be used in order to obtain spatial structures to be immersed into matrix. Using special technologies prepregs may be obtained but their applications are limited. When a reinforced structure might be obtained the use of fabrics is recommended instead of unidirectional reinforced prepregs or instead of randomly distributed fibers (as in case of layer-by-layer method used in car tuning for example).

For several decades researchers have been interested in textile processes for the production of composite reinforcement. These technologies have offered several promises: reduced fabrication costs, 3-D multi-axial reinforcement, and damage tolerance. Despite these advantages, textile composites have not reached the level of implementation of laminated composites. Among the limitations on the application of textile reinforced composites is the lack of adequate modeling capabilities for these materials (Ben Boubaker et al. 2007, Skordos et al. 2007).

More and more studies regarding the use of fabrics to form composites were developed recently (Iannucci, L., Willows, M. L. 2006) 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. In any case, the mechanical, thermal and physical properties of formed materials depend on quality of interface between components (Karkkainen, R. L. *et al.*, 2007, Daniel, I. M. *et al.* 2008)). Lately, in civil engineering, layers of fiber reinforced polymers are deposed on walls in order to diminish the effects of deflagrations, explosive accidents or earthquakes connected with concrete chips. 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.

While the design problem seems to be essential in order to form a high performance composite one may ask more: is it possible to form a material able to give information about its state? Is it possible to control the properties of a composite through alternation of its various layers? Is it possible, finally, to obtain a multifunctional material based on a right design, on a cheap forming technique, on accessible components? This study is about partially answering the above questions.

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 analyzing the electrical conductivity of laminae: 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. That is why the two fabrics were specially prepared before they had been used to form reinforced laminae.

First steps are intended to clean the fiber's surface and to increase its specific surface. After washing with detergent solution and distilled water rinsing, based on its oxidative properties, the fabric was treated with 50% hypochlorite aqueous solution. The last chemical step, after the second rinsing is the treatment with 20% NaOH aqueous solution to remove the residual hypochlorite and to attack fiber surfaces. After rinsing a film of PNB rubber is deposed on the fabric surfaces.

The rubber film has multiple effects; it will stabilize the fabric which has to be cut; it will ensure an elastic interface between fibers and matrix which will allow a smooth loading transfer between the two major components of the composite; based on the presence of Nitrogen atoms both in rubber and in pre-polymer it will ensure a better adhesion of epoxy at the fibers. The PNB rubber was sprayed from 20% solution in usual nitro diluent. The rubber solution was also added with 6% (weight ratio) clay and 6% carbon black in order to increase the specific surface and to change the electric properties of fabrics. As it may be noticed from the SEM images the specific area is highly increased such as it is expected that interface to be of improved quality.

The final step of the fabric preparation consists in deposing a film of clay and carbon black filled epoxy on the fabric. Once again the film was obtained by spraying A and B epoxy's components solutions on the surfaces. The amounts of clay and carbon black were dispersed into the A component and then diluted with above mentioned diluent (20% A solution with 6% clay and 6% carbon black), after diluent vaporization the B component solution (5%) was sprayed on the fabric. There is a difference between the recommended amounts of A and B components of RE 4020-DE 4020 epoxy system allowing, at the end, a porous aspect of the fabric surface.

As it was mentioned before the carbon black was used with

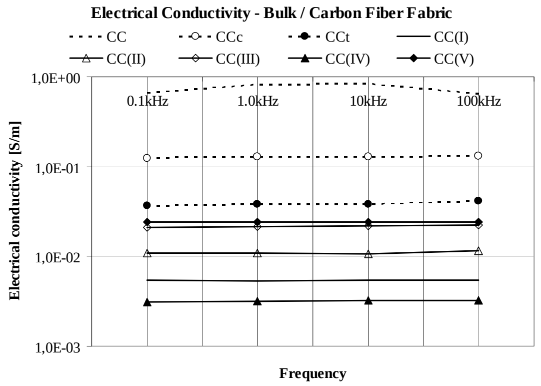

Fig. 1. Bulk electrical conductivity of carbon fiber fabric laminae

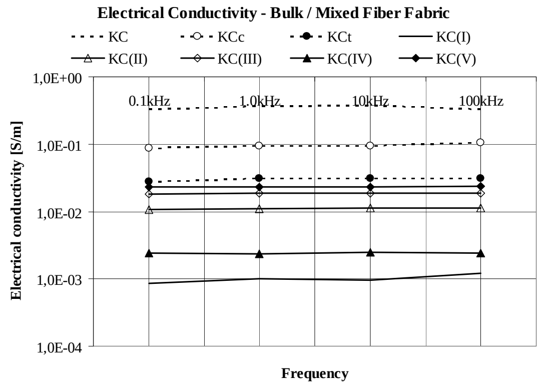

Fig. 2. Bulk electrical conductivity of mixed fiber fabric laminae

two aims: one to enlarge the specific surface of fibers and the other one to control the electric conductivity of fabric layers such as using CNT filled epoxy as matrix to obtain a composite with higher electrical conductivity.

The RE 4020 – DE 4020 epoxy system was used as matrix for the studied materials. During this study many powder fillers were used in order to emphasize their influence on physical properties. Based on the two treated fabrics laminae were formed with: epoxy matrix – (I); clay (5%) and talc (5%) and CNT (0,5%) filled epoxy - (II); clay (5%) and talc (5%) plus CNT (1%) and ferrite (5%) – (III); (II) plus ferrite (5%) – (IV); (II) plus ferrite (2%) and wolfram carbide (5%) – (V). All the powders were mechanically mixed and then dispersed into the right amount of A component of the epoxy system, the amount of B component was added and the fabrics were imbued with the pre-polymer mixture and placed between glass plates.

3. MEASUREMENTS AND RESULTS

For all the laminae and for fabrics bulk electrical conductivity was evaluated using measurement results for electric resistance. The measurements were performed using a 9216A Digital LCR meter from *Protek*; with recommended measurement cell. Each presented value is an average over, at least, 1000 values for electrical resistance measured through quality factor (Q – 500 of them) or dielectric loss (the other 500). In the presented curves (Fig.1 and Fig. 2) notations CC and KC for the respective fabric without any treatment; c for chemical treated fabric and t for full treated fabric were used. Also the dilatation behavior of laminae, matrix materials and fabrics was measured using TMA/SDTA 840 from *Mettler-Toledo* and the results are shown in **Table 1-2**.

	Matrix	Carbon fibers fabric	Mixed fibers fabric
II	1.78E-04	3.78E-04	8.91E-05
III	2.09E-04	1.57E-04	4.77E-04
IV	1.42E-04	2.57E-04	1.60E-04
V	1.39E-04	3.33E-04	3.33E-04

Tab. 1. CTE of reinforced filled epoxy [mm/K]

Treatment	Carbon fibers fabric	Mixed fibers fabric
none	-2.51E-04	-8.44E-04
chemical	1.91E-04	1.37E-04
rubber	2.85E-04	1.53E-04
full	1.62E-04	1.06E-04

Tab. 2. CTE of fabrics [mm/K]

4. CONCLUSION

The above described method for fabric treatment solves the stability during handling, the problem of interface between fibres and matrix but regarding the electrical conductivity – as may be noticed form the curves above – the method does not solve the problem. Generally, the lowest values correspond to the laminae formed with epoxy matrix (as expected taking into account the electrical insulator character of the polymer). The other materials show better values for the electrical conductivity both because of the fabric treatment and of the presence of fillers' particles in matrix. Regarding the dimensional stability it may be noticed that it decreases for the reinforced filled epoxy laminae due to the matrix presence.

In the case of mixed fibres fabric, during electrical resistance measurements, fluctuations of values were observed but they might be explained by the fact that the mentioned fabric acts, from the electrical point of view, as a network of capacitors during experimental procedure. The full treatment of this type of fabric leads to a better stability. In all the cases the electrical conductivity values for laminae are lower than the fabric's ones because the total amount of filler's is lower than the one required by the percolation theory.

The final goal is to form layered materials with different fabrics as reinforcements and various fillers at various levels such as the best mechanical, thermal and electrical properties to be reached. Using such laminae, imbued with filled pre-polymer before layering, allows obtaining stratified materials with the same type of polymer bonds in all the material volume but with different properties in each layer or group of layers (when the same type of filled matrix is used to imbue more than on sheet of treated fabric). Such material could be used in energy applications (windy energy) both because of its low specific weight and high strength and wear resistance.

5. ACKNOWLEDGEMENTS

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