THERMO-MECHANICAL PROPERTIES OF FABRIC REINFORCED COMPOSITES WITH FILED EPOXY MATRIX

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Abstract: *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. Two types of fiber fabric were used to form composites with filled epoxy matrix and materials bending and thermo-mechanical properties were evaluated using appropriate recommended methods.*

Keywords: carbon, aramide fiber, clay, talc, epoxy.

1.Introduction

While the design problem seems to be essential in order to form a high performance composite one may ask: 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.

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. 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).

Fabric reinforced or textile composites are increasingly used in aerospace, automotive, naval and other applications. They are convenient material forms providing adequate stiffness and strength in many structures. In such applications they are subjected to three-dimensional states of stress. The microstructure of composite laminates reinforced with woven or braided networks is significantly different from that of tape based laminates.

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 [1]. The powders can be dielectric as talc, clay or ferrite can be magnetic active as ferrite, or electric active as CNT or carbon nano-fibers. All these powders, added to the polymeric matrix, have effects on the electro-magnetic, thermal and mechanical properties of the composite [2]. What about using all of them, based on partially changes induced by each one? There exist many models regarding the mathematic description of electromagnetic properties of the bi-component composites [3, 4].

This study is performed to point out the connection between thermo-mechanical properties of certain laminae and the thermo-mechanical properties of a composite formed with those laminae.

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. That is why the two fabrics were specially prepared.

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 Clay and Talc (5%) filled PNB rubber is deposed on the fabric surfaces.

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 (Fig. 1).

Fig. 1. *Microscopic images before and after full treatment of Carbon Fiber Fabric (left) and Mixed Fabric (right)*

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 reinforced composites. Based on the two treated fabrics laminated-like materials were formed with: Clay (5%) and Talc (5%) filled matrix.

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. Ten different reinforcement structures were used to form the materials and these structures are presented in Table 1 where C denotes carbon fiber fabric and K denotes mixed fiber fabric and the angular values are relative orientations of yarn and fill to the mould edges.

Table 1. *Reinforcement structure of formed materials*

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

3.Measurements and Results

The thermo-mechanical properties are strongly influenced by the fabric due to the thermo-mechanical properties of carbon and aramide fibers. Coefficient of thermal expansion was evaluated both perpendicular on reinforcement and in plane of the reinforcement. Measurements were carried out using a TMA-SDTA 840 from *Mettler Toledo*.

The heating ratio was 10°C/min in both directions and interval temperature [50°C, 90°C]. The coefficient of thermal expansion was evaluated, using the same technique, for individual laminae and for filled epoxy matrix and the results are presented in Table 2. In the case of fabric laminae the CTE was measured only perpendicularly on the fabric.

Taking into account the ranges of coefficients it might be said that all the materials have the same thermal behavior. Regarding the parallel coefficient its values might be improved by using powders as carbon black or CNT which show negative values of the thermal expansion. It might be noticed that in the case of parallel with the reinforcement all the materials are stable. That is due to the presence of long carbon and aramide fibers which have negative values of CTE and compensate the matrix dilatation.

Table 2 *Coefficient of Thermal Expansion (CTE) for Individual Laminae and for Matrix*

	Carbon Fiber Fabric	Mixed Fiber Fabric	Filled Epoxy
CTE	1.62E-04 μm/°C	1.06E-04 μm/°C	1.97E-04 μm/°C

Using the mixing rule the values of CTE were evaluated based on above presented values of composites' components. It is easily to notice, from Fig. 2, that there are significant differences between measured and evaluated values of CET but the magnitude of values is the same.

These differences may occur due to the different values of matrix layers (inevitable using the described forming technique) or due to the fact that during molding the reinforcement sheets may deviate from the parallel position.

Also, due to the forming technique there might appear gaseous intrusions inside the matrix with strong effects on CET, even the tests were performed on samples extracted from various areas of formed plates.

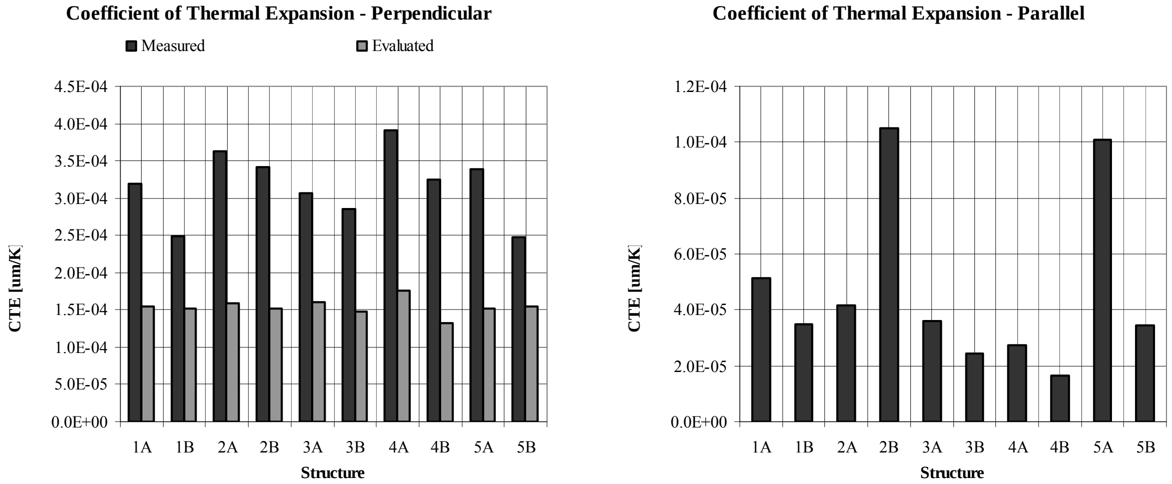

Fig. 2. *Coefficient of Thermal Expansion for formed materials*

4.Conclusions

The composite's design has to take into account all the aspects in order to offer right solutions for certain applications. Studies have to be carried out to find the influence of various polymers used in the same composite material at different levels – each one with a defined purpose – such as, at the end, the material to fit all the requirements. The use of carbon fibre allows even the opportunity to get information about material's or structures' state and integrity without using other devices which increase the costs and, not at least, the weight of applications.

The multi-component composites could represent the cheapest solution when controllable properties are required. A structural microscopically analysis is required in order to identify the quality of interfaces. In the case of a n-components composite there are n-1 interfaces each one of them having its own contribution at composites' properties. The filler presence in the matrix produces discontinuities at the fibre-matrix interface with consequences regarding mechanical properties.

References

[1] **Caloz, C., Itoh, T.**, *Electromagnetic Metamaterials: Transmission Line Theory and Microwave Applications – An Engineering Approach*, Wiley-Interscience Publications, 2006.

[2] **Winey, I. K., Vaia, A. R.** (ed), Polymer Nanocomposites, MRS Bulletin, Vol. 32, 2007.

[3] **Torquato, S., Hyun, S., Donev, A.**, *Optimal design of manufacturable three-dimensional composites with multifunctional characteristics*, Journal of Applied Physics, 94, 2003.

[4] **Torquato, S.**, *Modeling of physical properties of composite materials*, International Journal of Solids and Structures, 37, 2000.