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MECHANICAL PROPERTIES OF FILLED EPOXY BASED REINFORCED COMPOSITES

Vasile Bria[1], Igor Roman[1], Ion Postolache[1], Victor Ungureanu[2]
Iulian-Gabriel Bîrsan[1], Adrian Cîrciumaru[2]

[1] Faculty of Mechanical Engineering, Dunărea de Jos University, Galați, România
[2] Polymeric Composites Laboratory, Dunărea de Jos University, Galați, România
email: vbria@ugal.ro

ABSTRACT

While the aim of composites is to replace metals in various applications researchers are involved in improving not only the mechanical but also the electromagnetic and thermal properties of polymeric composites. Also, it is known that filled polymeric composites show interesting properties especially when the fillers are nanosized. In such conditions it is expected that laminate composites formed with filled epoxy will show different properties. One of the most important goals is to ensure adhesion of epoxy matrix to the reinforcement. The mechanical properties were evaluated using 3 point bending tests.

KEYWORDS: fiber fabric, clay, ferrite, CNT, epoxy

1. INTRODUCTION

Nowadays industrial world is marked by the use of composites in almost all the domains. A class of special composites is the polymer matrix class. Despite their excellent mechanical properties they are often rejected because of their thermal and electromagnetic properties. The cheapest way to change these properties is to fill the matrix with various powders such as clay, talc, CNT, ferrite. The use of fiber fabric as reinforcement leads to an easier manner to reinforce the composite. Because of their properties three simple type fabrics are suitable for use – carbon fiber, kevlar fiber and the mixed kevlar and carbon fiber fabric. The use of epoxy resin as matrix arises a challenge because as it is well known it is not adherent to the carbon fiber. This study is about how to ensure a high quality interface between fabric and matrix in the case of fabric based filled epoxy composites. A thin film of rubber was deposed on the fabric. The rubber was added with clay and carbon black.

Filling the matrix before its use on forming reinforced composites could lead to an improvement of one or more mechanical, electrical or thermal properties. When more than one filler are used in the same laminate it would be possible to locally improve certain properties.

It is well known that, in the case of reinforced composites, spatial 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 multiaxial 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 [1, 2].

More and more studies regarding the use of fabrics to form composites were developed recently [3, 4, 5, 6] 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 [7, 8, 9].

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 AND TECHNIQUE

Despite their ecological disadvantages the epoxy resins are still used as matrix for various fibrous materials in aircraft or automotive industry. Due to their excellent properties the epoxy resins cannot be replaced at the moment. The problem regarding their electrical properties is still one of major interest and the cheapest method is to fill the epoxy with various powders but increasing the filler's concentration there appear some inconvenient such as the particles' aggregates inside the polymer.

At the beginning, our research was focused on obtaining fabric reinforced composites with filled epoxy matrix. The forming method was layer-by-layer type. Sheets of fabric imbued with filled epoxy resin were placed into the mould in order to obtain laminate-like plates.

Some difficulties had appeared, firstly, when the cut of fabric was necessary, because the untwisted tows of filaments from which the fabric is made of are slipping when the scissors are used. The pieces of fabric were imbued with filled pre-polymer and then placed into the mould. During these operations the fabric is damaged and as consequence, the mechanical properties of the final material will be affected.

After first tests were performed it had been noticed that, in some cases, the polymer matrix was not totally adherent to the fiber (especially the carbon fiber). Since the forming technique is the layer-by-layer one the problem of epoxy-fiber adhesion had to be solved before moulding.

In order to solve these problems, we used, at the beginning, a thin film of rubber deposed on the fabric's surface. The thin film is deposed by pulverization of a rubber solution. The fabric is fixed into supports, washed with a low concentration detergent solution and rinsed out with distilled water. Due of this film the stability of fabric is ensured so the cutting and the handling during moulding are not longer affecting the integrity of fabric pieces.

The treatment had solved also the adhesion problem between epoxy resin and carbon fiber because the presence of nitrilic groups in the rubber. These groups interact with the nitrilic ones in the hardener ensuring the connections between polymeric chains and rubber chains.

Six materials were realized through layer-by-layer method using rubber covered fabric and filled epoxy (EPIPHEN RE 4020 – DE 4020 system). The fillers were Clay (20%) and CNT (0,5%) or Ferrite (0,5%).

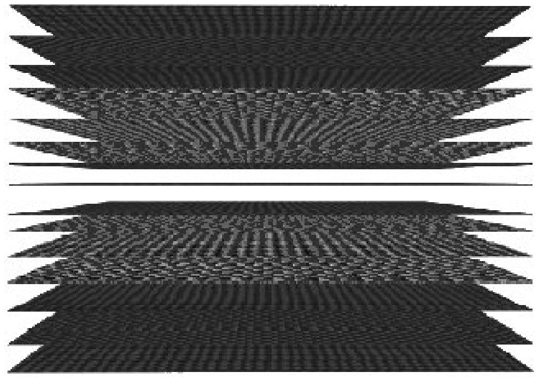

Fig. 1. 3-type placement of reinforcement sheets

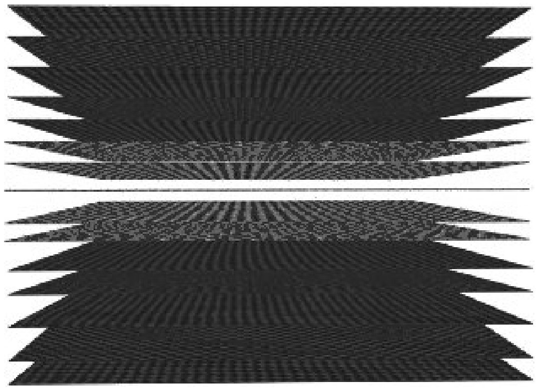

Fig. 2. 5-type placement of reinforcement sheets

For each filling mixture three types of reinforcement arrangements were used but respecting the [0^o, 45^o, 0^o] geometry relative to the sample's edges. Carbon fiber fabric and mixed Carbon and Aramide fiber fabric were used to provide the material's reinforcement. In Fig. 1 and Fig. 2. the 3-type and 5-type structures of reinforcement are shown. The 1-type consists in alternating one sheet of each type of fabric. It had to be noticed that external layers, for all the materials, consist on carbon fiber fabric.

3. MEASUREMENTS

All the evaluations are done based on results of three points bending of samples. The tests were performed according to DIN EN ISO 10545-4. on the *M350-5AT* testing machine from *Testometric* and the special software (also from Testometric) was used to determine the mechanical parameters Fig. 11.

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 [10, 11] Fig. 12. Specimens of 32mm x 10mm x 6mm 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). A load of 15 N was used and the abrasive disk is made from abrasive paper P 150 for three different sliding distances: 45,3 m, 79,2 m, 113 m.

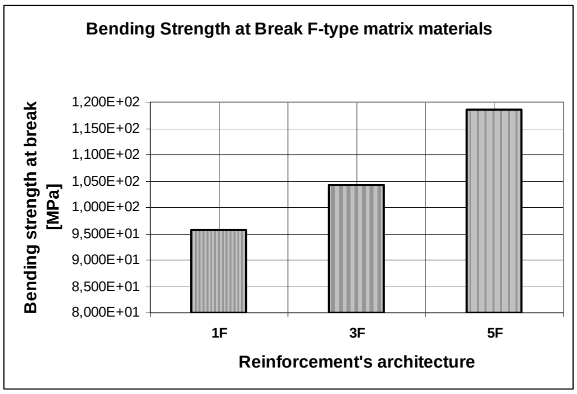

Fig. 3. Bending Strength at Break

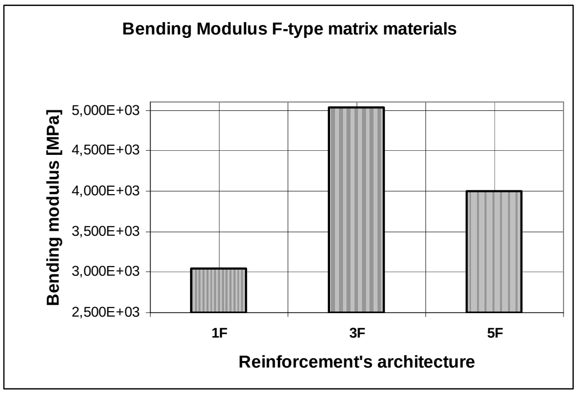

Fig. 4. Bending Modulus

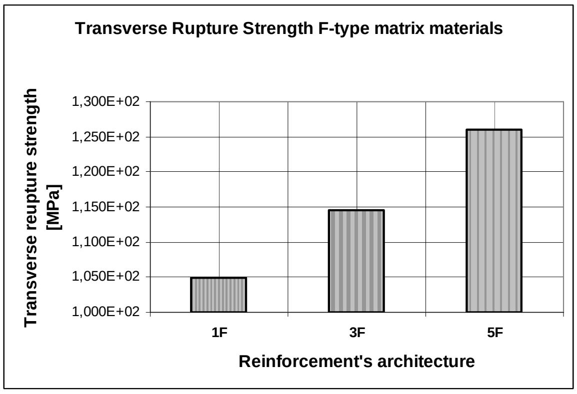

Fig. 5. Transverse Rupture Strength

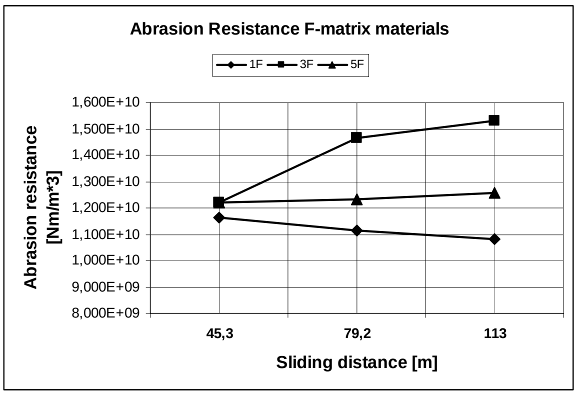

Fig. 6. Abrasion Resistance

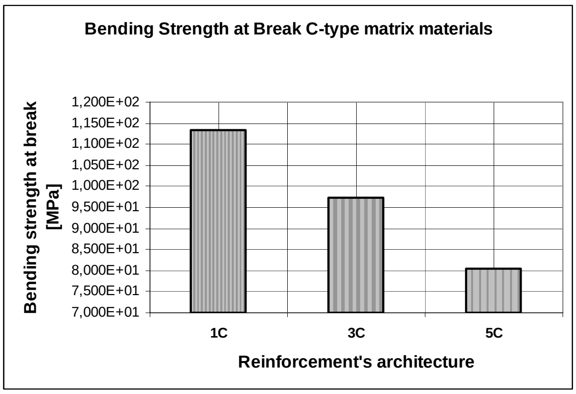

Fig. 7. Bending Strength at Break

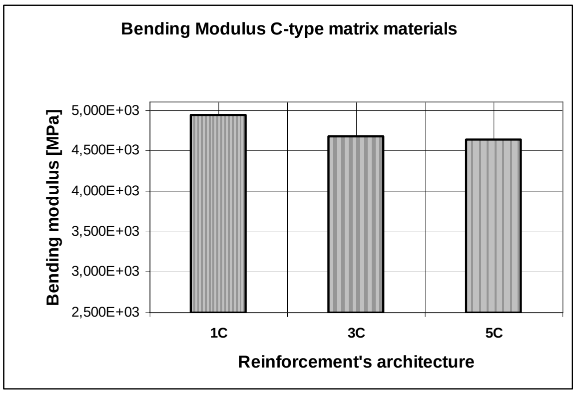

Fig. 8. Bending Modulus

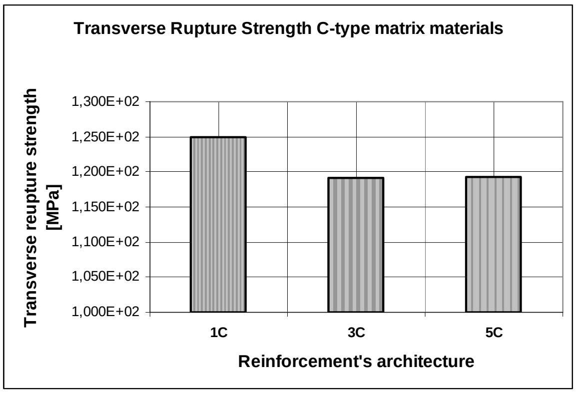

Fig. 9. Transverse Rupture Strength

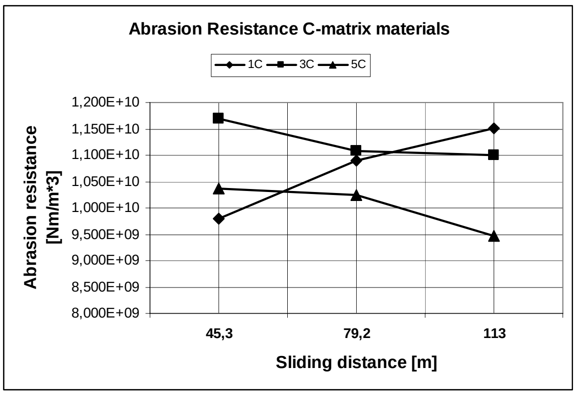

Fig. 10. Abrasion Resistance

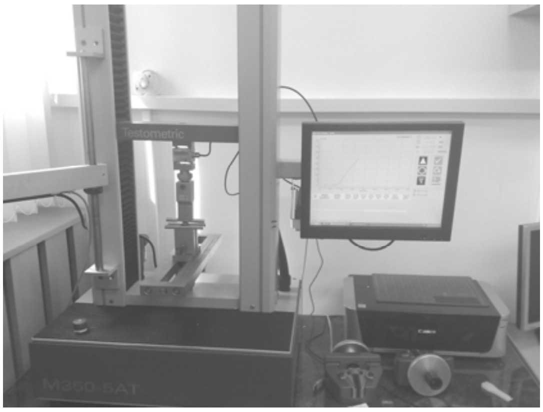

Fig. 11. Three point bending fixture

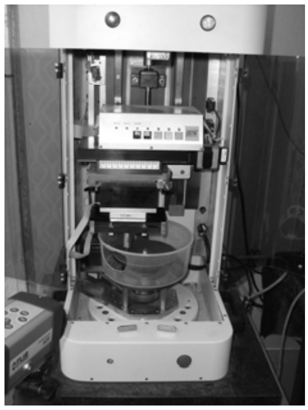

Fig. 12. Abrasive behaviour testing fixture

4. RESULTS

It is easily to notice that in the case of C-type materials (with CNT filled matrix) the Bending strength is decreasing when the number of the reinforcement sheets of reinforcement architecture is increasing. In the case of F-type matrix is opposite. One possible explanation could be that F-type matrix ensures a better interface with the mixed fabric.

The same explanation could be used for the bending modulus but in this case can be noticed the special aspect of 3F material which shows the highest value. I the case of C-type matrix the highest value is obtained for 1-type architecture and for these materials the most important contribution is the one of the matrix.

Regarding the transverse rupture strength the behaviour it can be noticed that the strength of the F-type materials increases when the number of carbon fiber sheets increases and in the case of C-type the strength decreases when the number of carbon fiber fabric sheets increases. That means that the interface between epoxy and reinforcement and carbon fiber fabric is stronger when the Ferite is used than the case in which the epoxy is filled with CNT.

5. CONCLUSIONS

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 behaviour of the obtained composite. 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. 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. Also there are studies regarding the bounds of models.

Taking into account that not only the electromagnetic properties are important but also the mechanical and thermal properties the design problem becomes almost impossible.

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 not only to analyze the electromagnetic and mechanical properties but also the thermal properties. A structural microscopically analysis is also required in order to identify the quality of interfaces. In the case of an n-components composite there are n-1 interfaces each one of them having its own contribution at composites' properties. The filler presence into the matrix produces discontinuities at the fibre-matrix interface with consequences regarding mechanical properties.

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