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MECHANICAL AND DIELECTRIC PROPERTIES OF STRATIFIED COMPOSITES

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ABSTRACT

The electric properties of the polymeric composites materials are insulators like ones and that is why their spreading is blocked some how. Starting with the idea that filling the matrix with various powders it is possible to change the electric behaviour some layered materials were formed having as reinforcement 15 layers of kevlar and carbon fibre simple type fabric. CNT, Ferrite and Talc were used as fillers and the Clay as modification agent for epoxy resin. The dielectric permittivity was evaluated using standard recommended method. Mechanical properties of materials were evaluated based on 3 point bending tests.

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

1. INTRODUCTION

Electromagnetic and mechanical properties of composites, as manifestations at the external changes, have to be averaged manifestations of the components. This is just an approach viewed as a starting point both for further studies and decision making in forming a composite with certain properties. It is extremely difficult to mathematically describe a multi-component composite even if there are various models for bi-component composites [1, 2, 3]. 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.

For the case in which the filled polymers are used in order to obtain laminate or pseudo-laminate composites it is necessary to know the behavior of filled polymers, there are interaction between reinforcement and matrix not only from the mechanical point of view but also from the electrical or thermal point of view. In the case of use of mixed fabric (kevlar and carbon fiber) there is some instability during the electrical measurement because of the multitude of capacitors which appears in the composite's structure. On another hand the use of such fabric ensures the in-plane electric conductivity due to the carbon fibers and the strength due to the kevlar fiber [4].

Regarding the models about forming and behaviour of a multi-component composite they are extremely complex due to the multitude of interfaces. As it is known the most important role in defining the composite's properties is played by the interfaces between phases [5, 6, 7, 8].

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.

The idea of increasing the filler's concentration using a modified polymer is based on aluminium filled epoxy – an epoxy resin used to form moulds. Taking into account that in such a mixture the aggregating probability is lower the aim of this study was to identify the way in which the polymer might be modified in order to allow dispersion of large amounts of fillers as CNT, ferrite or carbon black avoiding clusters and obtaining better properties for the formed composites. There are studies regarding the use of clay or talc as modifying agents for polymers. Increasing talc or clay concentration it is possible to obtain better dispersion for other fillers.

On one hand the reinforcement ensures good mechanical properties (and even electrical ones if carbon fibre is used) and another hand the filler is ensuring good electromagnetic and thermo-mechanical properties. From this point of view a composite able to replace a metal has to be, a least, a tri-component one.

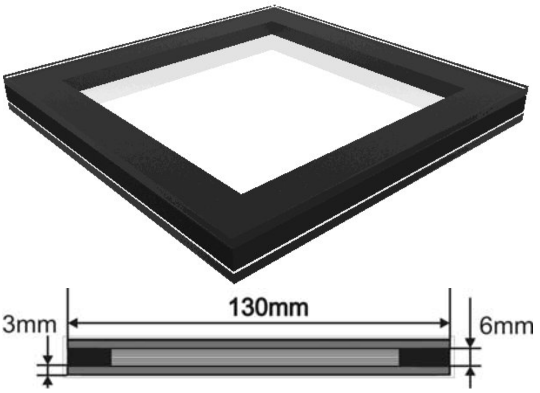

Fig. 1. The glass mould

2. MATERIALS AND TECHNIQUE

The forming technique is a hybrid one consisting in layer-by-layer adding of imbued sheets of fabric into a glass mould, Fig. 1.

At the beginning two glass plates are covered with demoulding agent, then on one of them a rectangular rubber seal is fixed using silicon glue. Filled pre-polymer imbued reinforcement sheets are placed inside the seal and the mould is closed. The mould is introduced in rubber bag and the air and other gases are removed using a vacuum pump.

The silicon glue is not interacting with the pre-polymer and it may be easily removed. The extraction of the formed material is even easier because of the flexibility of rubber seal. This technique allows the reutilization of each mould ensuring, mean time, an excellent quality for samples' surfaces. This quality depends on polish level of the glass plates.

As reinforcement 15 sheets of two types of fibre fabric were used for each type of material. From the geometrical point of view all the formed samples are of [0°, 45°, 0°] arrangement but three types of spatially placement were realized as in Fig. 2. and Fig. 3. The two fabrics used as reinforcement are of simple type one made of carbon untwisted tows as yarn and fill and one made of alternate carbon and aramide untwisted tows as yarn and fill. For all the materials external reinforcement sheets are of mixed fabric.

The presented types of architectures were realized in order to point out the influence of reinforcement.

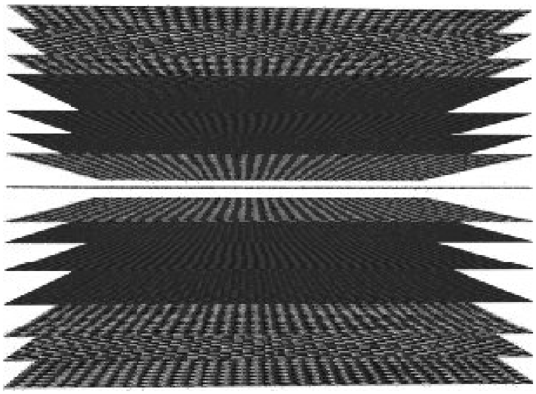

Fig. 2. 3-type placement of reinforcement sheets

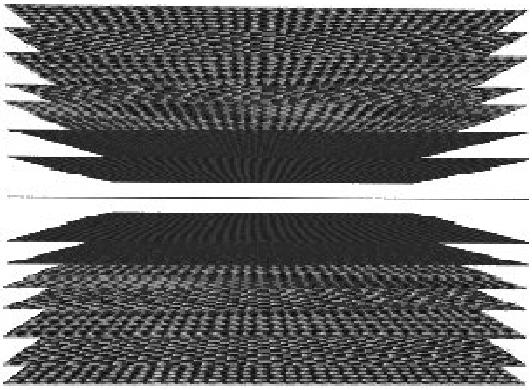

Fig. 3. 5-type placement of reinforcement sheets

The filled epoxy (EPIPHEN RE 4020 – EPIPHEN DE 4020 system) was used as matrix. For the 1C, 3C and 5C materials the matrix is filled with 20% Clay and 0,5% CNT (weight ratio) and for the 1F, 3F and 5F materials 20% Clay and 0,5% Ferrite.

The amounts of CNT and Ferrite were mechanically mixed with the Clay powder such as homogenous powders were obtained. These powders were dispersed into the A component of the epoxy system (RE 4020) and continuously mixed for 30 minutes then the B component (DE 4020) was added.

3. MEASUREMENTS

For dielectric permittivity measurement it had been used an experimental setup described by. This arrangement is made in order to determine the electric capacitance and, subsequently the dielectric permittivity. The method is based on the use of a measuring cell (three electrodes) and an apparatus able to measure electric capacitance. The measuring cell is also described in [9]. Using a *RLC-meter* it is possible to record also the quality factor and the dielectric loss. With those we have: $\varepsilon = C_V d / S$ where C_V is the read value of capacitance, $S = \pi r^2$ and d is the sample's thickness (all the dimensions are according the I.S.).

Mechanical properties of materials were evaluated in order to identify the influence of reinforcement and of filled matrix. All the evaluations are done based on results of three points bending of samples. According to EN 63, NFT 57-105 and NFT 51-001 the samples were cut from initial plates of materials using a high preasure jet machine Fig. 4. The tests were performed according to DIN EN ISO 10545-4.

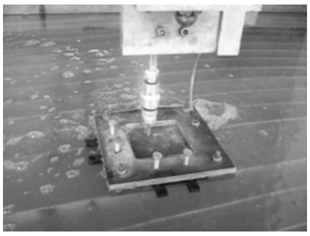

Fig. 4. Samples cutting

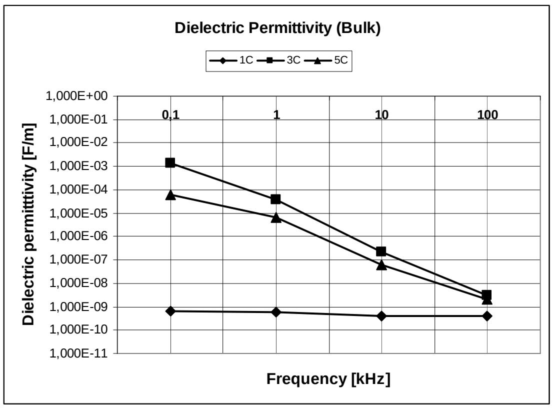

Fig. 5. Bulk dielectric permittivity - C-type materials

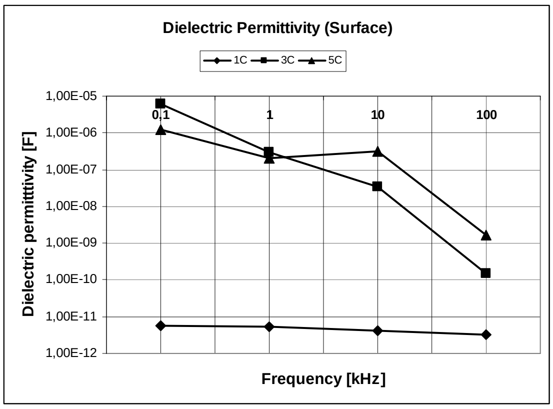

Fig. 6. Surface dielectric permittivity - C-type materials

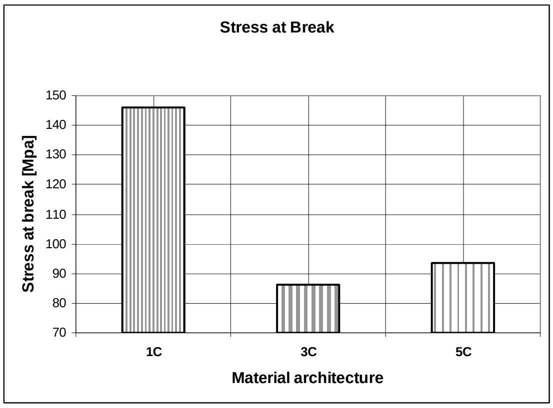

Fig. 7. Stress at Break - C-type materials

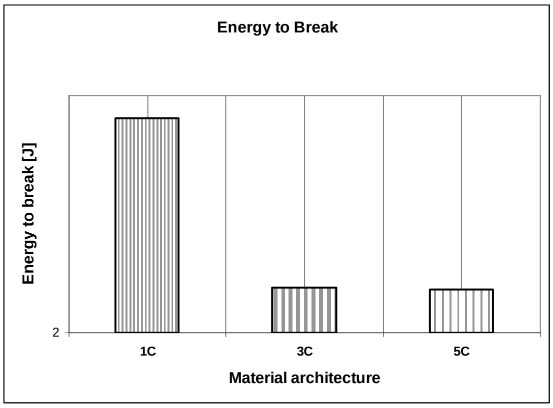

Fig. 8. Energy to Break - C-type materials

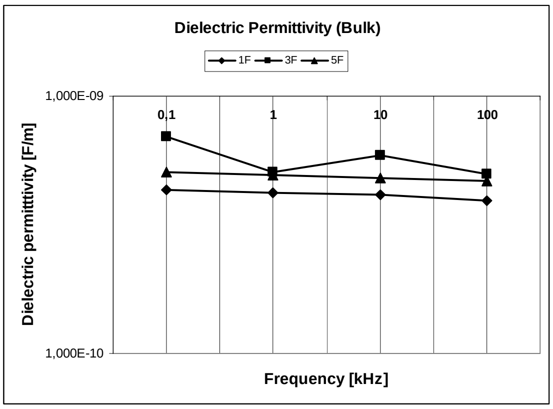

Fig. 9. Bulk dielectric permittivity - F-type materials

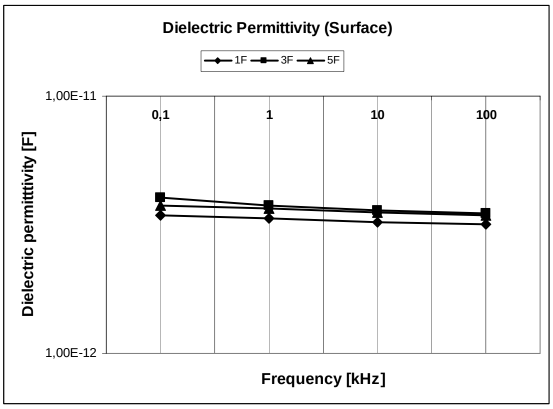

Fig. 10. Surface dielectric permittivity - F-type materials

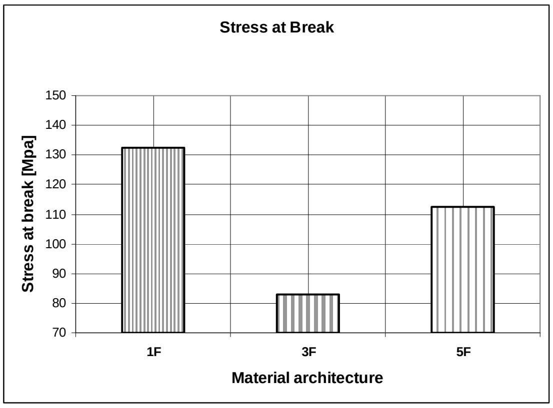

Fig. 11. Stress at Break - F-type materials

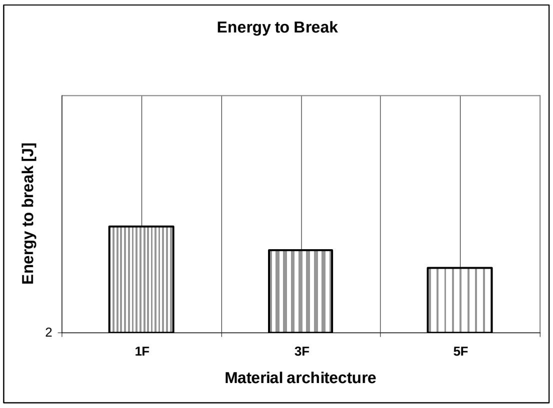

Fig. 12. Energy to Break - F-type materials

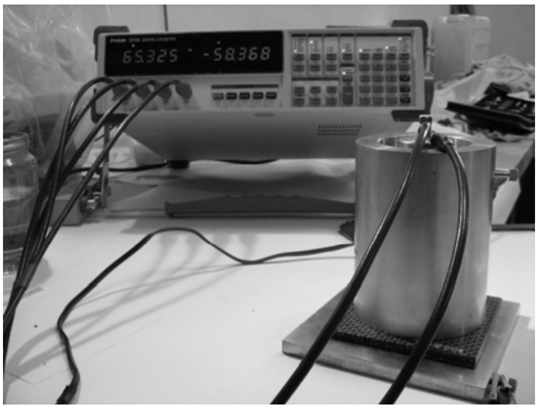

Fig. 13. Electric measurements fixture

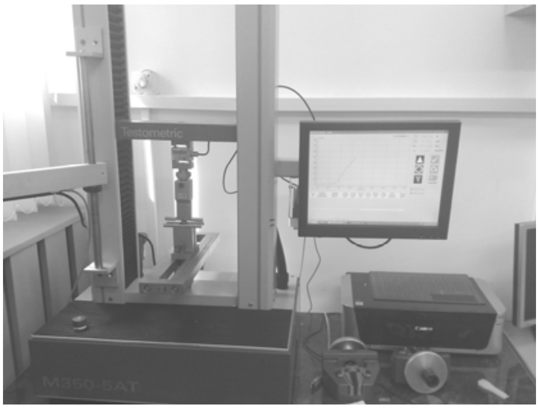

Fig. 14. Three point bending fixture

4. RESULTS

In order to determine the dielectric permittivity the experimental setup contains a digital LCR-meter (*Protek* 9216A) which ensures frequency dependent measurements of electric resistance, electric capacitance and electric inductance as well as quality factor and dielectric loss, Fig. 13.

It is easily to notice that in the case of C-type materials (with CNT filled matrix) the dielectric permittivity shows strong frequency dependence Fig. 5. and Fig. 6. This fact is explainable by the fact that the CNT have strong frequency dependent properties. In the case of F-type materials (Ferrite filled epoxy as matrix) both values of dielectric permittivity are practically frequency independent but it is expected that magnetic behaviour to be highly frequency dependent because of Ferrite's magnetic permeability frequency dependent Fig. 9. and Fig. 10.

In the case of C-type materials the both values of dielectric permittivity show variations in the case of 3 and 5 arrangements which means that the reinforcement influence is not negligible. In the case of F-type materials the dielectric behaviour is almost the same independent on the type of architecture. It might be said that the dielectric behaviour is more a matrix one than a reinforcement one.

In the case of mechanical evaluations the *M350-5AT* testing machine from *Testometric* was used to perform the 3 point bending tests and the special software (also from Testometric) was used to determine the mechanical parameters Fig. 14. As can be noticed from the Fig. 7. and Fig. 11. the 1 sheet architecture seems to be the most resistant. This fact is explainable by the high homogeneity of the materials while the other materials show lower values for stress at break.

It is noticeable that the 5 sheets materials are a little more resistant then the 3 sheets ones and that is because apparently they are formed from three almost homogenous materials. Taking into account the fact that the polymers chains are established through the reinforcement sheets and between them, the mechanical behaviour of materials may be interpreted in terms of matrix/reinforcement behaviour.

In the case of 1sheet architecture the material act as a homogenous one (the material break appears when the entire material is broken) while in the case of 3 and 5 sheets architectures the material acts as a laminated in which one thick layer is broken (a layer with 3 or 5 sheets of reinforcement). In this case is explainable the higher resistance of 5-type materials.

5. CONCLUSIONS

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 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.

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