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KOMPOZYTY
COMPOSITES

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SELECTED MECHANICAL PROPERTIES OF FABRIC REINFORCED COMPOSITES WITH TALC AND CARBON BLACK FILLED MATRIX

Fillers are used in order to improve the properties of polymeric composites. It is possible to use the filled polymer in order to form reinforced composites. In both cases it is assumed that using some strategies the fillers' particles are uniformly distributed in the volume of matrix. Clearly, using filled polymers, the mechanical properties of formed composites will be changed. In this study, the emphasis is on finding out the influence of filled layer distribution on the properties of formed composite. Plates of reinforced composites were formed using mixed kevlar and carbon fiber fabric and epoxy resin as matrix. As fillers talc and carbon black were used. Three point bending tests were performed in order to point out the effect of filler and fillers' distributions on mechanical properties of materials.

Keywords: **three points bending, kevlar and carbon fibers fabric, epoxy, talc, carbon black, filled epoxy**

WYBRANE WŁAŚCIWOŚCI MECHANICZNE KOMPOZYTÓW UMACNIANYCH TKANINĄ Z OSNOWĄ NEPEŁNIONĄ TALKIEM I SADZĄ

Napełniacze są stosowane w celu poprawy właściwości kompozytów polimerowych. Możliwe jest zastosowanie polimeru napełnionego do kształtowania kompozytów umacnianych. W obu przypadkach zakłada się, że cząstki napełniaczy są jednorodnie rozmieszczone w objętości osnowy. Niewątpliwie użycie napełnionych polimerów będzie zmieniać właściwości mechaniczne tworzonych kompozytów. Prezentowane badania miały na celu określenie wpływu rozmieszczenia wypełnionych warstw na właściwości utworzonych kompozytów. Płyty kompozytowe wytworzono przy zastosowaniu mieszanych tkanin z włókien kevlarowych i węglowych oraz żywicy epoksydowej jako osnowy. Jako napełniacze zastosowano talk i sadzę. Testy trójpunktowego zginania przeprowadzono w celu wykazania wpływu napełniacza i jego rozmieszczenia na właściwości mechaniczne materiałów.

Słowa kluczowe: **trójpunktowe zginanie, tkanina z włókien kevlarowych i węglowych, osnowa epoksydowa, talk, sadza**

INTRODUCTION

Both for engineers and physicists a new challenge arose in last years: how to improve the electro-magnetic properties of a composite. The necessity of metal replacement in aircraft and spacecraft application requires not only excellent mechanical properties but also good electromagnetic properties. More, it seems to be possible to obtain composite materials having electromagnetic properties better than metals ones. There are many researches and also many results published in various journals covering a range of interests from physics to engineering. There are also many papers concerning the modeling of electric properties of composites in order to ensure the design of composites [1]. However, it is considered that such an approach is just a partial one because the design has to take into account not only those properties but also the mechanical and thermal properties. Obviously, this is a very difficult approach and it can be found an extensive study over its complexity [2]. One of the cheapest and most convenient methods is to fill the polymer with various powders (metal powders, CNT, carbon black, clay, ferrites etc.) [3]. The cited paper is an excellent review of actual orientations and in the domain of filled polymer composites and it emphasizes the importance of filler dimensions and shapes bringing in attention the importance of interface. One of the most important assessments in last years is the highly contribution of interfaces at the macroscopic properties of composites [4].

MATERIALS

This is just a "trail and error" 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 four-component composite even if there are various models for bi-component composites. The aim of this study, based on intuition, is to present some empirical results in order to help the manufacturers in decision making of forming a special composite.

The forming of samples were made using a combined method, first a ”layer-by-layer” adding of resin imbued sheets of reinforcement. After the mould was closed the excess of resin was extract through application of a mechanical effort, then the mould was introduced in a rubber bag. The air and other gases from the bag were removed using a small vacuum pump in order to avoid the gas intrusions in the sample.

A set of 8 different materials were realized in order to evaluate the influence of filler over the electric and electromagnetic properties of the composite materials. The results are showed in [5]. Excepting the standard sample (NULK) there were made other seven samples using talc and carbon black at the same concentration as fillers for epoxy resin. Two of these samples are formed, in the way above described, but using filled epoxy as matrix. One time the epoxy was filled with Talc (TALC) and the other time with carbon black (CARB). Also, a sample was formed using both fillers (TACA). Considering that fillers were well distributed in polymer, these four samples might be considered of near homogenous matrix. The other four samples, formed in order to identify the influence of matrix structure, were realized alternating the matrix. So, there are two samples in which the external three sheets of reinforcement were imbued with Talc or Carbon Black filled epoxy while the internal seven were imbued with, respectively, Carbon Black (CARC) or Talc (TALN) filled epoxy. From the matrix point of view the structure of such a sample is 3T-7C-3T or 3C-7T-3C. The last two samples are formed by using alternatively Talc filled epoxy imbued sheets and Carbon Black filled epoxy imbued sheets. One has the external layers of Talc filled epoxy (TBON) the other one has the external layers of Carbon Black filled epoxy (CALC). From the matrix point of view, the structure of these samples is T-C-T-…-C-T or C-T-C-…-T-C.

MEASUREMENTS

The aim of this kind of approach is to identify the ways in which we might modify the electromagnetic response of the material and meantime achieving better mechanical properties. Also, there are more and more intentions regarding the use of filled matrix as metamaterial [6]. In such a case all the electromagnetic and optical properties could be controlled. It is important, in our opinion, to point out the dependencies between reinforcement and matrix in electromagnetic or thermal context.

It is well known that the electromagnetic and thermal properties of a composite material represent an averaged response of all the constituents when the environment changes. Using nanosized fillers, it is expected that the electromagnetic sizes (such as electric conductivity, electric permittivity and magnetic permeability) to be frequency dependent. Meantime it is important to emphasize that using filled polymers as matrix for composites the quality of reinforcement-matrix interface to be decreased. A poor quality of interfaces leads to a significant loss of mechanical properties that is why we consider that the design of a high quality composite is a problem of fine equilibrium.

The next step is to evaluate the mechanical properties of such materials in order to identify the influence of fillers. Also, the influence of various structures of filled epoxy layers is investigated. 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. The tests were performed according to DIN EN ISO 10545-4 [7].

The fabric used as reinforcement has the warp and the fill made alternating from yarns of kevlar and carbon fibers. It was our decision to use this type of fabric because it combines the exceptional electromagnetic properties of carbon fiber with the mechanical ones of the kevlar fiber. A difficult task was generated by the fact that the epoxy resin is not adhering to the carbon fiber. In order to ensure the adhesion of epoxy to the two types of fibers the fabrics were covered with a thin film of PNB rubber obtained through solution pulverization. After the thin rubber film deposition, the material was treated with epoxy solution such as it was cut avoiding its tear apart. All the 13 sheets of the reinforcement were placed such as the warp and the fill to be parallel with the mould edges. That is why the formed composite has a high level of anisotropy.

There is another aspect to be underlined about using the PNB. It is well known that the mechanical properties of a composite are depending on the nature and the quality of reinforcement-matrix interface, explicitly on the rate of the loading transfer between reinforcement and matrix. The PNB film ensures an elastic behavior and avoids the fiber fracture caused by the inequalities between elastic moduli.

The three point bending samples were cut using a high pressure water jet machine in order to avoid the contamination and the eventual structural changes induced by electromagnetic radiation or by high temperatures. The standard samples were cut along the warp, along the fill and also on a 45 degrees oriented direction, in order to point out the anisotropy of the material.

The electromagnetic properties of the formed materials were evaluated and the results were presented in [8] and [9]. The use of talc and carbon black as fillers was a result of analysis of their basic properties and costs. The aim of carbon black usage was the increase of the electric conductivity while the use of talc was recommended by its favorable rate cost/particles dimension and its inorganic structure.

A major task of this research was to obtain various electromagnetic behaviors of materials and to analyze the effect on mechanical properties.

RESULTS

The most important aspect regarding the curves in Figure 1 is that all of them, except the one for NULK, have the same profile presenting two quasi linear zones. In our opinion the first zone corresponds to the bulk elastic behavior of the sample (the domain of low loads) when the load transfer between matrix and reinforcement is good. Then, after the matrix is broken, the second zone corresponds to the elastic behavior of the interface fiber-matrix. Taking into account the above mentioned, we may say that filling the resin the quality of reinforcement-matrix interface decreases. According to [3] using the three point bending curve the bending apparent elastic modulus can be evaluated as $E = F$ [N]/y [mm] in any point of the linear zone. In our case we might determine two such parameters. In Figure 1 can be easily noticed that for all the filled matrix materials the first zone corresponding apparent modulus have greater values than the one of pure epoxy matrix.

In Figure 2 there are shown the three points bending curves for the normal samples (the ones which were cut such as the warp and the fill of the reinforcement sheets are parallel to the sample's edges). Once again, it is important to notice that except the standard sample all the others present the same profile with two important peaks. The first peak is corresponding to matrix fracture while the second one is corresponding to the fiber-matrix interface broken by internal shearing (all the tests were stopped before the samples broke apart) - the material integrity is lost but because of the kevlar fibers presence the samples cannot be divided (as in the case of carbon fiber fabric reinforcement). Analyzing both Figure 1 and Figure 2 it seems that using talc as filler the mechanical properties of composites are improved. Once again, the bending apparent elastic modulus seems to be better in the case of filled epoxy matrix. In order to evaluate the bending apparent elastic modulus for each sample we preferred to choose a linear domain of the curve $F(y)$ between F = 200 N and F = 400 N for the curves in Figure 1 and between F = 200 N and F = 600 N for the curves in Figure 2, the results are shown in Figures 3 and 4. For bending mechanical resistance and bending apparent elastic modulus evaluations were made according to [10] while for interlaminar shear strength evaluation is according to [11] (presented in Figures 5 and 6).

Because all the composites have the same type of reinforcement, it can be noticed that the solution with talc filled epoxy shows the highest bending mechanical resistance while the solution with both fillers leads to the highest value of bending apparent elastic modulus.

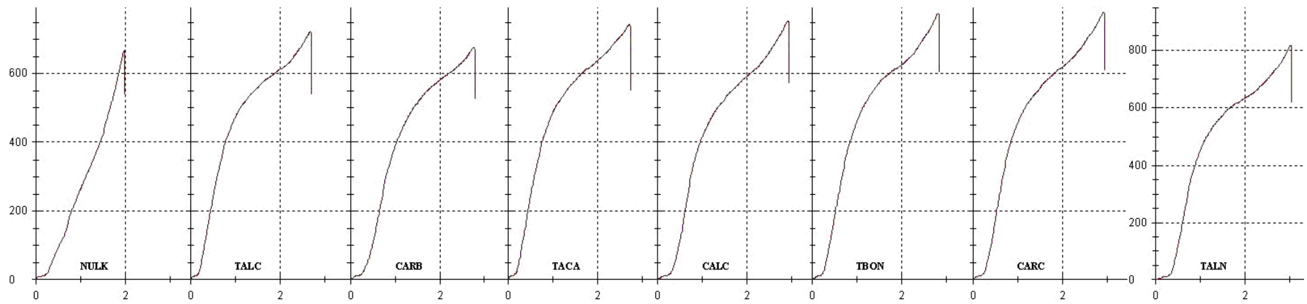

Fig. 1. Three point bending curves for the 45 degrees oriented samples (composed from individual curves), x axis: Travels in mm; y axis: Force in N

Rys. 1. Uśrednione krzywe trójpunktowego zginania dla próbek w orientacji pod katem 45 stopni, oś x - ugięcie w mm, oś y - siła w N

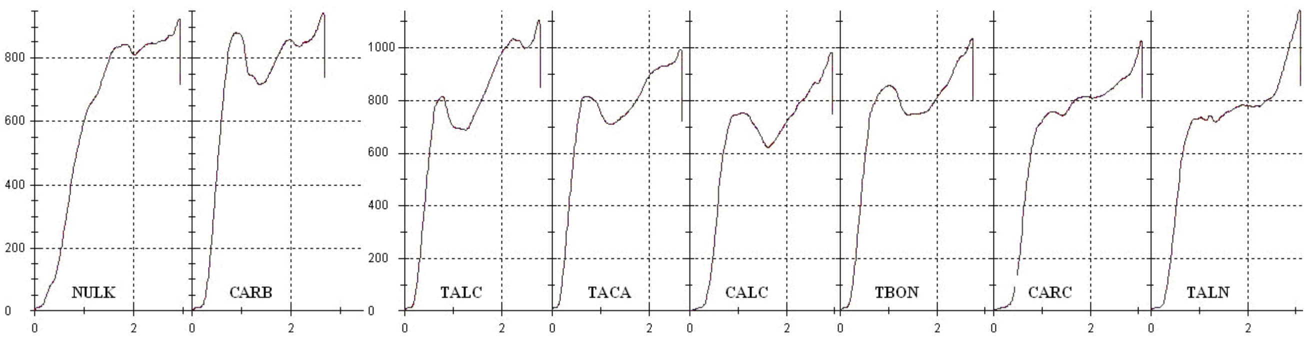

Fig. 2. Three point bending curves for the parallel oriented samples (composed from individual curves), x axis: Travels in mm; y axis: Force in N

Rys. 2. Uśrednione krzywe trójpunktowego zginania dla próbek w orientacji równoległej, oś x - ugięcie w mm, oś y - siła w N

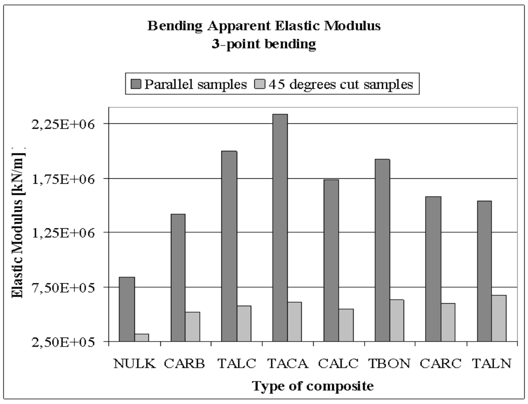

Fig. 3. Bending apparent elastic modulus [10]

Fig. 3. Moduł sprężystości wzdłużnej przy zginaniu [10]

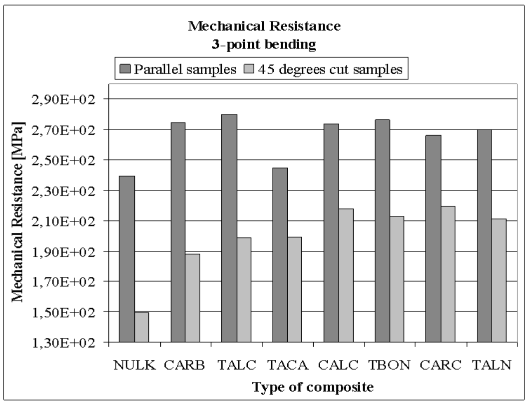

Fig. 4. Bending mechanical resistance [10]

Rys. 4. Wytrzymałość na zginanie [10]

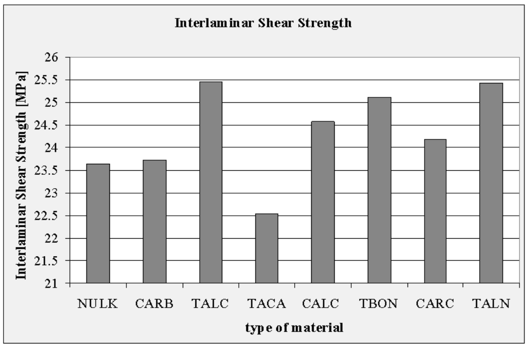

Fig. 5. Interlaminar shear strength (parallel samples) [11]

Rys. 5. Międzywarstwowa wytrzymałość na ścinanie (próbki równoległe) [11]

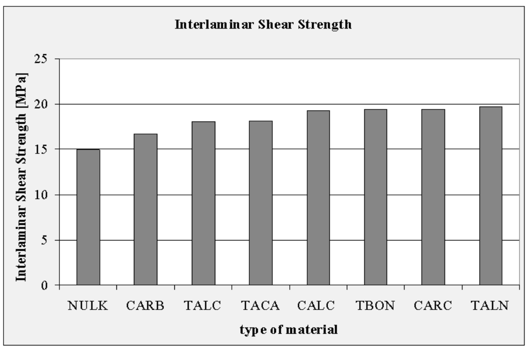

Fig. 6. Interlaminar shear strength (45 degrees samples) [11]

Rys. 6. Międzywarstwowa wytrzymałość na ścinanie (próbki pod kątem 45 stopni) [11]

CONCLUSIONS

The right decision regarding the use of one filler or other has to be taken after the complete analysis of all the properties. It is necessary to specify that the filler's concentrations were below the unit, based on conclusions of an anterior study carried out in our laboratory [12].

It is obvious that filling the epoxy resin the mechanical properties (at lest the ones regarding the bending) are improved. In the case of TACA materials the filler's concentration was double because we used both fillers in the same amount as in other samples. An interesting conclusion is that increasing the fillers' concentrations the bending apparent elastic modulus will be increased but the mechanical resistance is not very good. Regarding the bending mechanical resistance it can be noticed that the use of the talc leads to better results. Also, for the last two types of samples in which the resin layers are alternated we may say that the mechanical parameters are not changed. In this case important are the other properties (such as electromagnetic or thermal) in order to make the right decision.

It was our concern, based on known properties of kevlar and carbon fibers, to use the mixed fabric in order to evaluate the effects of fillers. The presence of distributed long kevlar fibers leads to a lower machining possibility. It is true that kevlar fibers ensure the impact resistance but, because of their machining resistance, the composite pieces or structures have to be directly formed, excluding post machining processes. Using fillers as carbon black or CNT in small amounts it can be obtained surfaces with better electric conductivities and using talc it can be obtained materials with harder cores. The use of the nanopowders might be the solution of properties control of the composites.

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