Polskie Towarzystwo Materiałów Kompozytowych
Polish Society for Composite Materials

Kompozyty 9: 2 (2009) 186-191

KOMPOZYTY
COMPOSITES

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Otrzymano (Received) 31.01.2009

SELECTED MECHANICAL PROPERTIES OF STRATFIED COMPOSITES WITH CNT FILLED MATRIX

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. These are the results of a trail-and-error study regarding the influence of fillers on the electrical (at first) and mechanical properties of reinforced composites with filled epoxy matrix. Two types of fiber fabric were used as reinforcements and ferrite, talc and CNT were used as fillers. 250 mm long, 120 mm wide and 5÷7 mm thick plates of composites were formed in glass moulds. Electrical standard tests and three point bending standard tests were performed.

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

WYBRANE WŁAŚCIWOŚCI MECHANICZNE KOMPOZYTÓW WARSTWOWYCH Z OSNOWĄ NAPEŁNIONĄ NANORURKAMI WĘGLOWYMI

Ponieważ celem projektowania kompozytów jest zastępowanie metali w różnych zastosowaniach, stawiane wymagania pociągają za sobą poprawę nie tylko właściwości mechanicznych, ale również elektrycznych i cieplnych kompozytów polimerowych. Wiadomo, że napełniane kompozyty polimerowe wykazują interesujące właściwości, zwłaszcza gdy napełniacze mają rozmiary nanomikrometrowe. W pracy przedstawiono wyniki, otrzymane metodą prób i błędów, wpływu napełniaczy na właściwości elektryczne i mechaniczne kompozytów z napełnioną osnową epoksydową. Zastosowano jako umocnienie dwa rodzaje tkanin, natomiast jako napełniaczy użyto ferrytu, talku i nanorurek węglowych. Kompozyty o wymiarach 250 mm długości, 120 mm szerokości i 5÷7 mm grubości formowano w formach szklanych. Przeprowadzono standardowe testy elektryczne oraz próby trójpunktowego zginania.

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

INTRODUCTION

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 electromagnetic properties of the composite depend not only on the electromagnetic properties of the components but also on quality and nature of the interface between the components and its electromagnetic properties. The word composite in the term composite material signifies that two or more materials are combined on a macroscopic scale to form a useful third material. The key is the macroscopic examination of a material wherein the components can be identified by the naked eye. Different materials can be combined on a microscopic scale, such as in metallic alloys, but the resulting material is, for practical purposes, macroscopically homogeneous, i.e., the components cannot be distinguished by the naked eye and essentially act together. The advantage of composite materials is that, if well designed, they usually exhibit the best qualities of their components or constituents and often some qualities that neither constituent possesses [1].

One question is if it is possible that a composite material can be, at the same time, a metamaterial [2]. 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. The powders can be dielectric as talc, clay or ferrites, magnetic active as ferrite, electric active as CNT or carbon nano-fibers. All these powders have effects on the electromagnetic properties and mechanical properties of the composite [3].

There exist many models regarding the mathematic description of electromagnetic properties of the bi-component composites [4, 5]. Also there are studies regarding the bounds of models [6]. Taking into account that not only the electromagnetic properties are important but also the mechanical and thermal properties, the design problem becomes almost impossible.

MATERIALS

A set of 10 different materials was realized in order to evaluate the influence of filler over the electric and electromagnetic properties of the composite materials. The results are showed in [7]. In order to identify the effects of reinforcement over composite's electric and electromagnetic properties, two types of samples were formed. Both types of samples have reinforcements of 13 sheets of simple type of fiber fabric. The mixed fabric is realized of alternate Kevlar and carbon fibers. The measurements were carried out according to [8].

For each type of reinforcement four types of matrix were realized by using filled epoxy resin in various setups. The samples were realized through layer-by-layer method. In this case the matrix was realized, each time, by using the same concentration of various fillers (CNT, Ferrite, Talc) but the filled resin was used in layers. In fact, the samples are named with four characters the first one denoting the type of reinforcement (K for Kevlar-carbon fiber fabric and C for carbon fiber fabric). The other three characters are denoting the epoxy's filler (C for CNT, F for ferrite, T for talc). Assuming the symmetry of reinforcement reported to mid-plane, there were used, for example, three layers of Ferrite filled epoxy (external layers), three layers of CNT filled epoxy (middle layers) and two of Talc filled epoxy (intermediate layers). So, the structure of the sample from the matrix point of view is 3F-2T-3C-2T-3F and for carbon fiber fabric reinforcement the sample is CFTC.

In the C-type samples there are alternate 0 degrees 45 degrees sheets of reinforcements wile in K-type of samples all sheets are placed such as fill and yarn are parallel. 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.

MEASUREMENTS

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 pressure jet machine. The tests were performed according to DIN EN ISO 10545-4 and travel and force were measured.

It was expected that using CNT as filler in the external layers of the samples the surface electric inductance to be decreased. In Figures 1 and 2 there are shown measured values of bulk inductance and surface inductance of all the ten samples. The presence of ferrite modifies the electric inductance of samples. Generally, one might notice that the profile on K-type and C-type is almost the same. The differences between them can be explained on the hypothesis of differences between reinforcements' properties. At the beginning, the use of the talc was intended in order to change the mechanical properties but its presence determines electric inductance decreasing. The electric capacitance, both for bulk and surface are showed in Figures 3 and 4. One of the main goals of this research is to find out a way to control the electro-magnetic properties of formed composites through changing fillers in various layers of the composite plate.

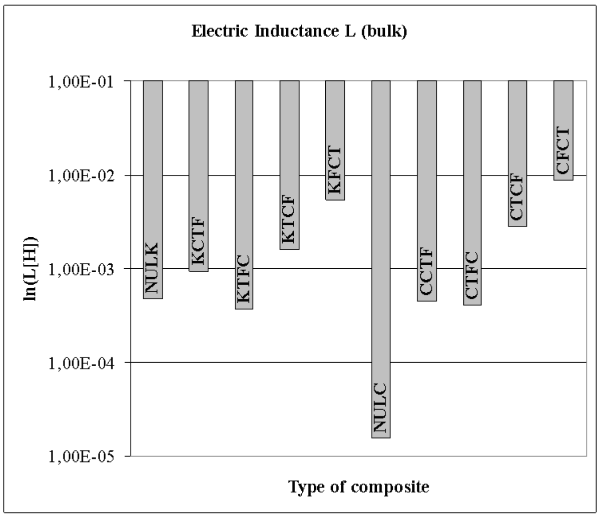

Fig. 1. Bulk electric inductance of formed materials

Rys. 1. Objętościowa indukcyjność elektryczna wytworzonych materiałów

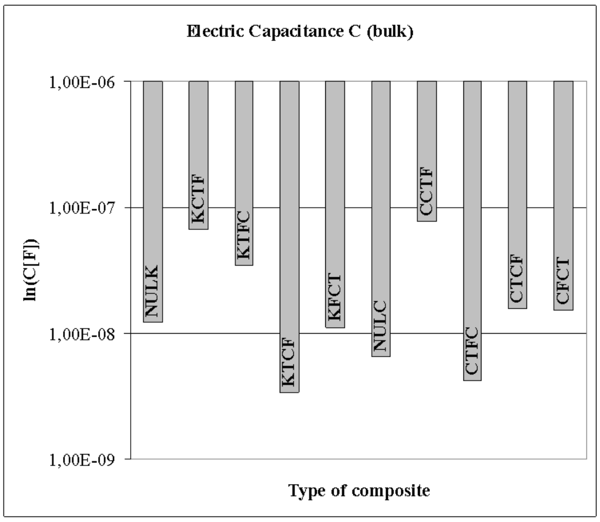

Fig. 2. Bulk electric capacitance of formed materials

Rys. 2. Objętościowa pojemność elektryczna wytworzonych materiałów

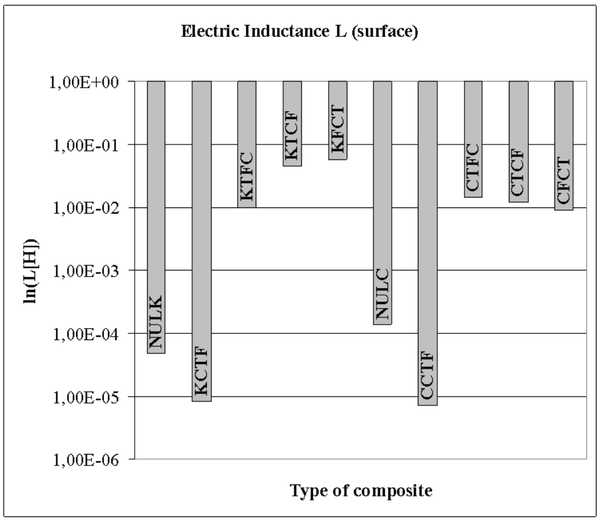

Fig. 3. Surface electric inductance of formed materials

Rys. 3. Powierzchniowa indukcyjność elektryczna wytworzonych materiałów

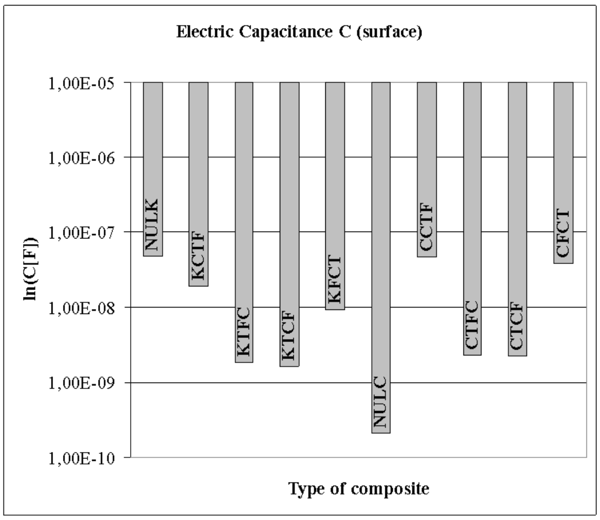

Fig. 4. Surface electric capacitance of formed composites

Rys. 4. Powierzchniowa pojemność elektryczna wytworzonych materiałów

Reason of use talc was to increase the thermal conductivity and the fire resistance of the composites but presented results show that talc presence could be a solution in order to modify the electro-magnetic properties of composites. A study regarding composites with two ore more mixed fillers is necessary because the presence of talc could attenuate the clusterization tendency of other fillers (ferrite, CNT).

RESULTS

Comparing the figures above one can notice that there are great differences between the force domains in the case of K-type and C-type samples (Figures 5 and 6). In our opinion, this fact is explainable through the fact that the C-samples have alternate reinforcement sheets, the odd ones have the warp and the fill parallel with the mould's edges while the even ones have the warp and the fill inclined at 45 degrees reported to mould's edges (Figures 7 and 8). In K-samples all the sheets have the warp and the fill parallel to the edges. We might say that in the C-type samples the degree of anisotropy is decreased. In both types of samples, it can be easily noticed the effect of external talc filled layers.

In order to emphasize the role of reinforcement sheets orientation, samples were cut along the yarn, across the yarn and such as the sample axis is oriented at 45 degrees relatively to the yarn direction. The results of three point bending tests shows that in the case of reinforcement sheets with alternate directions the degree of anisotropy is reduced. More than that, seems that the carbon fiber fabric reinforced composites have better mechanical properties than the ones with Kevlar-carbon fiber fabric, at least in the case of three point bending because it is well known that Kevlar reinforcements are used for chock resistant materials. Of course, in the case of kevlar-carbon reinforcement there exist two types of interfaces and that might be an explanation for the lower resistance if the hypothesis of first layer broken is taken into account [9].

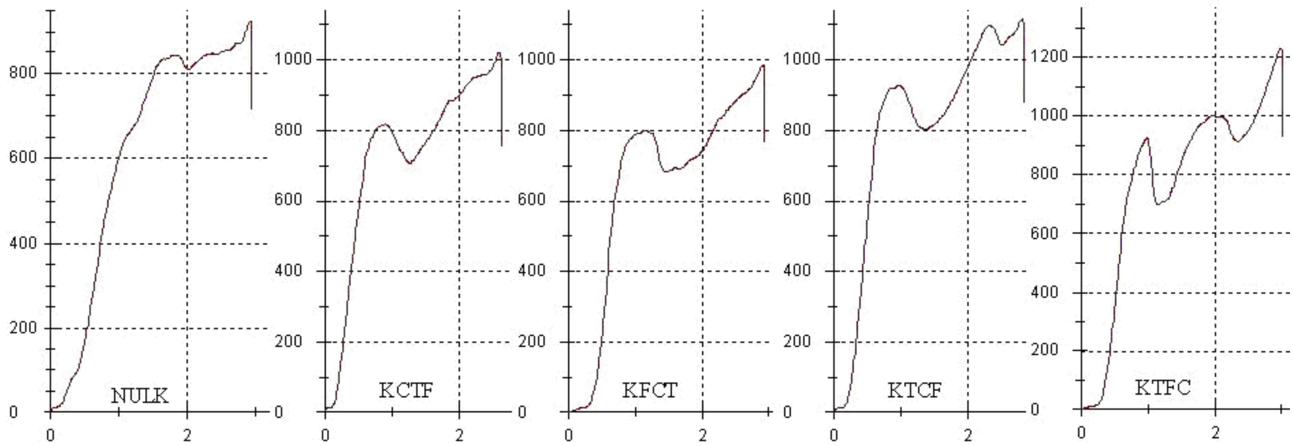

Fig. 5. Three point bending curves for the parallel oriented K-type samples (composed from individual curves); x axis: Travels in mm; y axis: Force in N

Rys. 5. Uśrednione krzywe trójpunktowego zginania dla równolegle zorientowanych próbek typu K, oś x - ugięcie [mm], oś y - siła [N]

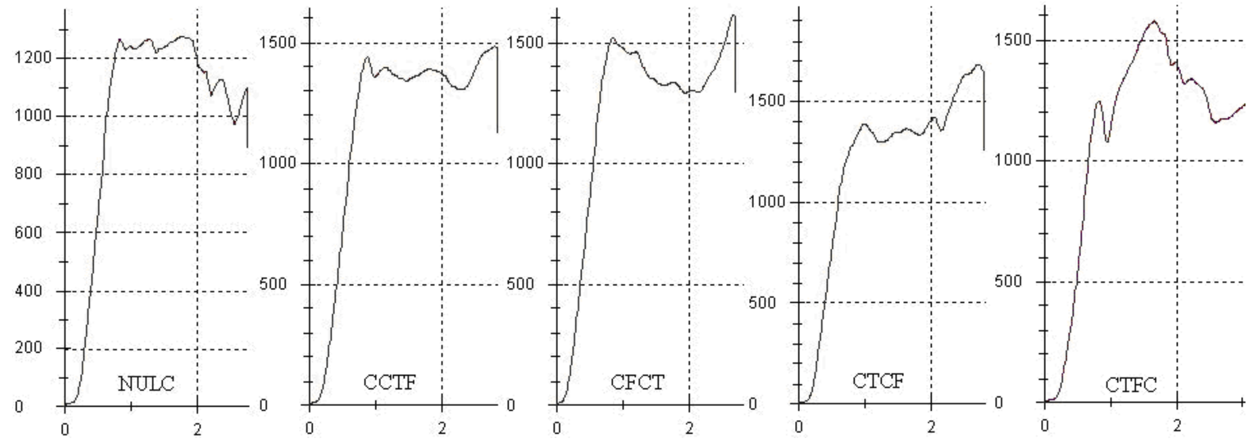

Fig. 6. Three point bending curves for the parallel oriented C-type samples (composed from individual curves); x axis: Travels in mm; y axis: Force in N

Rys. 6. Uśrednione krzywe trójpunktowego zginania dla równolegle zorientowanych próbek typu C, oś x - ugięcie [mm], oś y - siła [N]

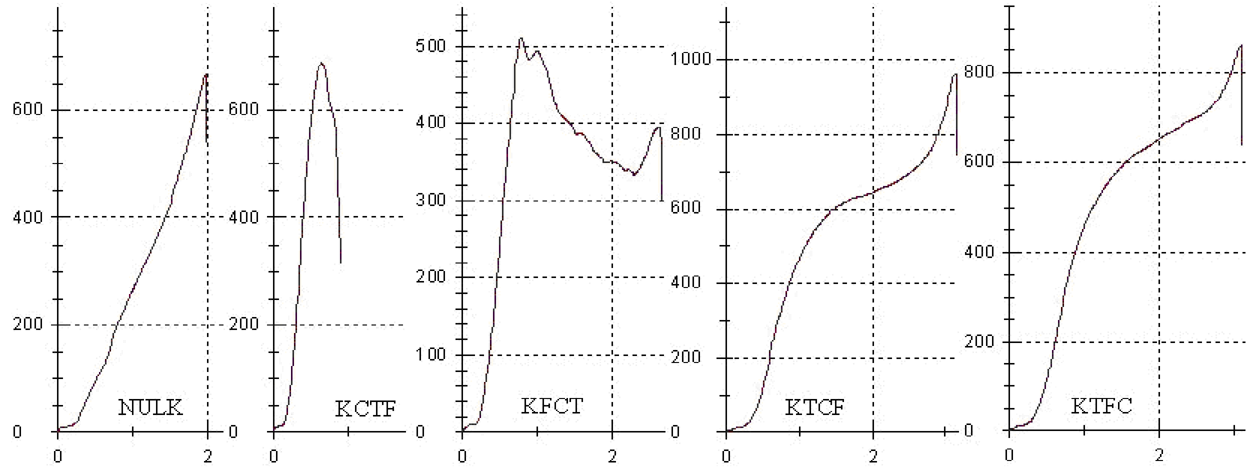

Fig. 7. Three point bending curves for the 45 degrees oriented K-type samples (composed from individual curves); x axis: Travels in mm; y axis: Force in N

Rys. 7. Uśrednione krzywe trójpunktowego zginania dla zorientowanych pod kątem 45 stopni próbek typu K, oś x - ugięcie [mm], oś y - siła [N]

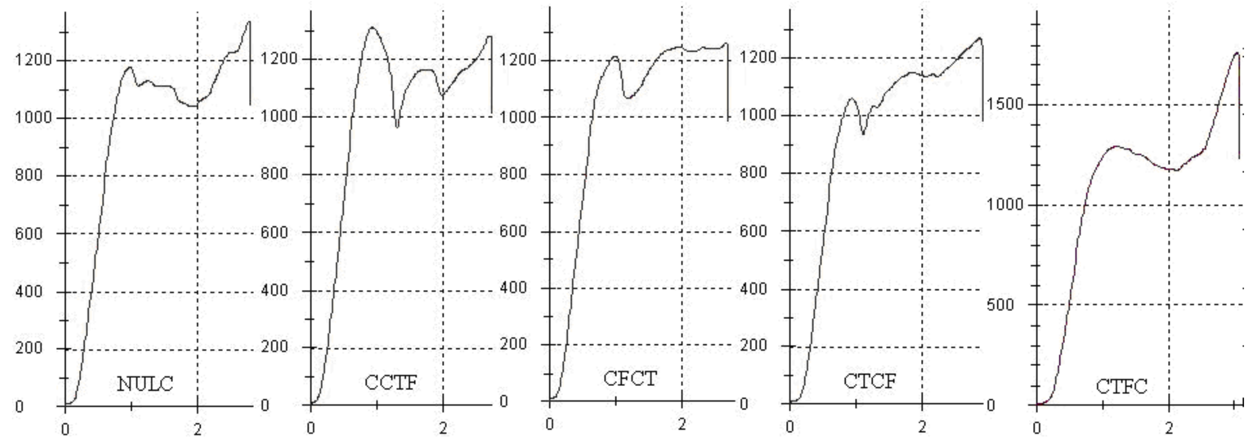

Fig. 8. Three point bending curves for the 45 degrees oriented C-type samples (composed from individual curves); x axis: Travels in mm; y axis: Force in N

Rys. 8. Uśrednione krzywe trójpunktowego zginania dla zorientowanych pod kątem 45 stopni próbek typu C, oś x - ugięcie [mm], oś y - siła [N]

CONCLUSIONS

Bending mechanical resistance and bending apparent elastic modulus are evaluated according to [10] (presented in Figures 9 and 10) while the interlaminar shear strength is evaluated according to [9].

Analyzing the above curves and below graphs, the main conclusion is the known one, regarding improving of mechanical properties by using various oriented sheets as reinforcement, a decrease of anisotropy [11]. Also we may conclude that the solution with more than one layer of filled matrix leads to weak results than the alternate layers one [12]. The carbon fiber fabric seems to be a better reinforcement solution in order to form strong composites. An impact analysis has to be performed in order to identify chock resistance of such materials. Also we intend to develop our research by forming kevlar-carbon fiber fabric based composites but alternating the orientations of the sheets. It is our concern that it can be found the better concentrations combination of two or more fillers, in the same polymer, in order to reach the intended properties of the final material. Thermal and thermo-mechanical analysis might be performed in order to refine the solution about composition and the architecture of pseudo-laminate plate. We use the term pseudo-laminate because in our case we cannot say that we used laminae in order to obtain the final laminate, in fact our reinforcement sheets cannot be treated as laminae.

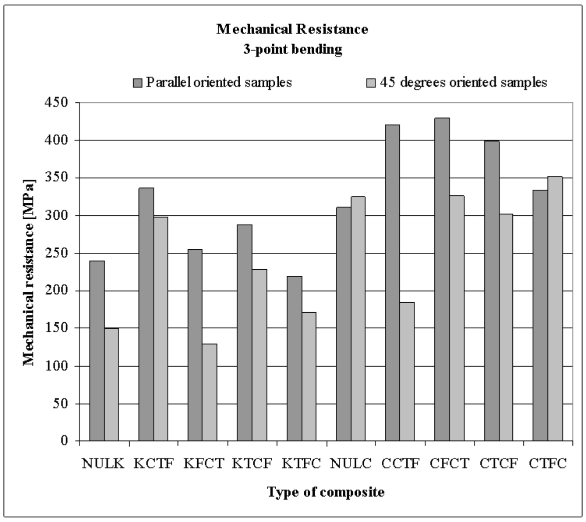

Fig. 9. Mechanical resistance (according [10])

Rys. 9. Wytrzymałość na zginanie (według [10])

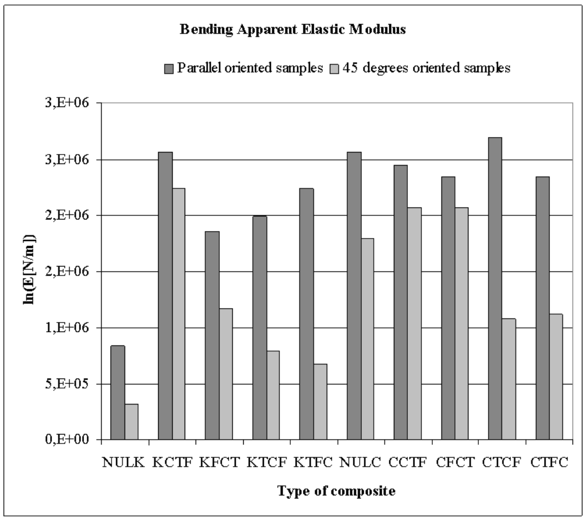

Fig. 10. Bending apparent elastic modulus (according [10])

Rys. 10. Moduł sprężystości wzdłużnej przy zginaniu (według [10])

Regarding Figures 11 and 12 it can be easily noticed that the composites with carbon fiber reinforcement show better values of the interlaminar shear strength, both for the parallel samples and the 45 degrees ones. This fact is explainable due to the presence of a single type of matrix-reinforcement interface and due to the alternate orientation of the reinforcement sheets. The best fabric reinforcement seems to be (as expected) the one with different orientations for the layers.

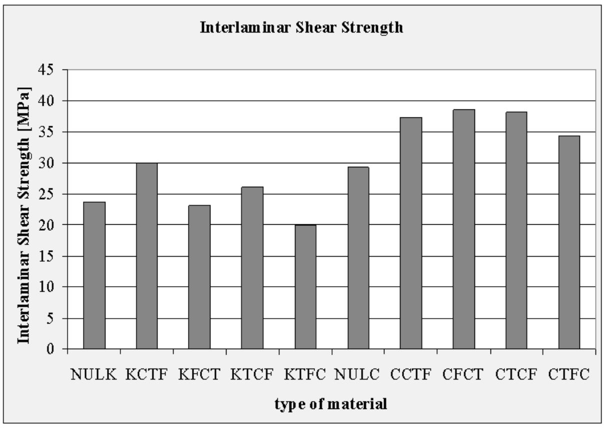

Fig. 11. Interlaminar shear strength (parallel samples)

Rys. 11. Międzywarstwowa wytrzymałość na ścinanie (próbki równoległe)

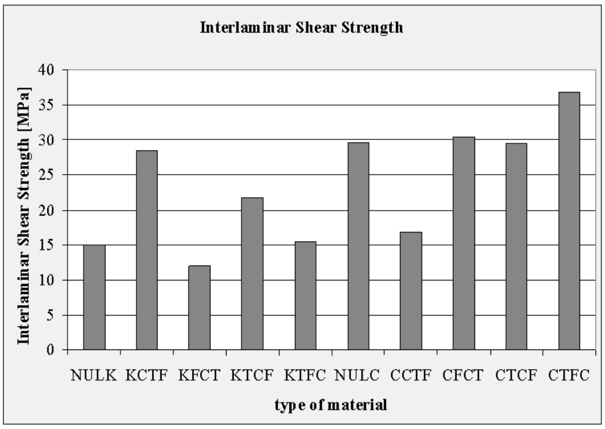

Fig. 12. Interlaminar shear strength (45 degrees samples)

Rys. 12. Międzywarstwowa wytrzymałość na ścinanie (próbki pod kątem 45 stopni)

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