INFLUENCE OF THE ADDITTION OF FUNCTIONALIZED MWCNT ON MECHANICAL PROPERTIES ON EPOXY/CARBON FIBER AND EPOXY/CARBON-ARAMID FIBER COMPOSITES

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Abstract:

We investigated the effect of the inclusion of carbon nanotubes (CNT) on the mechanical properties and wear behavior of epoxy/carbon and epoxy/carbon-aramid composites in this study. Epoxy/carbon and epoxy/carbon-aramid composites with 0 wt.% CNT and 0.3 wt.% CNT were manufactured by RTM, amino functionalized multi-walled CNT (MWCNT) were used to modify the matrix. Tensile, compression, two rail shear, Charpy impact tests and Pin On Disc (POD) were performed on the four composites. The EP/CAF composites showed better impact resistance than the ones containing carbon woven. The addition of CNTs improves the shear modulus in 5% for EP/CF composites and 6% for EP/CAF. The results also show that the dynamic friction coefficient is independent of the CNT content, and the specific wear rate shows no improvement with the selected test parameters.

Keywords: *Nanocomposites, mechanical properties, wear, RTM.*

1 Introduction

Fiber reinforced composites are the most studied materials to replace metallic components due to their high strength/weight ratio. Polymeric matrix, specifically epoxy matrix are the most used in the field. However, their mechanical properties are lower than the reinforcement.

Carbon nanotubes (CNTs) act as matrix modifiers and have excellent stiffness and strength, as well as mechanical, thermal, electrical and tribological properties. On the other hand, the dispersion on the matrix is a common problem that has been long studied by several authors. They tend to agglomerate due to their insolubility on other molecular species. Functionalization aims to minimize the agglomeration by forming functional groups on their outer wall that improves the interfacial interaction between CNTs and the matrix.

Wear has become a problem in the industry due to the cost of materials replacement, making tribological properties of composites of great interest. Several authors demonstrated the improvement on wear properties by the addition of CNTs [1].

The aim of this study is to improve the mechanical and tribological properties of epoxy(EP)/carbon fiber(CF) and EP/carbon aramid fiber (CAF) composites by incorporating amino functionalized multiwall carbon nanotubes (MWCNTs).

2 Experimental

Epoxy resin L20 bisphenol-A based and amine-based hardener EPH 161 were selected as the polymer matrix and were obtained from R&G, Germany. Two woven fibers were used in this research: carbon fiber twill weave 2/2 204 g/m^2 and carbon-aramid fiber till wave 210 g/m^2.

The amino functionalized MWCNTs NC 3152 employed in this work were purchased from Nanocyl S.A., Belgium, which were produced by the catalytic carbon vapor deposition (CCVD) method and specified with a 90% purity.

The CNTs were dispersed into the epoxy matrix by mechanical stirring for 10 min and subsequently by sonication with the Elmasonic P70H from Elma-ultrasonic, Germany for 1.5 h. at 80 kHz at controlled temperature of 30ºC. Finally, the hardener was added into the mixture at the resin to hardener weight ratio of 4:1.

The manufacturing technique was RTM at 4 Bar, and carried out at 40ºC in order to obtain low viscosity of the resin.

The composite was left to cure in a hot plate at room temperature for 24 h. and it was post-cured in an oven for 15 h. at 100 °C.

Two composites of each woven type containing 0 and 0.3 wt.% MWCNT were obtained from RTM process with a 50% fiber volume fraction.

2.1 Mechanical properties

Four mechanical tests were developed in order to characterize the materials: Tensile test, compression test, in plane shear two rail test and Charpy impact test. A total of 15 samples of each material were tested in order to obtain representatives measures.

The tensile test is performed according to the ASTM D3039. Samplesof 250x25x2.5 mm^3 were measured by Instron 8801 and Strain Indicator P3500 at room temperature. The ultimate strength (σ_r), elastic modulus (E), and Poisson coefficient (γ) were calculated.

The compression test is performed according to the ASTM D0695. Samples of 10x10x10 mm^3 were measured by Instron 8801 and Strain Indicator P3500 at room temperature. The ultimate strength (σ_{rc}) and elastic modulus (E_c) were calculated.

The in plane two rail test is performed according to the ASTM D4255. Samples of 150x75x1.5 mm^3 were measured by Instron 8801 and Strain Indicator P3500 at room temperature. The ultimate strength (σ_{rs}) and the shear modulus (G) were calculated.

The Charpy impact resistance is determinated with a simple beam (Charpy-Type) Impact machine. Samples of 10x10x57mm^3 [2] were tested at room temperature and the impact resistance was calculated.

2.2 Wear test

Square samples of 38,5x38,5x10 mm^3 were tested tribologically by a Pin On Disc (POD) test in a tribometer (High Temperature Tribometer, CSM) at the University of Liege, Belgium.

A minimum of three samples per configuration were tested in plane direction. The tests condition depends on the normal load, velocity, sliding distance and pin radius. Table 1 shows the parameters for the tests.

Table 1. Tests conditions

	Value
Normal load (N)	2
Sliding distance (m)	10.000
Velocity (m/s)	1
Tool radius (mm)	5

3 Results

The first comparison was established between the EP/CF and EP/CAF composite in order to determine the difference between both laminates. As shown in fig.1, the more significant differences are the lower specific wear rate (ὡ) of EP/CF in comparison to EP/CAF, due to the lubricant effect of carbon, and the impact resistance enhancement of EP/CAF composites. The other mechanical properties remain without important variations.

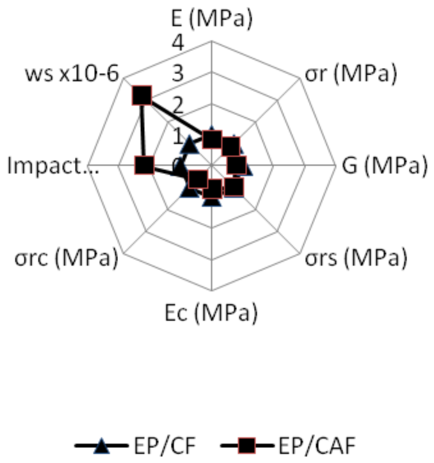

Fig. 1.Mechanical and tribological properties of EP/CF and EP/CAF composites.

Fig. 2 shows the effect of the addition of 0,3 wt.% CNT on the mechanical and tribological properties of EP/CF composite. As shown in this figure, the properties on the tensile test, such as Young modulus and ultimate strength, don't improve with the addition of CNTs. This is expected, due to the low influence of the matrix in this test. The two rail shear test shows an improvement of the shear modulus of 5%. Compression test shows that the compression modulus increases 7% and the ultimate strength increases 12%. Other properties don't show significant improvement due to the addition of CNT.

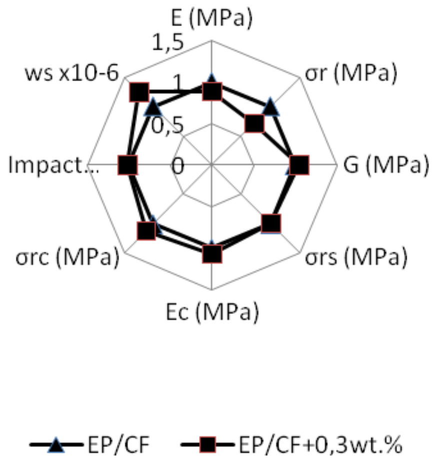

Fig. 2.Mechanical and tribological properties of EP/CF and EP/CF+0,3wt.% CNT composites.

Fig. 3 shows the effect of the addition of 0,3 wt.% CNT on the mechanical and tribological properties of EP/CAF composite. As mentioned in the preceding paragraph, changes on tensile test properties aren't expected. The two rail shear test shows an improvement of the shear modulus of 6% and 18% of the compression ultimate strength. Other properties don't show significant improvement due to the addition of CNT.

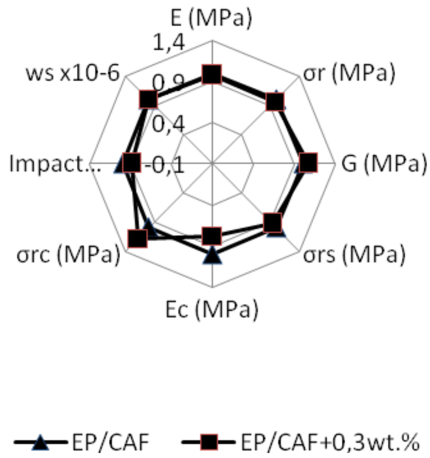

Fig. 3.Mechanical and tribological properties of EP/CAF and EP/CAF+0,3wt.% CNT composites.

Wear properties are shown in table 3, for all the configurations. Under the established conditions, the addition of a 0,3wt.% CNT on EP/CF composites did not produce the expected behavior of reducing the wear rate as in shown in fig. 4. The same phenomenon was observed with the addition of a 0.3wt.% CNT on EP/CAF composites.

The dynamic friction coefficient (μ) remains constant with the addition of CNT.

Table 3. Wear properties

	EP/CF	EP/CF +0,3%	EP/CFA	EP/CFA +0,3%
μ	0,363	0,343	0,321	0,346
$\dot{\omega}_s$ x10^{-6} (mm^3/N·m)	24,138	30,172	76,666	77,778
P·v (Mpa·m/s)	102,7	107,6	86,1	73

New Pin On Disc (POD) tests are being developed in order to evaluate the influence of the sliding distance, normal load and Pv condition on the specific wear rate. Longer sliding distances should show the autolubricant effect of CNTs on the composite.

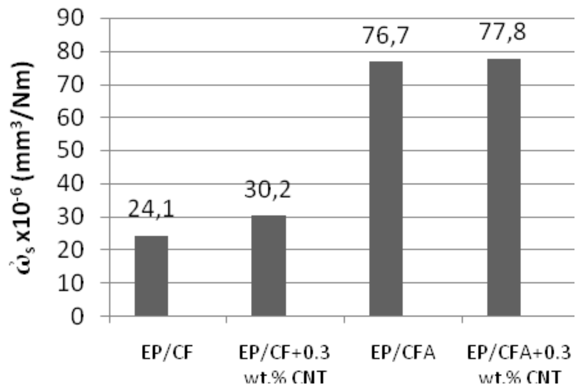

Fig. 4. Influence of CNTs on the specific wear rate.

4 Conclusions

The additions of CNTs to the matrix increase the in plane shear properties and compression properties for all woven types.

Tensile modulus and ultimate strength are not affected due to the low influence of the matrix in the tensile test.

The impact Charpy tests do not show any improvement on the impact resistance due to the addition of the CNT. Composites with hybrid woven have much better properties. This is associated to the aramid fiber.

Finally, the filler does not influence the wear properties with the test parameters used. A new investigation is being developed to evaluate the influence of the parameters on the specific wear rate.

References

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