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Development of Hybrids Composites of Carbon and Aramid Fibers to Reinforce Matrix of Epoxy Resins Part I

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Abstract: Composite materials may be composed of several types of fiber and resin. The design of hybrid composites intends to improve the physico-mechanical properties of this kind of materials, compared to standard composites, which consist of epoxy resin matrixes and carbon fibers, which presents low impact resistance. Our goal was the development and characterization of a hybrid material composed of two kinds of fibers, carbon and Kevlar, in the fabric format, joined by epoxy resin matrix. The standard composition is the Composition 1: containing 55%-60% carbon fiber and 40%-45% epoxy resin. The hybrid composite is the Composition 2: that contains 30%-33% carbon fiber, 25%-27% Kevlar fiber and 40%-45% of epoxy resin. The composite plates were prepared using a laminator machine and later they were process in a vacuum bag and cured in oven. The study aimed at comparing the physical and mechanical properties of these materials. The mechanical tests were focus on measurements of the tensile, flexural and impact charpy stresses, and physics tests by measures of bulk densities. Through these procedures, we hope to find out data that may be useful for a partial characterization of these products for applications in the aerospace industry.

Key words: Hybrid composites, fibers Kevlar/carbon, physical and mechanics properties.

1. Introduction

Composite materials can be made out of different types of fibers and resins. When composites have only one fiber type, there final properties of the composite are limited by these fiber properties. Resins are part of the matrix of these products and can be modified as convenient.

Nevertheless, changes on the matrix can bring undesired factors for the general properties of the composite.

So, modifications on the matrix properties maybe are not the best solution for certain problems [1, 2].

The development of hybrid materials containing more than one type of fiber can solve the problem above without affecting other desired properties of the composite that need to be preserved.

In general, the goal of bringing two types of fibers on a composite is to keep the advantages of both fibers and relief some disadvantages. For example, glass fibers instead of carbon fibers on a laminated can significantly reduce the cost, while bending properties remain almost unaltered [3, 4].

If a hybrid composite is introduced on the same direction of the fiber under tension, the more fragile fibers will fail before the ductile ones.

Therefore, fibers with high deformation properties can be combined with low elongation fibers in various different configurations, but there are three basic combinations that are the most important to be studied [5].

The simplest one in the interlayer configuration, where the layers of two types of fibers are deposited one above the other, in a layer-by-layer configuration as can be seen in Fig. 1a.

On the intra-layer hybrid, the two types of fiber as mixed on the interior of the layers as shown in Fig. 1b and in the third type the fibers can be weaved in the intra-yarn form as shown in Fig. 1c [6-8].

Literature data show that composites of carbon fibers reinforcing epoxy resin matrices have lower impact resistance when compared to materials of the

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same resin reinforced with Kevlar fibers [9, 10].

The development of hybrid materials can fulfill the need of tenacity to fracture and at the same time preserve physical properties of composites constituted of only one type of fiber.

This study intends to develop hybrid composite materials with more than one type of fiber, more specifically, carbon fibers and Kevlar fibers together by intra-layer process. Comparative data was obtained by mechanical essays between a composite with carbon fibers and the one with carbon/Kevlar.

2. Experimental Setup

2.1 Materials

The materials used for this research were based on available materials found on national market, in twill format prepregs for both composites. The average composition of composites were, Composition 1: Regular composition, with 55%-60% of carbon fibers and 40%-45% of epoxy resin. Composition 2: Hybrid composition, with 30-33% of carbon fibers, 25%-27% of KEVLAR® fibers and 40%-45% of epoxy resin. The fiber distribution on the hybrid composite was approximately 55% of carbon fibers on the weft and 45% of KEVLAR® fibers on warp. It must be noticed that both materials were made with the same resin and there were some differences on the relative amount of the resin on the matrix. The grammage of the fibers was also different, being 200 g/m² for the pure carbon composite and 220 g/m² for the hybrid composite. Despite the differences above, the proposed goals were reached by comparing the final products, as the interest was on verifying improvement or loss of some properties.

2.2 Fabrication Process and Tests

The prepregs, were laminated as plain plates with dimensions 300 × 300 and further dimensions imposed by the type of tests as will be presented through this article. This plates were placed on a vacuum bag and then in oven for cure in high temperatures. Specimen prepregs were laminated on subsequent layers and then placed at a vacuum bag at pressure of close to one bar and taken to the oven for cure at 150 °C.

3. Experimental Results

3.1 Measurements of Bulk Densities

The bulk density results were obtained through measurement and weighting of the specimens. The theoretical values were calculated by of the mixtures rule. The bulk density results compared with theoretical density showed just 6% difference, what can be perfectly predictable for the vacuum bag process. This reveals that both products were made under the same conditions of processing and with acceptable technical parameters.

3.2 Mechanical Properties

Mechanical properties of materials used on the research are on Table 1.

The data were obtained following ASTM protocol for the essays and were performed on at least five specimens for each type of essay.

For better visualization and understanding, there are graphics showing individual results on Figs. 2-4.

In Fig. 2 there are the results for comparative tensile stress resistance between the composite with only

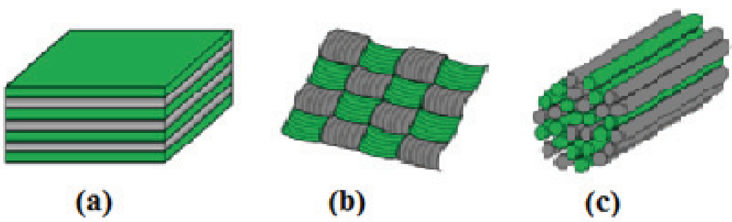

Fig. 1 The three main hybrid configurations: (a) inter-layer, (b) intra-layer, and (c) intra-yarn [3].

Table 1 Results of mechanical essays and their standard deviation.

Essays/materials		Carbon	Aramid/carbon
Tensile resistance	MPa	783 ± 29	526 ± 38
Flexure resistance	MPa	820 ± 34	577 ± 35
Charpy impact resistance	kJ/m^2	300 ± 54	872 ± 79

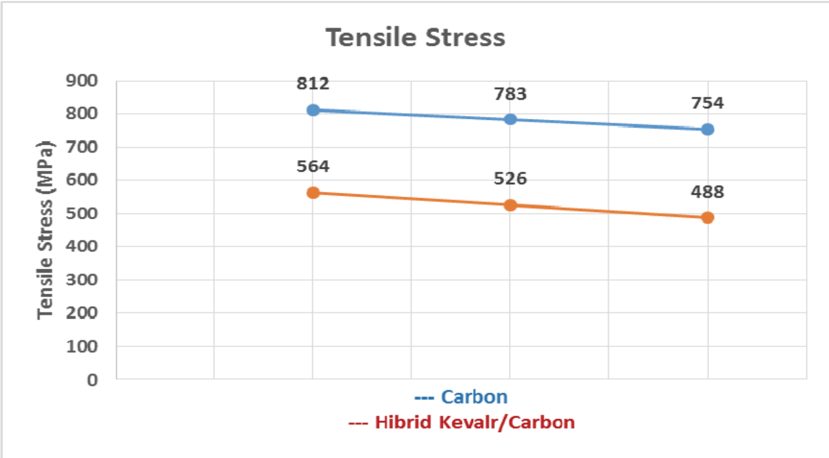

Fig. 2 Tensile stress and standard deviation.

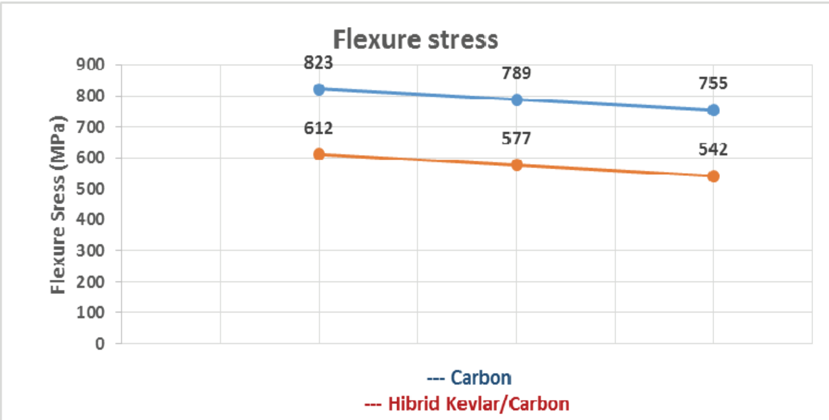

Fig. 3 Flexure stress and standard deviation.

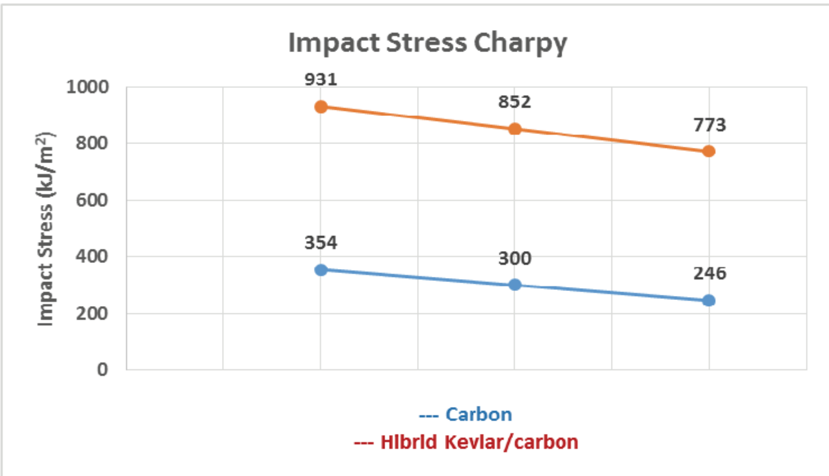

Fig. 4 Impact stress and standard deviation.

carbon fibers (in blue) and the one with carbon and aramid fibers (in red), both with their respective standard deviation.

There is a drop of 33% on tensile resistance of the hybrid material with aramid/carbon fibers compared with the carbon fiber material.

Analyzing the data from Fig. 3, it is noticed a decrease of 27% on flexure resistance of the hybrid material compared to the one with pure carbon fibers.

Through data analysis of impact resistance (Fig. 4) it is verified an inversion of the material impact properties, where the material with aramid fibers and carbon fibers shows an increase of impact resistance 282% greater than the material with only carbon fibers.

This result is very significant for the materials studied on this research because it allows us to say that varying only one part of the volumetric fraction of the fibers on a matrix can significantly vary the impact properties, without great losses of other properties like flexure and tensile resistance.

4. Conclusions

The results obtained showed that it is possible to modify the mechanical properties of composite materials by hybridization without great loss of other desired properties.

This work opens great perspectives for most areas of knowledge because other compositions with higher or lower quantities of aramid fibers on hybrid weaves can have no deleterious effects on materials of this class. This is true even for applications where its goal is to improve the resistance to impact properties, as it is the case for composite materials for aeronautic industry. Other compositions must be studied in order to maintain original properties of carbon fibers composites with addition of fewer aramid fibers and also with another distribution of the fibers on the weave.

Future research on this area should be, developed in our institution.

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