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Performance Mechanical of Polyester Composites Reinforced By Plain Woven Based On Aramid Fiber

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ABSTRACT

This study investigates the mechanical properties of aramid woven fabric fiber reinforced polyester composites. Composites made of fiberglass, carbon fiber, and aramid fibers are widely accepted in the composites industry due to their high specific strength, high specific modulus, and excellent chemical resistance. However, the mechanical strength of these composites is closely related to the orientation of the reinforcement provided by high-performance fibers and the interaction between the fiber and polymer matrix. This research aims to develop plain-woven fabrics using a handloom machine and evaluate their efficiency in enhancing the mechanical performance when reinforced with polyester resin. Tensile testing was conducted on the developed composites, and the fracture surfaces were analyzed using scanning electron microscopy. The results present that the addition of reinforcement in the resin significantly improves the tensile strength of the composites. The influence of fabric structure and test direction on the mechanical behavior of the composites is also discussed. Overall, this study provides valuable insights into the design and performance of aramid woven fabric fiber reinforced polyester composites.

Keywords: aramid fibers, woven fabric, polyester composites, mechanical properties, reinforcement

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I. INTRODUCTION

Within the composites industry, woven, knitted and nonwoven reinforcements made of fiberglass, carbon fiber and aramid fibers are now widely accepted as technical textile products. Composites can satisfy design requirements that often cannot be met by traditionally used engineering materials such as steel and aluminum [1;4].

High specific strength, high specific modulus and excellent chemical resistance are attractive properties that polymer composites offer when, compared to metallic materials. However, due to the anisotropic characteristics of the material, the mechanical strength is closely related to the orientation of the reinforcement provided by high-performance fibers, where the mechanical strength is given in the same building material, distribution and interaction between fiber and polymer matrix [3-5].

Mechanical strength and stiffness exhibit variation depending on the type and orientation of the building structure and the proportions of the component materials. When considering a fabric, the properties of the fibers and yarns essentially determine the properties of the fabric. Geometric criteria such as the weave structure of the fabric or the knitted or nonwoven construction, the coverage factor, and the yarn crimp in woven fabrics must also be considered. [2-5].

The plain woven is formed by the interlacement of two sets of threads, namely, warp and weft threads. These threads, are interlaced with one another according to the type of weave or design. The warp threads are those that run longitudinally along the length of the fabric and the weft threads are those that run transversely across the fabric. The density of weft and warp fibers and the direction of fabric determine the cover factor of woven. [2,3, 5]

The major problem observed by scientists, technologists and manufacturers are associated with resin adhesion to textile fabrics. The problem is that nearly all fabrics are designed to be flexible and may be deformed with relatively low levels of loading stress. Considerable stress is put upon any adhesive joints between the coating and the textile, and ideally the coating must deform and recover with the textile, if a satisfactory performance is to be obtained [1,5-9]. The incorporation of different types of fibers into a single matrix has led to the development of hybrid composites. In this case, the behavior of hybrid composites is a consequence of the combination of individual components in which, there is a more favorable balance between the inherent advantages and disadvantages. Also, using a hybrid composite that contains two or more types of fiber, the advantages of one type of fiber could complement with what is lacking in the other [10-16].

Therefore, a balance in cost and performance can be achieved through proper material design. The properties of a hybrid composite mainly depend upon the fiber content, length of individual fibers, orientation, extent of intermingling of fibers, the interface, and the structure of woven. [1, 3, 6, 8-14]

The strength of the hybrid composite is also dependent on the failure strain of individual fibers. Maximum hybrid results are obtained when the fibers are a highly compatible strain [1,4,5, 15-19].

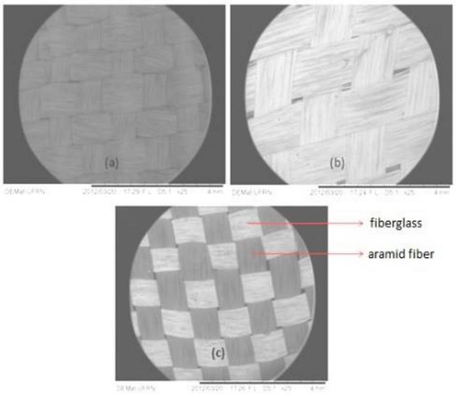
The aim of this work is the development of plain-woven using handloom machine and evaluation the efficiency of fabric composition on mechanical performance when reinforced with polyester resin.

II. EXPERIMENTAL

The material under study was developed in laboratory scale using handloom machine for producing aramid fabrics (Fig 1a) using structures of plain woven represented by Figures 1 and 2.

Figure 1- Handloom process (a) warp process; (b) handloom machine;

Figure 2 – Structure of fabric produced



Two structures of fabrics were produced in laboratorial scale with the following compositions (Figure 2): a) Aramid (CTA composite); c) Aramid/E-glass fiber 65/35 (CTH composites). Commercial fiberglass fabric was also used (b). The laminate was made of layers of biaxial fabrics produced using Aramid fibers supplied for Dupont, hybrid structure Aramid/E- glass fibers and commercial fiberglass fabric in a matrix of Polyester resin (Table 1). The stacking sequence of the laminate consists of three layers of biaxial fabrics and the volume fraction was 35% and is estimated by the manufacturer by the usual weighting method. Layers of fabrics cut with the mold dimensions (200x150 mm) were aligned and disposed in the mold to produce composites using compression molding under 5 tons for 4 h at room temperature.

The composites with similar fiber contents in warp direction (aramid fiber) were obtained, although the fiber content in weft direction was varied as function fiber composition into structure of the fabrics.

Table 1 - Technical sheet of fabrics and composites

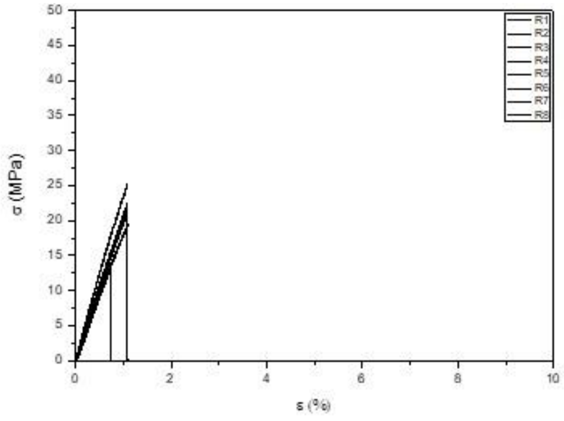
FABRICS		TEX		GRAMATURE
Sample	**Composition**	**Warp**	**Weft**	
UP	Polyester resin			
CTA	100% Aramid	110	110	251 g/m^2
CTH	65% Aramid/35% glass	110	75	216 g/m^2
CTV	100% glass	102	102	130 g/m^2

Tensile testing was carried using SHIMADZU AG-X 300 KN, at room temperature and 1 mm/min test speed and pre-tensile 1 Kgf, along the warp and weft direction out according to ASTM D 3039 standards The fracture surfaces are evaluated using Hitachi TM1000/TM3000 Tabletop Scanning Electron Microscopes operating at 15 kV.

III. RESULTS AND DISCUSSION

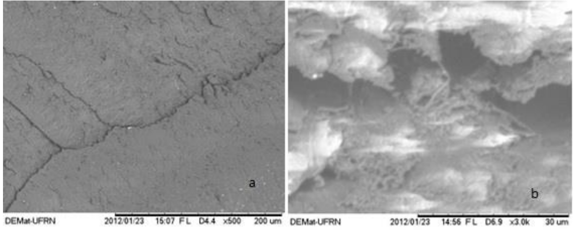
The results obtained for the matrix will be discussed and these results will be correlated with the main parameter the influence of the reinforcement structure on the mechanical behavior of the composites. As a supplementary consideration, the evaluation of the fracture surface of the specimens and the evaluation of the fiber/matrix interface through scanning electron microscopy.

Figure 3- Tensile properties for polyester resin



Analyzing the Fig.3 it was observed that the polyester matrix (UP) shows a fracture behavior characteristic of a brittle material. That behavior was corroborated by the analysis of the fracture surface obtained with SEM, as shown in the Fig.4. The average value of deformation of the samples tested was approximately 1.2% with an average tensile strength of 20 MPa.

Figure 4 – SEM surface fracture of the bare matrix after tensile test (a) 500X; (b). 3000X



Analyzing the images presented in Figure 4(a), cracks propagation observed in several directions indicate that this material presents a typically fragile fracture. This behavior is expected, considering that this resin is a thermoset material. Where the bonds for the formation of the polymer structure occurs through covalent bonds in the main chain and between chains, thus forming a three-dimensional structure. In fact, this can be observed in Figure 4(b) in which a surface morphology, detail of the crazes like scale. This morphology as a characteristic of the thermoset resins.

Figure 5. Tensile properties for CTV composites

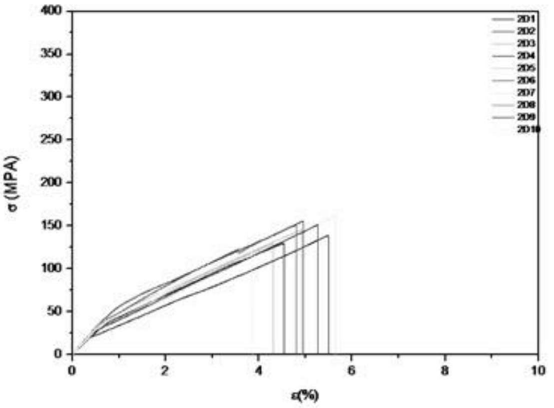


Figure 5 shows the results of the mechanical test of the composite reinforced with fiberglass fabric (CTV). The results of the tensile test indicated that this composite obtained a tensile strength in the order of 140 MPa, with a deformation of approximately 5%. When comparing these results with the ones obtained with the UP matrix, it is observed that the addition of 35% of reinforcement in the resin was promoted. An increase of resistance in the material in the order of 86%. This behavior was expected considering that the literature reinforces the efficiency of the use of glass fiber as a reinforcing thermoset resin

Figure 6 showed fracture surface of the CTV composites.

Exploring Figure 6a it was possible to observe the good interface between fiber reinforce and the polyester resin. In the figure 6b an open interface is highlighted. This behavior is due to the fabric structure. In this case, a dislocation of a group of fibers in the polyester matrix, is observed, resulting in the interlacement structure. This fabric owns the same fibers in all directions, i.e, warp and warm. It also can be observed that fracture surface of glass fiber as brittle. The efficiency of configuration of the reinforcement in the CTV composites it is demonstrated throughout these analyses.

Figure 6- SEM images of fracture surface for CTV composites after tensile test. (a) 500X; (b). 2000X

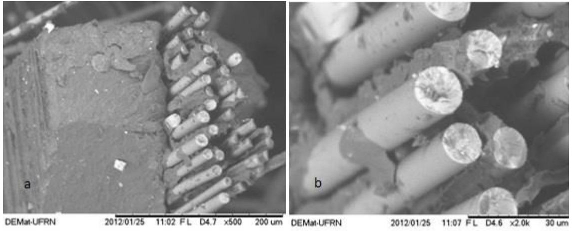
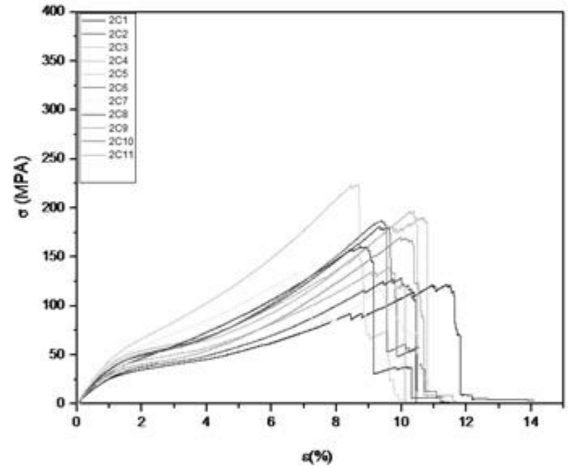


Figure 7 shows the influence of Aramid fabric reinforced polyester composite (CTA). The data reported in the graph: stress x strain indicates that the average stress of rupture was about 180 MPa, with a strain of about 11%. This corresponds to an increase of approximately nine times of tensile rupture, when compared to the polyester matrix.

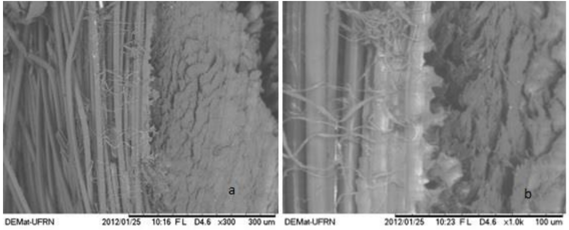
Figure 7. Tensile properties for CTA composites



It was also possible to observe the phenomenon of flow in same specimens. This behavior being attributed to the mooring structure of the fabric, i.e., weft direction, stabilizes the structure resulting a rigidity in the structure, thereby raising failure stress to the composite. For these samples, delamination was observed over the tensile test.

SEM analysis of the fracture surfaces reported in the Fig. 8 showed that the aramid yarn did not suffer any strain, but the form of rupture was fibrillar. It is also possible to observe a slight coating of the fibers by the matrix, despite the opening interface (b). This behavior can be attributed to the large difference in mechanical properties of the aramid fibers when compared to the matrix, and the interlocking structure of the fabric.

Figure 8- SEM images of fracture surface for CTA composites after tensile test. (a) 300X; (b). 1000X



The results presented in Figures 9 and 10 showed the influence of fabric structure and direction of the test under tensile properties of the composites developed. In this case, the results are compared with the graph of the figures, 5 and 7.

For the hybrid composites (CTH) the sample was tested in the warp and weft directions, as shown in Figures 9 and 10.

Figure 9. Tensile properties for CTH composites tested in the warp direction

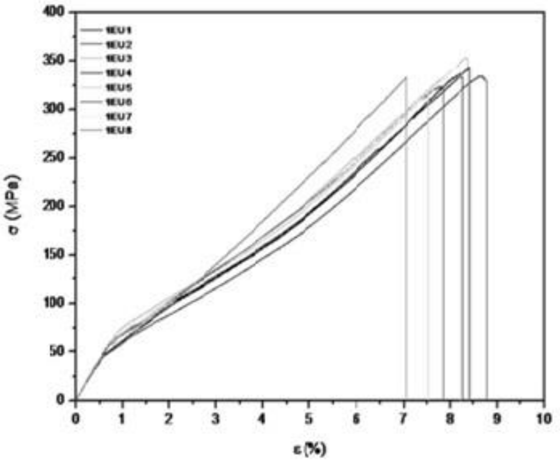
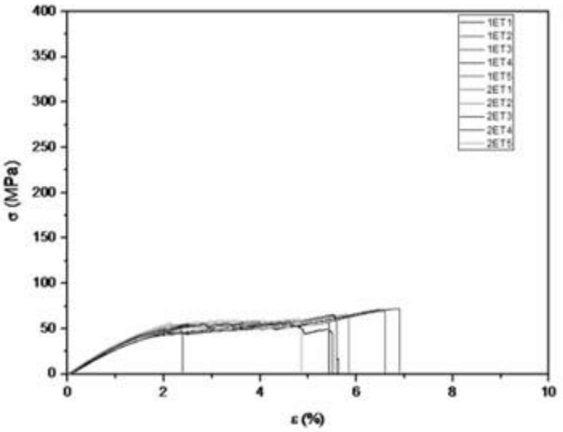


Figure 10. Tensile properties for CTH composites tested in the weft direction



The best results were obtained in composites tested in the warp direction, ie, Aramid fiber (fig 9). That behavior was expected when considered the fiber structure although delaminating of samples was verified. Comparing the values of tensile strength of the composite CTH tested in warp direction with CTA composite, is observed an increase of about 100% in the resistance using a hybrid fabric with the same structure as Aramid fabric. Is worth emphasizing that the content of aramid fiber in the composite CTA is approximately 36%, while for the CTH composite reinforcement content is 31%, where the content of this composition aramid is only 19.7%. This fact is an indication that although this material has a lower content of aramid, the existence of the glass fiber composition of 11.3%, the anchor structure of the fabric gives the material a better resistance due to better interface this fiber polyester matrix. When observed the behavior for the tensile tested in weft direction, i.e glass fiber, the result presented low resistance (Fig10). This result may be attributed to the low content of fiberglass in the fabric, 11%. In addition, the glass fiber is more brittle when compared to Aramid fiber, therefore considering the low fiber concentration in the fabric, this behavior was expected. When compared the mechanical behavior of the hybrid composites (CTH) with the CTA and CTV, it becomes evident the influence of the test direction on the strength of the material, since when the composite was tested in the warp direction, the tensile strength was approximately 350 MPa with an average strain of 8.5% while in the weft direction the values obtained for the strength and strain were respectively 50 MPa and 5.5%.

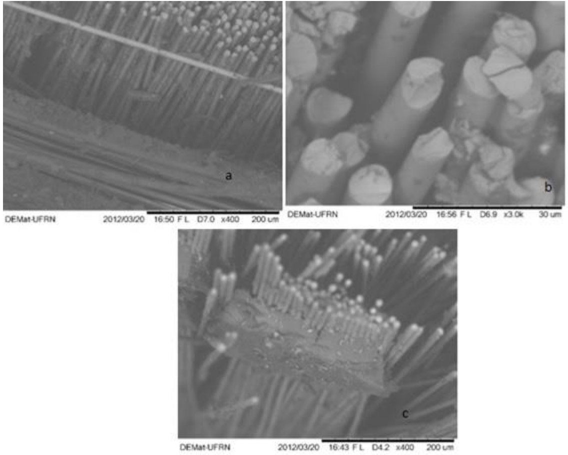
These results, as an indication that when a hybridization is processed in the structure of the fabric, there is a great possibility of combination of the individual properties of each fiber. this behavior so that the fabric will present an anisotropic behavior, different from fabrics composed by one type of fiber that are isotropic. This behavior can also be explained in view that the anisotropy characteristic of the plain fabric, where the use of the continuous fiber reinforcement as a reinforcement element confers a directional character (anisotropy) to the properties of the composites (OCHOLA et al., 2004).

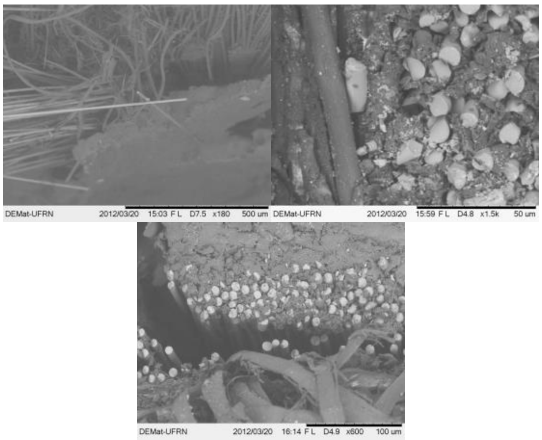
It was also observed that for the hybrid composites, the interface between the fiber and matrix components and associated with fabric composition, is a decisive factor in the properties of samples tested. This behavior as can be seen in the SEM images presented in Figures 11 and 12.

Analyzing SEM micrographs of the composite CTH tested in the warp direction, Figure 11, it was observed that during the application of tensile stress, the aramid fiber shows a fibrillar behavior (a), similar to the composite CTA, however the glass fibers contained in the composite structure are brittle. In images (b) and (c), where the magnifications are larger, it is possible to see the matrix coating on the aramid fiber and the homogeneous fracture of the glass fibers. Another behavior observed on the fracture surface of the tested specimen is related to the glass fibers that remained grouped in the same position, indicating that this composite is not delaminating.

With respect to the images of the fracture surface of composites tested in the weft direction (Fig12), it is possible to observe that in this direction the aramid fibers do not suffer deformation or fibrillar rupture. In this case the fiber acted only as an element of support glass fibers, since these fibers are intertwined with each other during formation of the fabric. This fact shows the influence of the composition and design structure of the fabric in the properties of the composites.

Figure 11 – SEM images of fracture surface for CTH composites after tensile test. (a) 400X; (b). 3000X; (c) 400x





IV. CONCLUSION

For textile fabric reinforced composites, the hybridization of fabric structure plain weave becomes viable in terms of mechanical properties and cost of the product. In this case, better properties are obtained when the application of stress occurs in the warp direction (aramid fiber).

The produced aramid fabrics (CTA) showed good mechanical performance. However, the hybrid fabric produced, despite having a low aramid content when compared to the CTA, the tensile properties were superior when tested in the fiber direction. These results obtained are an indication that the hybrid fabrics of low grammature, considered light, are a feasible option in the face of the lower cost.

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