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MECHANICAL PROPERTIES OF POLYPROPYLENE MATRIX COMPOSITES WITH JUTE FIBER FABRIC

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Summary: *In recent years the polymer matrix composites reinforced with fibers have aroused the interest of companies operating in segments such as automotive, construction, among others. Thus, for this study was molded by hot compression some types of composites using thermoplastic polymeric matrix and fibers of jute. For this were used a hydraulic press and a metal mold in which the materials were inserted, in case the thermoplastic matrix of polypropylene (PP) added with 30% grafted PP with maleic anhydride, and jute fabrics in the case of molding of composites. After, the molding materials were cut for tensile and flexural tests in a universal mechanical testing machine. The results of the tensile and flexural tests showed increases in some mechanical properties of the composite, such as strength values, maximum tension and deformation, mainly for composites PP matrix with two layers of fabric jute in flexural tests as compared to PP matrix without jute fabric.*

1. INTRODUCTION

Polymeric materials have many uses in our daily lives and they can be classified in relation to their end applications. Among many commodity polymers can be detached polypropylene (PP), a thermoplastic with features provide optimal performance in relation to cost-effective as it is a polymeric material of low cost, rapid processing, while also reducing costs related to energy and time. [1,2]

The polypropylene (PP) can also be used as matrix composites, allowing a variety of technological applications since it introduces some mechanical properties equivalent to those found in thermoset polymers, but with the advantage of enabling recycling. [1,3]

For some years, the use of thermoplastic matrix composites reinforced with natural fibers have been highlighted because they are a renewable and biodegradable materials besides the favorable properties of potential in industry due to their easy processing. Furthermore, natural fibers generally exhibit low cost when compared with synthetic fibers [4].

The development of composites using natural fibers has increased in recent years, also aiming to minimize environmental impacts. In the technical manufacture of component parts, polymers reinforced with natural fibers are increasingly important, in addition to also advantageous for obtaining carbon credits. Such composites containing polymers and natural

fibers, when compared to composites containing glass fibers, for example, reduce the emission of CO_2 into the atmosphere during its processing cycle, use and production. [4][5][6]

In this work, during the process of definition of materials to be used, a thermoplastic matrix consisting of 70% polypropylene (PP) and 30% Polypropylene grafted by weight was prepared. As vegetable fiber, jute fiber fabric was chosen because jute is one of the best-known fibers and cultivated worldwide and presents suitable properties for use in various types of parts or automotive components. [7]

Finally to compare properties of the polymer matrix with the properties of the composite containing jute fiber fabric, molded plates were cut into test specimens, which were submitted to the tensile and flexural tests in universal testing machine.

2. EXPERIMENTAL

Materials

As composite reinforcement layer was used jute fiber fabric with plain weave type arrangement, yarn weight of approximately 230 g/m^2; available in UFSCar/Campus Sorocaba/Brazil. As the thermoplastic matrix was used the mixture in the proportion of 70% by weight of PP (*Braskem*) in pellets, with 30% PP grafted with maleic anhydride (PP-AM), trademark *Poly Bond* 3150, *Chemtura*.

Molding and Conditions of Tensile Test

The compression molding of materials was done in a hydraulic press, *Marconi*, model MA098 A/E using a rectangular metal mold of dimensions 127 mm of width x 248 mm of length and 3 mm of thickness.

For comparison mechanical properties was molded a thermoplastic matrix PP (70 wt%) containing 30% PP-AM. Using the same proportion of matrix to PP PP-AM, plates were molded composites containing single and double layer of jute fiber fabric, respectively.

During molding, the mold was heated to a temperature of 190 C and a molding force of 5 tons. The molding time was 50 minutes and the mold under pressure to the continued cooling. Subsequently, the plates (Figure 1) were removed from the compression mold. The same molding procedures were performed for each type of molded material.

For subsequent tensile tests, the specimens were cut into the dimensions 250 mm of length and 25 mm of width in accordance with ASTM D3039 [8] and a thickness of 3mm. The cutting of the specimens was performed with use of a cutting band saw machine, *Baldan*, SF-2 model.

For the tensile tests was used a universal machine *EMIC-INSTRON Brasil*, DL 30000N model, 20KN load cell and test speed of 5 mm/min (Figure 2). The test data were sent to the Tesc software (version 4.3) available in Testing Laboratory and Material Characterization (LECMat) UFSCar/Campus Sorocaba/Brazil.

In order to enable comparison of mechanical properties of composites, all tests were performed under the same technical conditions.

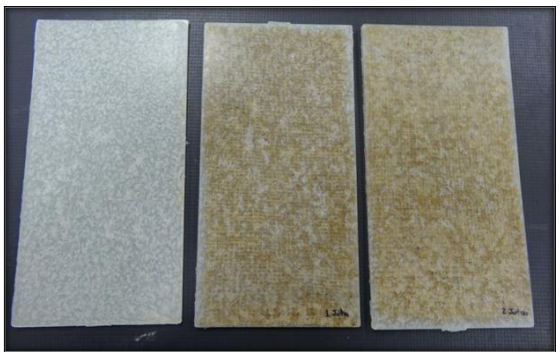

Figure 1: Molded of PP/PP-AM without jute, one and two layers of jute fabric, respectively.

Figure 2: Tensile test of a specimen of PP/PP-AM containing 2 layers of fabric jute fibers.

Molding and Conditions of Flexural Test

The molding of the materials used in the flexural test was similar to the molding materials for the tensile test. Initially three plates were molded thermoplastic matrix containing 70% PP and 30% PP grafted. Subsequently, the other six plates were molded, three containing only one layer of jute fiber fabric and the other three with two layers of jute fiber fabric.

Compression molding technique was used in a hydraulic press and another metal mold (180mm of length x160mm of width and 5mm of thickness). The molding conditions (temperature, time, molding force) were the same as mentioned in the previous item. Subsequently, the plates were removed from the mold and were cut test specimens of dimensions 127mm in length and 12.7 mm in width (Figure 3), according to ASTM D790. [9]

The flexural test was carried out in the universal machine EMIC DL 10.000N (Figure 4). The test speed was defined by the formula: $R = zL^2/6d$ where R is the speed (mm/s); L is the distance between the support expressed by 16 times the thickness of the specimen (mm); d is the thickness (mm) of the specimen; z is a constant value of 0.01, according to ASTM D790 [9].

Figure 3: Photography of PP/PP-AM matrix composite specimens containing 2 layers of jute fibers fabric for flexural test.

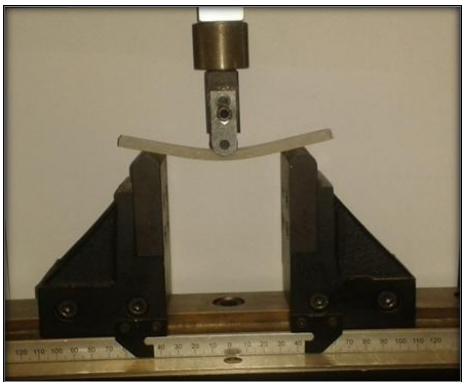

Figure 4: Photography of a specimen in flexural test.

3. RESULTS AND DISCUSSION

The results of the tensile tests are summarized in Table 1, which corresponds to the average and standard deviation of the results of 10 test samples for each type of molded material.

Jute Fabric	Maximum Force (N)	Maximum Resistance (MPa)	Maximum Deformation (mm)	Modulus of Elasticity (MPa)
0	924.90 ± 212.50	12.33 ± 2.83	2.44 ± 1.08	1067.00 ± 99,00
1	1417.00 ± 244.00	18.89 ± 3.25	4.37 ± 1.60	824.60 ± 330,30
2	1901.00 ± 370.50	25.35 ± 4.94	4.82 ± 1.02	1006.00 ± 456,00

Table 1: Comparison of average and standard deviation of some mechanical properties obtained in tensile tests.

In Table 1 it can be seen that the PP matrix composite containing a single layer of jute fabric showed approximately 53.20% increase in the value of maximum resistance and 79.10% increase in the amount of maximum deformation, as compared the results of tensile tests without the jute matrix (Table 1).

Regarding the mechanical properties of the matrix without jute, PP matrix composite containing two layers of jute fiber fabrics (Table 1) showed an increase of approximately 105.60% of the maximum resistance value and 97.54% in the amount of maximum

deformation. For better visualization of some mechanical properties was plotted (Figure 5) the results of tensile tests obtained with the PP matrix and composites containing one and two layers of jute fiber fabric.

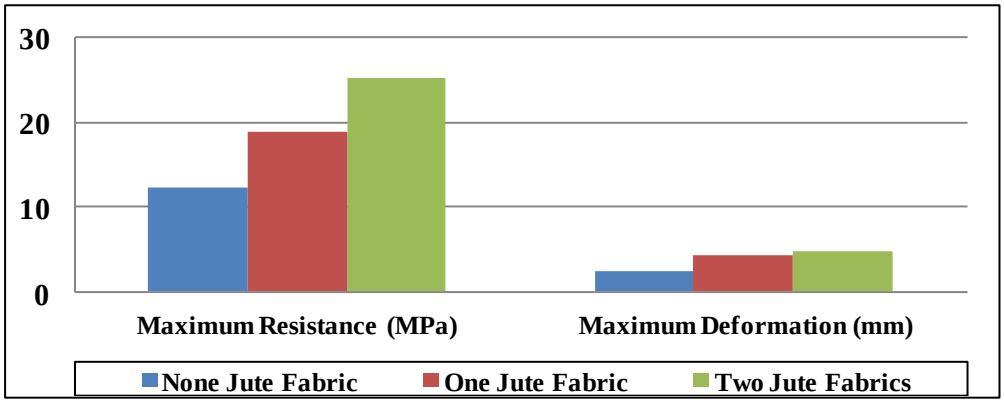

Figure 5: Graphic of resistance and deformation of the tensile tests of PP matrix and composites with single and double layer of jute fabric, respectively.

In Table 1 can also be observed that the modulus of elasticity of composite containing a layer of jute fiber fabric showed a decrease compared to PP matrix without jute. However, when the number of jute fiber fabric layer has been increased it can be observed increasing the modulus of elasticity of the composite of two layers of jute fiber fabric.

The results of flexural tests are summarized in Table 2, which contains the mean and standard deviation of the results of 10 test samples for each type of molded material.

Jute Fabric	Maximum Force (N)	Maximum Resistance (MPa)	Maximum Deformation (mm)	Modulus of Elasticity (MPa)
0	9.34 ± 1.30	31.03 ± 4.43	5.81 ± 1.79	1601.00 ± 202.20
1	10.11 ± 1.01	33.21 ± 3.58	5.95 ± 0.93	1731.00 ± 189.30
2	13.79 ± 1.46	45.63 ± 4.80	8.25 ± 2.25	2466.00 ± 367.20

Table 2: Comparison of average and standard deviation of some mechanical properties obtained in flexural tests.

In Table 2 it can be seen that the addition of one layer of jute fiber fabric resulted in an increase of about 7.0% in maximum resistance, 2.4% increase in maximum deformation, and increased 8.1% elasticity modulus compared to the polymer matrix without jute. Since the addition of two layers of woven jute fibers caused an increase of approximately 47.1% in the maximum resistance and increase of 42.0% in the maximum deformation and 54.0% in elastic modulus.

The comparative percentages of the results of tensile and flexural tests indicated that the addition of jute fiber fabric layers favor certain mechanical properties of the polypropylene matrix (PP) added with 30% of grafted polypropylene.

For better visualization of the mechanical properties was plotted (Figure 6) the results of

flexural tests obtained with the PP matrix and composites containing one and two layers of jute fiber fabric.

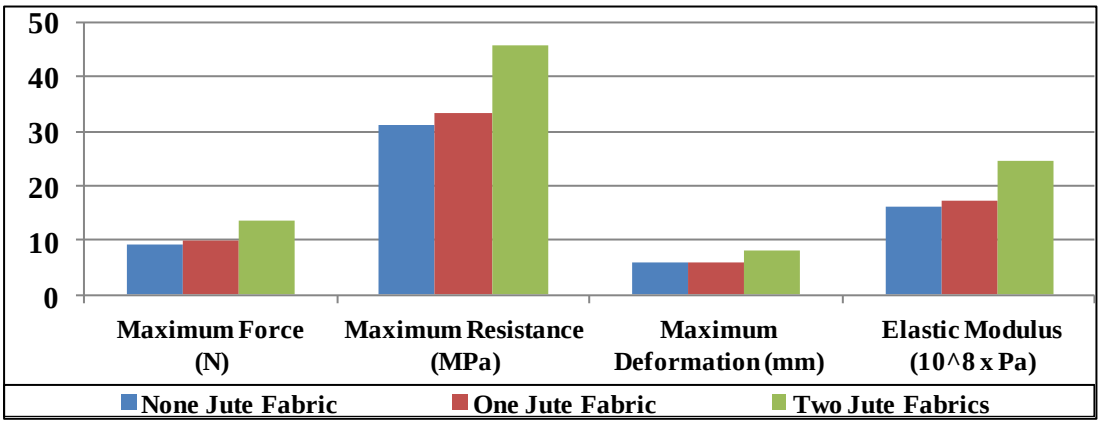

Figure 6: Graphic of mechanical properties of the flexural tests of PP matrix and composites with single and double layer of jute fabric, respectively.

The results of the mechanical tests (Tables 1 and 2) may be compared to other studies composites reinforced with different fibers. In one of these studies were used residual fibers of sisal which conferred to the polypropylene matrix higher modulus and higher impact resistance [10]. In literature [10] was cited lack of adherence and sisal fiber compatibility with the polymer matrix (virgin PP), a fact which had a negative influence on stress at break and strain.

The sisal fiber was used in the comparison of the properties of mechanical resistance in flexural and tensile tests of polyethylene composite (PE) reinforced with sisal fiber and composites reinforced with curauá, plant cultivated in Para State/Brazil. The results of this research have shown that maintaining the same processing conditions and testing, the composite with curauá fibers showed higher mechanical strength than composites of sisal fibers added. [11]

In another part of the work it was noticed that the use of coupling agent poly(propylene-co-maleic anhydride) and poly(ethylene-co-maleic anhydride) of 2% percentage did not change significantly the mechanical properties of polypropylene matrix composite containing sisal fibers and composite high-density polyethylene matrix with sisal fibers. [11]

Good results of flexural strength of the composite containing sisal fibers arranged in the form of random fiber mat were found in a search, whose polymeric matrix PP was added with 10% PP grafted with maleic anhydride (PP-g-MA). In this research it was observed that the flexural resistance increased 24% when compared to PP-PP-g-AM matrix. This result proved the efficiency of the use of PP-g-AM aimed to improve the adhesion of the fiber with the polymer matrix, contributing to the sisal mats act as reinforcement. [12]

During a study of mechanical properties of composites with oat hulls it was noted that the addition of 20% of the fiber in the polymer matrix occasioned good results. However, a greater increase in the percentage of oat hull fiber caused discontinuities in the polymeric matrix of polypropylene (PP) causing decrease in mechanical strength of the composite. This negative effect was weak interaction of the composite constituents, since compatibilizing agents have not been used to improve adhesion between the oat hull fibers (hydrophilic nature) and PP matrix (hydrophobic nature) [13].

In an experiment using coconut fiber mats it was observed that as the amount of fiber was increased to 20% (volume) of fiber, the tensile strength of the material was reduced. This is due to poor adherence in the interfacial area between the fiber and the matrix [14]. Similar results were found in another study that attributed the decrease in the mechanical strength to the agglomeration of the fibers and the blocking stress transfer [15].

Returning to this work and comparing the results of the polymeric matrix (PP/PP-AM) with composite containing jute fibers using single and double layer of jute fabrics showed good results. However, tests have not been made with greater amount of jute fibers to determine whether they would occur some decrease in mechanical properties. Some factors that may explain the positive effect of the addition of jute fabrics are related to its small thickness and yarn weight, which not caused significant increase in interfacial area between the matrix and the jute fiber, and the use of 30% of PP grafted with maleic anhydride in the composition of the PP polymeric matrix.

4. CONCLUSIONS

The results of mechanical testing tensile and flexural shown that the incorporation of fabrics of jute fibers with PP matrix containing 30% of PP grafted with maleic anhydride caused increases in the values of the mechanical properties of the molded composites. It may be noted that the use of two layers of jute fiber fabric was more significant for increasing the mechanical properties of tensile and flexural strength of the composites.

The results of this study clearly demonstrate the positive influence of the incorporation of jute fibers for most of the mechanical properties of composites with polymeric matrix of polypropylene (PP) containing 30% PP-AM.

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