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Comparative analysis of the mechanical and thermal properties of polyester hybrid composites reinforced by jute and glass fiber.

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ABSTRACT
This work describes the study to investigate and compare the mechanical and thermal properties of raw jute and glass fiber reinforced polyester hybrid composites. To improve the mechanical properties, jute fiber was hybridized with glass fiber. Polyester resin, jute and glass fibers were laminated in three weight ratios(77/23/0, 68/25/7 and 56/21/23) respectively to form composites. The tensile, flexural, impact, density, thermal and water absorption tests were carried out using hybrid composite samples. This study shows that the addition of jute fiber and glass fiber in polyester, increase the density, the impact energy, the tensile strength and the flexural strength, but decrease the loss mass in function of temperature and the water absorption. Morphological analysis was carried out to observe fracture behavior and fiber pull-out of the samples using scanning electron microscope.
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I. Introduction

The 60's were the decade of beginning of the international community concerns with the limits of development of the planet, when the discussions about the risks of environmental degradation appeared. Due to the increase of these discussion, the UN (United Nation) has promoted a Conference on Environment, realized in Stockholm, Sweden, in 1972 [1]. Since then there is a growing interest in the use of lignocellulosic materials (sisal fibers, coconut, banana and jute) as reinforcement in thermoset or thermoplastic matrices composites [2]. The interest of using natural fibers as a reinforcing agent is related to its low cost and lower density. In addition they are renewable, non-abrasive and biodegradable [3].

The composites are materials composed of two or more chemically distinct constituents, having a distinct interface separating them. One or more discontinuous phases therefore, are embedded in a continuous phase to form a composite [8]. The discontinuous phase is usually harder and stronger than the continuous phase and is called the reinforcement, where the continuous phase is termed the matrix [4]. Jute is a hydrophobic material and moisture absorption alters the dimensional and mechanical characteristics of jute fibers laminate [5, 6].

The matrix material can be metallic, polymeric or ceramic. When the matrix is a polymer, the composite is called polymer matrix composite (PMC). The reinforcing phase can either be fibrous or non-fibrous (particulates) in nature and if the fibers are derived from plants or some other living species, they are called natural-fibers. The fiber reinforced polymers (FRPs) consist of fibers of high strength and modulus embedded in or bonded to a matrix with a distinct interface between them. In this form, both fibers and matrix retain their physical and chemical identities. In general, fibers are the principal load carrying members, while the matrix keeps them at the desired location and orientation, acts as a load transfer medium between them, and protects them from environmental damage [7-11].

Laminates Composite are formed by stacking several thin layers of fibers impregnated with resin, also known as blades. Consist of laminated layers of at least two different materials connected by means of a matrix. Laminates offer the opportunity to have their properties modified by stacking of layers with fibers oriented in different directions. The reason why to use the lamination process is the combination of best features of the constituent layers in order to obtain a material with certain features not found in a single material. Some properties that may be cited as improved by lamination are strength, stiffness, weight reduction, corrosion resistance and aesthetics, thermal and acoustic insulation, for instance the laminated glass of automobiles [12].

II. Experimental

2.1. Materials

To form the laminated composites used in this study, was used these following materials described below, and the composites with layers kind and the percentage of mass is at Table 1:

- **Polyester resin:** The two types of polyester resin (rigid and flexible) and hardener resin, also known as curing schedule used in the experiment, has been respectively identified as: Policron 10-116, Resapol 10-255and 1,0% ofMethylEthylKetone Peroxide.
- **Jute fiber:**The jute fibers in fabric form used was:Grammage – 361,1 g/m^2
- **Glass fiber:** The glass fibers in fabric form used was: Grammage – 194,4 g/m^2

Table 1 - Percentage by mass of samples

Composites	Symbol	Percentage by mass of samples		
		Polyester resin (% in mass)	**Jute fiber (% in mass)**	**Glass fiber (% in mass)**
Polyester resin 3 layers of jute fabric	PO77-JU23-VI0	77	23	0
Polyester resin 1 jute fiber fabric layer 1 glass fiber fabric layer 1 jute fiber fabric layer	PO68-JU25-VI7	68	25	7
Polyester resin 1 glass fiber fabric layer 1 jute fiber fabric layer 1 glass fiber fabric layer	PO56-JU21-VI23	56	21	23

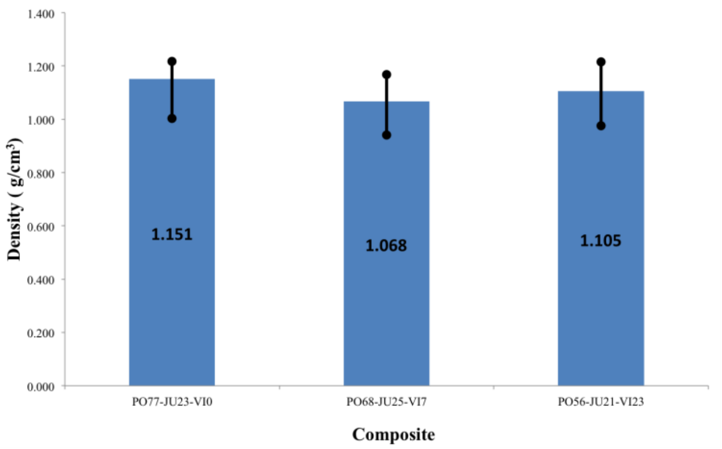

Fig. 1 – Density graph of composite materials.

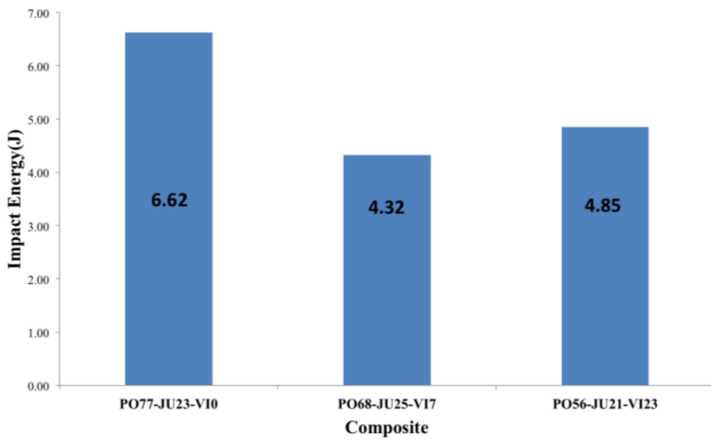

Fig. 2 – Impact energy graphof composite materials.

Table 2 – Mechanical properties of composite materials.

Symbol	Tensile strength (Mpa)	Flexural strength (Mpa)	Flexural modulus (Mpa)
PO77-JU23-VI0	27.48	33.92	1931.74
PO68-JU25-VI7	38.78	15.74	676.81
PO56-JU21-VI23	53.06	15.48	1624.86

2.2. Scanning electron microscopy (SEM)

The Figs. 3–5 display the micrograph of fractured specimens of tensile test of raw jute and glass fiber reinforcedpolyester hybrid composites. Fiber pull-out phenomena wasobserved for the hybrid composite. The SEM images clearly indicatethat there was more breakage of fibers and few voids presentdue to fiber pull-out. This shows that there was a fiber–matrixinteraction between the fibers and the polymer matrix. This resultsfor better mechanical bonding between the fiber and polymermatrix.

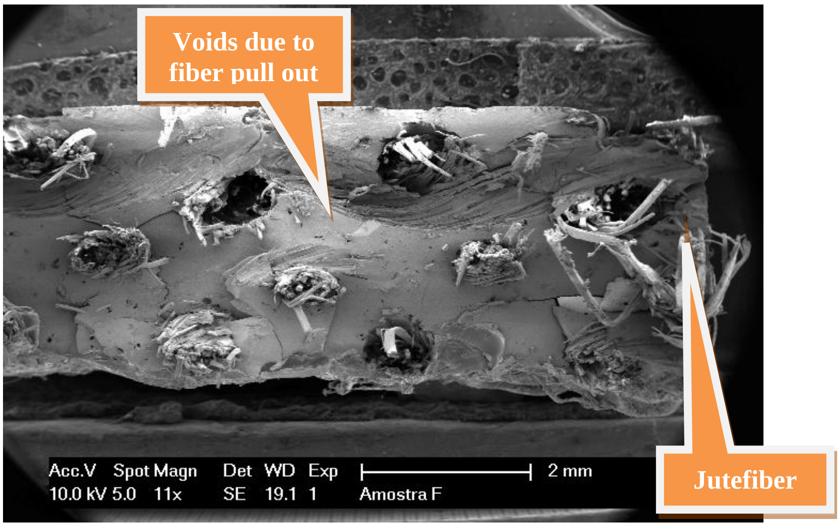

Fig. 3 – SEM image for PO77-JU23-VI0 hybrid compositesrelated the voids between fiber and resin.

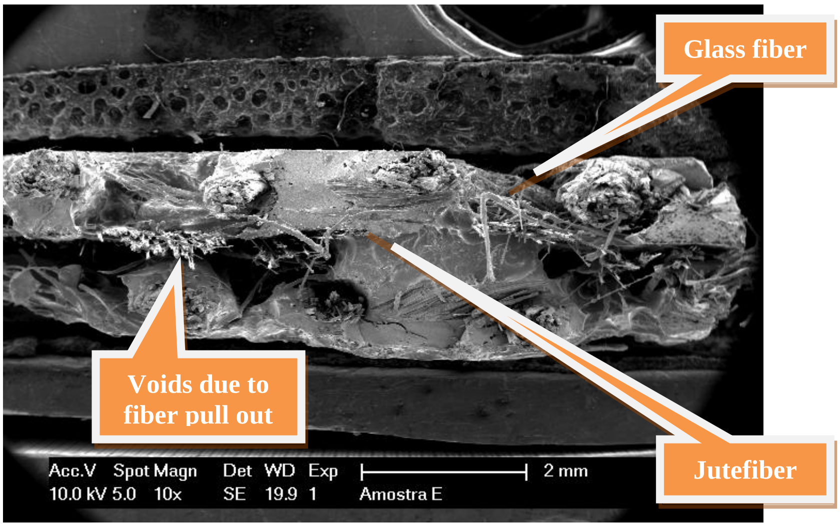

Fig. 4 – SEM image for PO68-JU25-VI7 hybrid composites related the voids between fibers and resin.

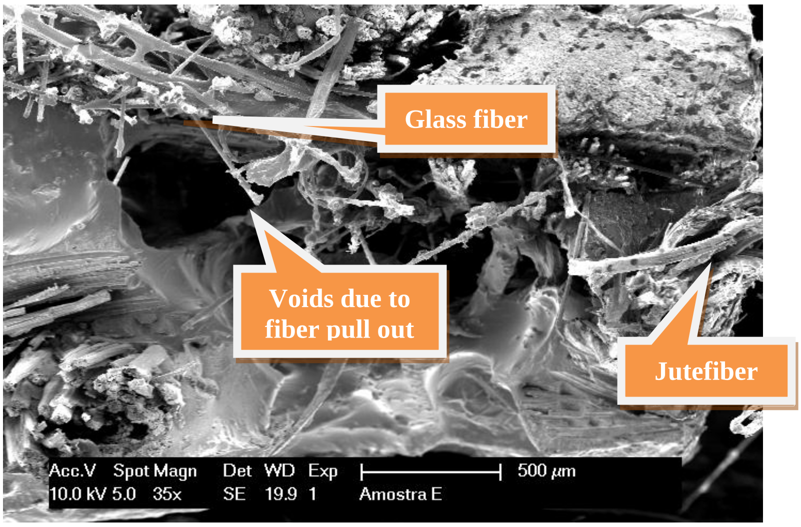

Fig. 5 – SEM image for PO56-JU21-VI23 hybrid composites related the voids between fibers and resin.

3.3. Thermal studies - Thermogravimetric analysis (TGA)

The percentage of mass versus temperature curves are shown in Fig. 6, which shows that with increasing jute fiber content and decreasing the glass fiber and polyester resin, there is also a reduction in mass loss as a function of temperature.

The TGA result of 23% jute fiber and 0% glass fiber reinforced with polyester resin (PO77-JU23-VI0) was illustrated in Fig. 6A. Until the temperature of 100 °C the composite loses only 2.15% of the initial weight, with 200 °C the weight loss already is 4.11% of mass corresponds to removal of solvent in polymer matrix. Between 200 °C and 450 °C the weight loss was approximately 85.43%, due to degradation and volatilization with polyester jute fibers present in the composite. After that the composite maintains a linear mass loss up to 1000 °C, where the final residue is only 2.95% of the original mass.

The TGA result of 25% jute fiber and 7% glass fiber reinforced with polyester resin (PO68-JU25-VI7) was illustrated in Fig. 6B. Until the temperature of 100 °C the composite loses only 0.69% of the initial weight, with 200 °C the weight loss already is 2.38% of mass corresponds to removal of solvent in polymer matrix. Between 200 °C and 450 °C the weight loss was approximately 81.00%, due to degradation and volatilization with polyester jute fibers present in the composite. After that the composite maintains a linear mass loss up to 1000 °C, where the final residue is only 10.29% of the original mass.

The TGA result of 21% jute fiber and 23% glass fiber reinforced with polyester resin (PO56-JU21-VI23) was illustrated in Fig. 6C. Until the temperature of 100 °C the composite loses only 1.13% of the initial weight, with 200 °C the weight loss already is 2.57% of mass corresponds to removal of solvent in polymer matrix. Between 200 °C and 450 °C the weight loss was approximately 68.15%, due to degradation and volatilization with polyester jute fibers present in the composite. After that the composite maintains a linear mass loss up to 1000 °C, where the final residue is only 24.67% of the original mass.

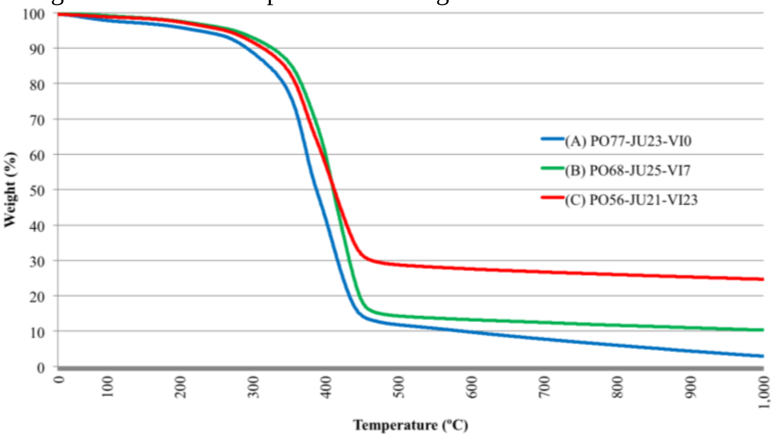

Fig. 6 – Combined TGA graph of all three different composite material.

3.4. Water absorption studies

The water absorption behavior of all three specimens was determined in terms of weight increase for composite specimen immersed in water at 23 ºC. The increase in weight percent were compared and showed in Figure 7.

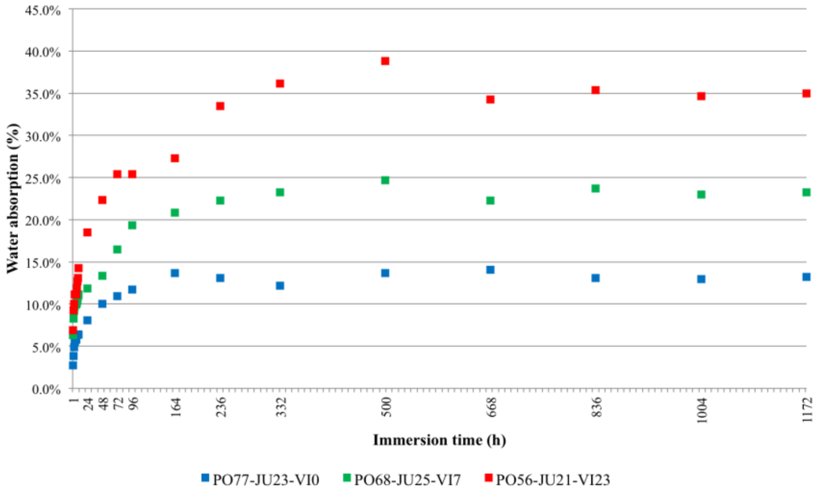

Fig. 7 – Water absorption graph by time of all composite material.

III. Conclusions

The investigation deals about the mechanical, thermal properties and water absorption property was studied for jute fiber and glass fiber reinforced polyester hybrid composites.

The density of PO68-JU25-VI7 composite with more percentage of jute fiber is better 4.40% in relation of PO56-JU21-VI23 composite and 7.77% in relation of PO77-JU23-VI0 composite.The impact energy of PO77-JU23-VI0 composite without glass fiber is better 36.49% in relation toPO56-JU21-VI23 composite and 53.24% in relation to PO68-JU25-VI7 composite.The mechanical property related to tensile strength increased with more proportions of glass fibers, the tensile strength increased 41.12% to the PO68-JU25-VI7composite and a further increase 93.09% toPO56-JU21-VI23 composite in relation to PO77-JU23-VI0composite. Contrary to what happened to tensile strength, increasing the percentage of glass fibers caused the decrease in flexural strength, the flexural strength decreased 46.40% toPO68-JU25-VI7composite and 45.64% toPO56-JU21-VI23composite in relation to PO77-JU23-VI0composite.

In terms of thermal properties, the composite PO77-JU23-V10 without glass fiber lost more mass in function of temperature and the composite with more percentage of glass fiberPO56-JU21-VI23 lost less weight with increasing temperature. After 1172 hours of immersion in water, the absorption of PO77-JU23-V10, PO68-JU25-VI7 andPO56-JU21-VI23composites was 13.2%, 23.2% and 35.0 % respectively. So the composite with more percentage of glass fiber absorbed more water them the composites with more jute fiber.

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