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Analysis of the mechanical and thermal properties of jute and glass fiber as reinforcement epoxy hybrid composites

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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 epoxy hybrid composites. To improve the mechanical properties, jute fiber was hybridized with glass fiber. Epoxy resin, jute and glass fibers were laminated in three weight ratios (69/31/0, 68/25/7 and 64/18/19) 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 epoxy, increases the density, the impact energy, the tensile strength and the flexural strength, but decreases 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.

1. Introduction

The 60s was the decade of the 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 discussions, 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 [4]. 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 [5]. Jute is a hydrophobic material and moisture absorption alters the dimensional and mechanical characteristics of jute fibers laminate [6,7].

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 [8–11].

Laminate composites 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 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 esthetics, and thermal and acoustic insulation, for instance the laminated glass of automobiles [12].

2. 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:

- *Epoxy resin*: The epoxy resin and hardener resin, also known as curing schedule used in the experiment, have been identified as: RenLam M (Araldite M).

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Table 1
Percentage by mass of samples.

Composites	Symbol	Percentage by mass of samples		
		Epoxy resin (% in mass)	Jute fiber (% in mass)	Glass fiber (% in mass)
Epoxy resin 3 layers of jute fabric	E69-J31-V0	69	31	0
Epoxy resin 1 jute fiber fabric layer 1 glass fiber fabric layer 1 jute fiber fabric layer	E68-J25-V7	68	25	7
Epoxy resin 1 glass fiber fabric layer 1 jute fiber fabric layer 1 glass fiber fabric layer	E64-J18-V19	64	18	19

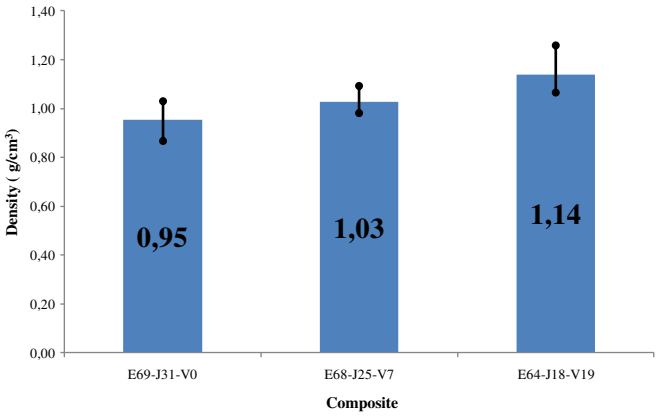

Fig. 1. Density graph of composite materials.

- *Jute fiber*: The jute fibers used in fabric form were: Grammage — 361,1 g/m^2.
- *Glass fiber*: The glass fibers used in fabric form were: Grammage — 194,4 g/m^2.

2.2. Composite fabrication

Fabric jute fibers and glass fibers were reinforced in epoxy resin to prepare the composites. The jute fibers and the epoxy resin have a modulus of about 55 and 3.42 GPa respectively and have density of 1.38 and 1.65 g/cm^3 respectively. The process of manual mixture proportions that has been used for resin and hardner was 10 (ten) parts resin to 1 (a) curing agent, or hardener. It took 20 to 30 min to work with a mixture until the mixture began its process of polymerization. Some steps were necessary in order to obtain a perfect lamination of the plate and also ensure a better finish in the play and avoid places where the resin does not fully impregnate: Step 1 — Implementation of the first layer of resin with a brush over the mold previously prepared; Step 2 — Positioning the first jute fiber blanket on the resin; Step 3 — Application of resin on jute fiber blanket, using a brush; Step 4 — Elimination of air bubbles using the roller across the surface of the mold. Repeat the steps 2, 3 and 4 to position the second and third fiber jute fabric layer or glass fiber fabric layer.

After those steps the cast stayed for 5 (five) days of total rest for the polymerization and curing step, in the open air and at room temperature at about 25 °C. This time was in accordance with the specifications of the supplier. Specimens of suitable dimension were cut using a diamond cutter for physical characterization, thermal and mechanical testing. Utmost care was taken to maintain uniformity and homogeneity of the composite.

2.3. Mechanical studies

After fabrication, the test specimens were subjected to various mechanical tests as per ASTM standards. The density test was performed at 23 °C temperatures in the specimens and a relative humidity of 50%. The tensile test was performed at 23 °C temperatures in the specimens and a relative humidity of 50%, according to ASTM D638 [13], at a speed of 50.0 mm/min and the load cell used was 30.0 kN in a Universal Instron 4467 machine. The bending test was performed at 23 °C ambient temperature in the specimens and a relative humidity of 50%, according to ASTM D790 [14], at a speed of 2.0 mm/min and the load cell used was 30.0 kN in a Universal Instron 4467 machine. The impact test for the sample dart drop was performed as ASTM D256 [15], in a CEAST equipment model 6545 to 23 °C ambient temperature and relative humidity of 50%. Were tested 8 samples to density test, 10 samples to tensile test, 10 samples to bending test and 7 samples to impact test. Was used an average to show the results of each test.

2.4. Scanning electronic microscope (SEM)

The morphology of the samples was studied from tensile tests, to verify the fiber–matrix adhesion in the fracture region. The equipment used was a scanning electron microscope (SEM) Philips XL30 model New 139-2.5, with 9 increases to 20,000 times. The fractured portions of the samples were cut and gold coated uniformly over the surface for examination. The accelerating voltage used in this work was 10 kV. Only one sample was tested .

2.5. Thermal studies

Thermogravimetric analysis allows one to track the weight loss that occurs in a sample due to temperature rise or analysis time. Variations in mass occur due to chemical or physical changes such as loss of material by evaporation, decomposition or vaporization. The TGA analyses were performed on a TA Instruments, model Discovery TGA under N_2. Analyses were carried out in the temperature that range from 35 °C to 1000 °C at a heating rate of 20 °C/min. The amount of sample used was approximately 10.0 mg. Were tested 3 samples to thermogravimetric analysis and was used an average to show the results.

2.6. Water absorption test

For the water absorption test, ASTM D 570 [16], the specimens were weighed in the dry state and were then completely immersed in water and after 1 h, the samples were gently dried with a paper towel, and weighed again immersed in water for a subsequent test period. After this, they were removed from the water and weighed again. The test stopped at the time that the samples reached a state of equilibrium,

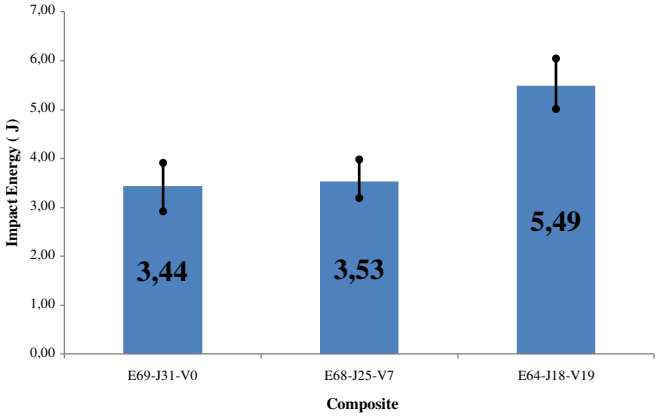

Fig. 2. Impact energy graph of composite materials.