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Physical and Mechanical Characteristics of the Jute Fibre Reinforced Polymer Composites

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ABSTRACT

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus. The fiber which serves as a reinforcement in reinforced plastics may be synthetic or natural. Past studies show that only synthetic fibers such as glass, carbon etc., have been used in fiber-reinforced plastics. Although glass and other synthetic fiber-reinforced plastics possess high specific strength, their fields of application are very limited because of their inherent higher cost of production. In this connection, an investigation has been carried out to make use of jute, a natural fiber abundantly available in India. Natural fibers are not only strong and lightweight but also relatively very cheap. The present work describes the development and characterization of a new set of natural fiber based polymer composites consisting of jute as reinforcement and epoxy resin. The newly developed composites are characterized with respect to their physical and mechanical characteristics. Experiments are carried out to study the effect of fiber loading on physical and mechanical behavior of these epoxy based polymer composites. This work also includes the comparison of elastic properties of composites using micromechanical models with experimental and existing analytical formulations like rule of mixture, Halpin-Tsai, and Lewis and Nielsen models that are used extensively in material modeling.

Keywords: Composites, Natural fiber, Physical Characteristics, Mechanical Characteristics

I. INTRODUCTION

The development of composite materials and their related design and manufacturing technologies is one of the most important advances in the history of materials. Composites are the material used in various fields having exclusive mechanical and physical properties and are developed for particular application [1]. Composite materials having a range of advantages over other conventional materials such as tensile strength, impact strength, flexural strengths, stiffness and fatigue characteristics. Because of their numerous advantages they are widely used in the aerospace industry, commercial mechanical engineering applications, like machine components, automobiles, combustion engines, mechanical components like drive shafts, tanks, brakes, pressure vessels and flywheels, thermal control and electronic packaging, railway coaches and aircraft structures etc [2].

When two or more materials with different properties are combined together, they form a composite material. Composite material comprises of strong load carrying material (known as reinforcement) imbedded with weaker materials (known as matrix). The primary functions of the matrix are to transfer stresses between the reinforcing fibres/particles and to protect them from mechanical and/or environmental damage whereas the presence of fibers/particles in a composite improves its mechanical properties like tensile strength, flexural strength, impact strength, stiffness etc [3].

In the recent years there is a vast growth in natural fibre based polymer composites due to its various attractive features likes biodegradability, no abrasiveness, flexibility, availability, low cost, light weight etc. Different researchers have performed various experiments to enhance the mechanical properties of natural fibre based polymer composites. Gregory et al. [4] studied the effect of length on mechanical behaviour of coir fibre reinforced epoxy composites and observed that the hardness is decreasing with the increase in fibre length up to 20 mm. Luo and Nikkeshi [5] studied the tensile and flexural properties of polymer composites with different pineapple fibre content and compared them with the virgin resin. Rusu [6] reported the effectiveness of cellulose fibre in improving the stiffness and reducing the damping in polypropylene cellulose composites.

II. METHODS AND MATERIAL

A. Materials Description

In the present work, epoxy resin (LY 556) is used as the matrix material and its common name is Bisphenol-A-Diglycidyl-Ether chemically belongs to 'epoxide' family. The resin and the corresponding hardener (HY 951) were supplied by Ciba Geigy India Ltd. Banana (Musa sapientum) and jute (Corchorus capsularis) fibers are used as reinforcement materials for fabricating the composite specimen. Banana fiber has been obtained from V. K Enterprise, Gujarat and jute fiber has been obtained from the local supplier.

B. Fabrication of Composite

The fabrication of the epoxy based polymer composites is done by conventional hand lay-up technique followed by light compression moulding. Fiber are taken for the study such as unidirectional. Composites are fabricated with five different fiber loadings (0 wt.%, 10 wt.%, 20 wt.%, 30 wt.%, and 40 wt.%). The composition and designation of various composites fabricated using epoxy as the base matrices are presented in Table 4.2. For epoxy based composites, the epoxy and hardener HY951 are mixed in a ratio of 10:1 by weight as recommended. Care is taken to avoid the formation of air bubbles during preparation. A moderate pressure of 0.1 MPa is applied from the top and then mould is allowed to cure at room temperature for 48 hrs. After 48 hrs, the samples are taken out of the mould and cut into required size by diamond cutter for physical and mechanical tests. Figure 4.6 shows the fabricated composite sheets.

C. Physical and Mechanical Testing

The theoretical where, W and ρ represent the weight fraction and density respectively. The suffixes f and m stand for the fiber and matrix respectively density of composite materials in terms of weight fractions of different constituents can easily be obtained as for the following equation given by Agarwal and Broutman. The tensile strength of hybrid composites is determined using the ASTM D3039-76 standard. The dimensions of the specimen are 153 mm × 12.7 mm × 4 mm. The tensile test is performed in universal testing machine Instron 1195 at a cross head speed of 2 mm/min. Three-point bend test was carried out in the same machine to obtain the flexural strength as per ASTM D790. The dimensions of the specimen are 100 mm × 12.7 mm × 4 mm. Impact energy of the composites is evaluated as per ASTM D 256 test standards by using Izod impact tester supplied by VEEKAY test lab, India. Hardness measurement is done using a Leitz micro-hardness tester.

III. RESULTS AND DISCUSSION

A. Density

Density of a composite material depends on the relative proportion of reinforcement and matrix and is one of the most important factors in determining the properties of composites. The void content of composites is the difference between the experimental density and the theoretically density values of composites. Densities and void fraction of different composites are shown in Table 1. It can be seen that the void content in the composites increases with the increase in fiber content. Presence of large amounts of the hydroxyl group in natural fibers makes them polar and hydrophilic in nature; on the other hand, most polymers are hydrophobic in nature. This polar nature also results in high moisture absorption in natural fiber based polymer composites, leading to fiber swelling and voids in the fibe-matrix interface [7].

TABLE I. DENSITIES AND VOID FRACTION OF DIFFERENT COMPOSITES

Composite	Theoretical Density	Experimental Density	Void fraction
C1	1.15	1.146	0.347
C2	1.1709	1.157	1.187
C3	1.1925	1.165	2.313
C4	1.2150	1.173	3.464
C5	1.2389	1.152	4.559

B. Effect of Fiber Length on Tensile Strength

The test results for tensile strength shown in Figure 1. It is seen that the tensile strength of the composite increases with increase in fiber length. There can be two reasons for this increase in the strength properties of these composites compared. One possibility is that the chemical reaction at the interface between the filler particles and the matrix may be too strong to transfer the tensile strength [8].

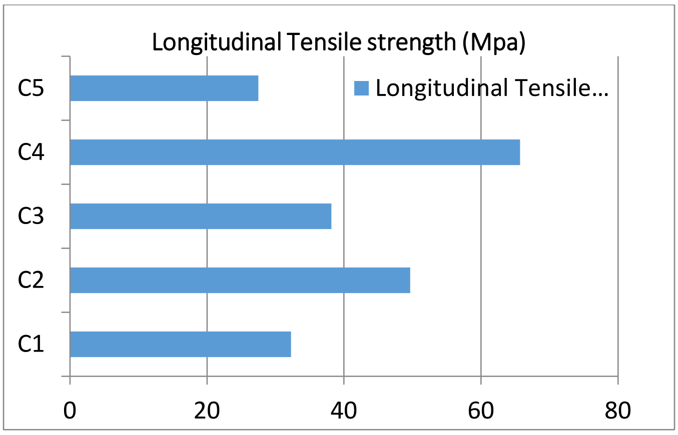

Figure 1: Fibre loading Vs Tensile strength

C. Effect of Fiber Length on Flexural Strength

The Figure 2 shows the comparison of flexural strengths of the composites obtained experimentally from the bend tests. It is interesting to note that flexural strength increases with increase in fibre content. This may be due to the good compatibility of fibre and epoxy resin [9].

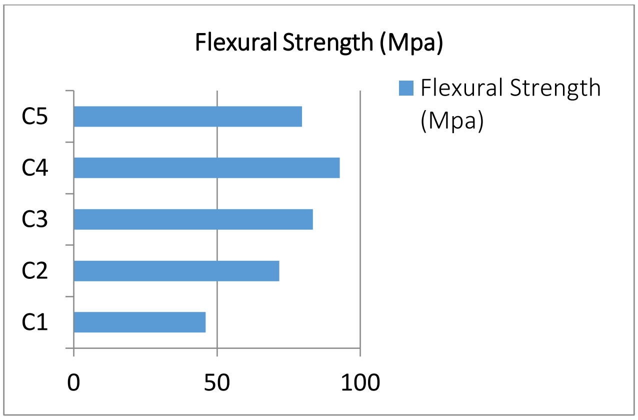

Figure 2: Fibre loading Vs Flexural strength

D. Effect of Fiber Length on Impact Strength

The impact energy values of different composites recorded during the impact tests are given in Figure 3. It shows that the resistance to impact loading of jute fiber reinforced epoxy composites improves with increase in filler content as shown in Figure 3. High strain rates or impact loads maybe expected in many engineering applications of composite materials. The suitability of a composite for such applications should therefore be determined not only by usual design parameters, but by its impact or energy absorbing properties [10].

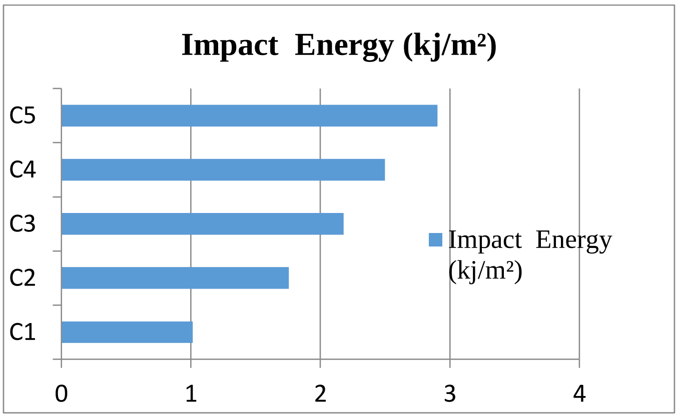

Figure 3: Fibre loading Vs Impact Strength

E. Effect of Fiber Length on Hardness

Figure 4 shows the influence of fibre content on micro-hardness of jute fiber reinforced epoxy composites. From the figure it is clear that fibre content has significant influence over micro-hardness. With the filler content the micro-hardness value increases and reaches maximum up to 39.1 Hv for fibre up to 40 wt% [11].

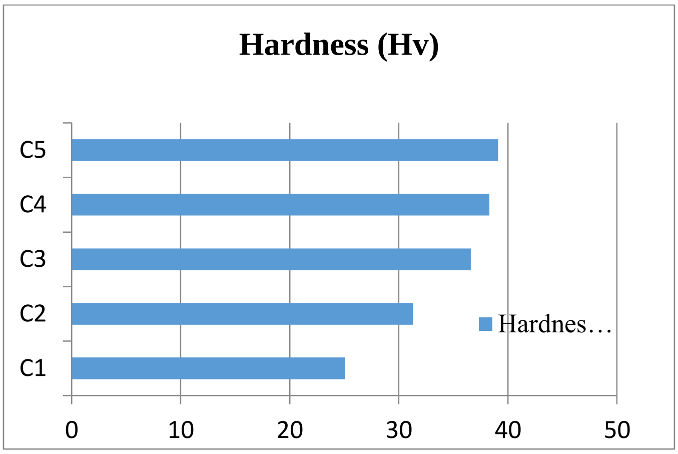

Figure 4: Fibre loading Vs Hardness

IV.CONCLUSION

The present analytical, experimental and numerical investigation of epoxy based composites reinforced with jute fiber has led to the following conclusions:

1. Fabrication of unidirectional jute fiber reinforced epoxy based composites with different fiber loading has been done successfully with hand layup technique.

2. The density, void content and water absorption coefficients of the unidirectional composites are greatly affected by the type of fiber material, fiber loading, and type of matrix materials. With increase in fiber loading, density, void content and water absorption coefficients increases invariably for both the epoxy based composites.
3. The mechanical properties of the composites are improved by adding the jute fiber as reinforcement in polymer matrix.

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