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Evaluation of mechanical properties of abaca–jute–glass fibre reinforced epoxy composite

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Highlights

- The hybrid composite withstands more strain before failure in tensile testing than the single fibre composite.
- Abaca has the highest flexural strength since its strength increases with improved interfacial adhesion.
- Morphological analysis like fibre failure, cause of voids and fibre pullout during loading condition is studied using SEM.
- The hybrid composite is more ductile than the single type composite.
- Abaca exhibits more strength when it absorbs moisture.

Abstract

Natural fibre composites are a class of materials which are currently replacing the synthetic fibre composites for practical applications. This paper deals with the fabrication and investigation of hybrid natural fibre composites and compares it with other normal natural fibre composites like abaca and jute as reinforcements used separately. Mechanical characterization of the natural composite is obtained by testing the composite lamina for tensile, flexural, shear, and impact strength. The structure of the composite is such that, the jute fibre is present at the center flanked by abaca fibre on both sides. Glass fibre is used to laminate the composite on top and bottom, which improves the surface finish and adds strength. The natural fibres are arranged in horizontal and vertical directions to provide strength on all sides. The composite is manufactured by hand layup process and volume fraction of the fibres is up to 0.40. It is found that the abaca–jute hybrid composite has better properties than the abaca fibre alone in tensile and shear. However the abaca composite is superior to hybrid composite in flexural and impact strength. The internal structure of the composite is observed under scanning electron microscope (SEM) and the fractures, voids and fibre delamination are analyzed.

Introduction

Natural fibre composites are nowadays widely used instead of synthetic fibres due to their advantages like biodegradability, low weight, low cost and high specific mechanical properties. Synthetic fibre composites have far better mechanical properties than natural fibre composites but since they are highly expensive, they are justified only for aircraft and military applications. Many authors have previously investigated composites with natural fibres reinforcement with polymer matrices [1], [2], [3], [4], [5], [6], [7]. Natural fibres are extracted from plants such as banana, oil palm, bamboo and sugarcane. These plants are extensively found in tropical and equatorial countries and hence are used as reinforcement in low-cost composites [1], [2], [3]. El-Tayeb [1], [4] used sugarcane fibre (SCF) to develop low cost polymeric composite materials with reasonable mechanical and tribological properties. The composites were prepared with two different types of reinforcements namely, chopped fibres (C-SCRP) and unidirectional fibres (U-SCRP). Coir fibre composite is used in design of liquid storage tanks [5]. The tests conducted on the natural composite materials show that the fibre absorbs more low viscosity liquids than high viscosity liquids.

The properties of natural composites depend on the strength of the fibre and the interfacial adhesion of the matrix with the fibre. The properties of the composite can be improved by using glass fibre. Pavithran et al. [6] improved the properties of coir-polyester composites by using glass as the intermediate layer between the coir layers. Many researchers [8], [9], [10], [11], [12], [13], [14], [15] have reported that the mechanical efficiency of the fibre reinforced polymer composites depends on fibre–matrix interface and the ability to transfer stress from the matrix to fibre. Best properties can be obtained by combining the synthetic fibre with natural fibre in the same matrix. The impact behaviour of the composites is dependent on the infinite material permutations including fibre and resin types, quantities, architecture, interfaces and the production methods used [16]. Epoxy resin matrix has better mechanical properties than polymer matrices. It is due to good interfacial adhesion between the fibre and the matrix. Enhanced mechanical properties and shorter curing time is characterized by the presence of bonding agents. Impurities like gums and dust particles decrease the strength of the composite. The effect of interfacial adhesion was discussed by Wong et al. and Yang et al. [17], [18]. Chen and Sun [19] investigated the impact responses of the composite laminates with and without initial stresses using the finite element method. The deflections produced are small for simple cases and simple material architecture. Whereas, the deflections produced are complicated when complex architectures are considered. Finite element analysis is an important tool which is used to assess the strength of a natural composite. The finite element model was used to simulate the performance of the woven composites under different loading conditions [20] and the failures under combined tension and bending loading were studied. It was found that the failure occurred near the fixture where the composite was subjected to maximum bending.

Many researchers have shown that the strength of the natural composites can be improved by treating the fibres suitably. Herrera-Franco and Valadez-Gonzalez [21] improved the tensile, flexural and shear properties of the short fibre laminates by using saline treatment and matrix-resin pre-impregnation process through which the tensile and flexural moduli remain unaffected. The mechanical properties of jute fibre-unsaturated polyester composites prepared by solution impregnation and hot curing methods were studied by Dash et al., bleached fibres were found to have better mechanical properties at 60% weight loading than unbleached fibres. Alwar [22] studied the properties of date palm fibre which was subjected to different types of treatment processes. 1% NaOH treatment resulted in increase in the mechanical properties whereas HCl treatment resulted in deterioration of its properties.

Abaca fibre is obtained from the pseudo-stem of the plant (Musa textiles). It is a bast fibre and is also known as Manila hemp [23]. It belongs to the Musacea family of plants. Abaca fibre is obtained from banana farms, as a waste product of the banana plant. Since it is cheap, it is used for industrial and commercial purposes. It is used as an under floor protection in Daimler Chrysler cars. Fibre glass is a lightweight, extremely strong, and robust material [24]. Though its strength is lower thancarbon fibre, the material is less brittle, and in expensive. It shows increased strength when fibre absorbs moisture, hence proving to be corrosion resistant. Woven rovings of glass fibre have high strength compared to individual glass fibres. Jute, which is also a natural fibre, is produced by retting process where the stem is separated to form the fibre. The value of Young's modulus divided by specific gravity is about 40 GN m^2 for jute compared with about 30 GN m^2 for glass fibre [25].

Section snippets

Natural fibres

Natural fibres are materials that belong to a class of hair like materials which are in the form of continuous filaments. Natural fibres are classified into two types, as plant (vegetable) fibres and animal fibres. Plant fibres namely cotton, flax, hemp, abaca, sisal, jute, kenaf, bamboo and coconut are widely used. They are preferred mostly since they are eco-friendly, and also available in less cost.

Tensile test

The fabricated hybrid composite is cut using a saw cutter to get the dimension of the specimen for tensile testing as per ASTM: D638 standards. The schematic diagram of tensile test specimen is shown is Fig. 4.

The test was carried out using a universal testing machine at a room temperature with 40% relative humidity. The tensile stress is recorded with respect to increase in strain. Three different types of specimens are prepared based on fibres used namely, abaca–GFRP, jute–GFRP and

Tensile properties

The three different composite specimens like jute–GFRP, abaca–GFRP and abaca–jute–GFRP are tested in the universal testing machine to find the tensile properties. A sample graph showing stress vs strain of abaca–jute–GFRP is shown in Fig. 12.

The various mechanical properties of the fabricated composite (abaca–GFRP, jute–GFRP, abaca–jute–GFRP) are summarized in the Table 1 for better comparison. It is clearly seen that the tensile strength of the abaca and jute composite is high. Even though the

Morphological analysis (scanning electron microscopy analysis)

Morphological analysis was done using scanning electron microscope. The surface characteristics of the composite material were studied through SEM after conducting tests. The samples were taken from each test, dried and coated with 15–20nm thick layer of gold with an ion-sputter coater device. Subsequently the specimens were inspected by a scanning electron microscope. The interfacial adhesion between matrix and the fibre is clearly seen from scanning electron micrographs.

The SEM micrograph of

Conclusion

In this work, different natural fibre composites are fabricated with fibres like jute, abaca and combining them as well. All the composites have the highest volume fraction of 0.40 along with GFRP. Their mechanical properties like tensile strength, flexural strength, shear strength and impact strength are investigated and from the results obtained, the following conclusions were drawn.

- The tensile strength of abaca and jute composite is the relatively more than jute composite and much higher

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