Evaluation of mechanical properties of ramie/banana reinforced hybrid composites

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ABSTRACT

In the present article, hybrid polymer composites with ramie and banana fibres have been prepared using hand layup technique. Effect of banana fibre on mechanical properties of ramie/polyester composites has been investigated in the present study. Total five types of hybrid composites were developed based on 0 %, 1 %, 2 %, 3 % and 4 % weight fractions of banana fibres in ramie/polyester composites. A fixed percentage of 20 % by weight was used for ramie fibre in all the developed composites. Ramie fibre was used in bidirectional mat form, while banana fibre in the form of short fibre (10 mm length). Mechanical properties of fabricated composites such as tensile, flexural and impact strength have been evaluated. The results have revealed that hybridization of banana fibre had significant influence on the mechanical properties of ramie/polyester composites. It was observed that hybrid composites with 1 % banana fibre reinforcement exhibited the highest mechanical properties among the developed composites. Increments of 57.9 %, 18.3 % and 9.38 % in tensile, bending and impact strength respectively were observed for hybrid composites with 1 % banana fibre reinforcement in comparison to ramie/polyester composites. The morphological study to examine fractured surface has been carried out by scanning electron microscopy, to evaluate the failure mechanism of composites.

Keywords: *Ramie Fibre; Banana; Polyester; Tensile; Flexural*

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Introduction

Use of non- renewable synthetic fibre such as glass, carbon, etc. has been reduced due to its higher cost as well as non-eco-friendly nature [1, 2]. Demand of natural fibre is increasing day by day in various fields such as aerospace, automobile, defence, etc. Natural fibres are attracting most of the researchers over the conventional synthetic fibres due to lightweight, low cost, availability, satisfactory mechanical strength, biodegradability etc. Natural fibres such as jute, flax, kenaf, banana, sisal etc., are widely being used as reinforcement in polymeric composites [3–6]. Natural fibre possesses good acoustic and thermal insulation capability, which is due to their low density and cellular structure. However, there are some challenges involved with these fibres like moisture absorption, compatibility for fibre-matrix interface. These factors significantly reduce the performance of these composites. These issues can be overcome by chemical or some other treatment of natural fibres.

Thiruchitrambalam et al. investigated mechanical properties of banana-kenaf/polyester hybrid composites. The effect of SLS (Sodium Lauryl Sulfate) treatment on Banana/Kenaf hybrid composites and woven hybrid composites was explored. The improvement in mechanical behaviour due to SLS treatment of the composites was observed [3]. Boopalan et al. investigated effect of fibre loading on the mechanical behaviour of jute-banana/epoxy hybrid composites. Results showed an increase in the mechanical as well as thermal properties of the composite and decreases in moisture absorption when both fibres were mixed up to 50 % by weight [6]. Akil et al. analyzed pultruded Jute /Glass based unsaturated polyester composites. At high temperature, hybrid composite shows superior properties as well as high retention of various mechanical properties as compared to jute fibre based composites [5].

Chaudhary et al. studied mechanical properties of hybrid epoxy composites with Jute/Hemp/Flax as base. Results showed that hybridization for various combinations of 3 fibres exhibited improvement in mechanical behaviour as compared to individual fibre based composites [7]. Indian variety of ramie fibre is a potential candidate as reinforcement for polymeric composites. Kumar and Anand investigated mechanical properties of Indian ramie/epoxy composites. Authors concluded that a maximum rise of 75 %, 94 % and 163 % in tensile, impact and bending strength was observed for fabricated composites. Indian variety of ramie fibre is not much explored [8]. In the present work Indian variety of ramie fibre (Hazarika-R1411) and banana fibre reinforced polyester composites have been fabricated as per the details given in Table 1. The results obtained for hybrid composites are compared with ramie/polyester composites.

Materials and Methods

A fixed percentage of 20% by weight was used for ramie fibre in all the developed composites. A total five types of hybrid composites were developed based on 0 %, 1 %, 2 %, 3 % and 4 % weight fractions of banana fibres in ramie/polyester composites as shown in Table 1. Ramie fibre was used in bidirectional mat form, while banana fibre in short fibre form of 10 mm length. Firstly, a mixture of banana fibre and polyester resin (including hardener and accelerator) was prepared manually in the beaker with glass rod. One layer of mixture was spread over the teflon sheet on which silica release was already applied. On this layer ramie fibre mat was put. Over ramie fibre mat mixture of banana/polyester was spread. Then, the top layer was covered with teflon sheet. A uniform weight of 25 kg was placed over the composite to distribute resin uniformly. Both ramie and banana fibres were dried in a hot air oven at 105° C for 4 hours to ensure water removal and good adhesion at fibre-matrix interface. Open mould hand layup technique was used for the composite fabrication.

Water immersion method commonly known as Archimedes principle has been used to determine the actual densities for fabricated hybrid, and theoretical densities were determined by the following equation

$$\frac{1}{\rho_t} = \frac{\omega_f}{\rho_f} + \frac{\omega_m}{\rho_m} \tag{1}$$

where, ω_f , ω_m are weight fractions of fiber and base matrix respectively and ρ_f, ρ_m are densities of fiber and base matrix respectively. In case of hybrid composites above equation is modified to equation (2)

$$\frac{1}{\rho_t} = \frac{\omega_r}{\rho_r} + \frac{\omega_b}{\rho_b} + \frac{\omega_m}{\rho_m} \tag{2}$$

Where, ω_r , ω_b and ω_m are weight fractions of ramie fibre, banana fibre and matrix (polyester) respectively. ρ_r , ρ_b and ρ_m are densities of ramie, banana and matrix respectively. The percentage change in density is calculated by following equation:

$$\%\ Change\ in\ density = \frac{Theoretical\ Density - Experimental\ Density}{TheoreticalDensity} \times 100 \tag{3}$$

Table 1: Compositions and Densities

S.No.	Composition (Abbreviation)	Theoretical Density (g/cm^3)	Experimental Density (g/cm^3)	Void Fraction (%)
1	20% Ramie + 80% Polyester (RP)	1.40	1.24	11.42
2	20% Ramie + 1% Banana + 79% Polyester (RB1P)	1.39	1.27	8.63
3	20% Ramie + 2% Banana + 78% Polyester (RB2P)	1.38	1.21	12.31
4	20% Ramie + 3% Banana + 77% Polyester (RB3P)	1.35	1.21	10.37
5	20% Ramie + 4% Banana + 76% Polyester (RB4P)	1.34	1.20	10.45

ASTM D3039 and ASTMD 790 standards have been used to carry out tensile testing and flexure of the prepared composites. The tests were carried out on Universal Testing Machine (AGIS, 50KN) with a crosshead speed of 5 mm/min. The Impact testing of the samples was carried out on Charpy impact testing machine. Specimens were prepared as per procedure suggested by Graupner et al. (2009) [9]. The conditioning of the specimens has been carried out prior to various tests at 27 ˚C and 50% relative humidity for duration of 48 hours.

Results and Discussions

Density

The densities of fabricated composites are shown in Table 1. The presence of voids is given by the difference in the theoretical and experimental density. Void formation has also been seen in the samples with naked eye. This is attributed to the entrapment of air. The minimization of air entrapment has been minimized by employing a roller after each layer of fibre and polymer.

Tensile testing

Tensile strength of the fabricated composites is shown in Figure 1. Tensile strength observed for developed composites RP, RB1P, RB2P, RB3P and RB4P were 19 MPa, 30 MPa, 20 MPa, 15 MPa and 14 MPa respectively.

Hybrid composites having 1 % of banana fibre (RB1P) showed maximum tensile strength among all the developed composites. An increment of 57.9 % in comparison to ramie/polyester (RP) composites was observed for RB1P composites. Further increment in banana fibre loading led to decrement in tensile strength. However, RB2P composites showed slightly higher tensile strength in comparison to RP composites. With the increase in banana fibre loading grouping of fibres takes place leading to poor wetting of fibres and ultimately poor adhesion between fibre and matrix. Fibre properties and adhesion at fibre-matrix interface are the critical factors in determining end properties of these composites [10, 11].

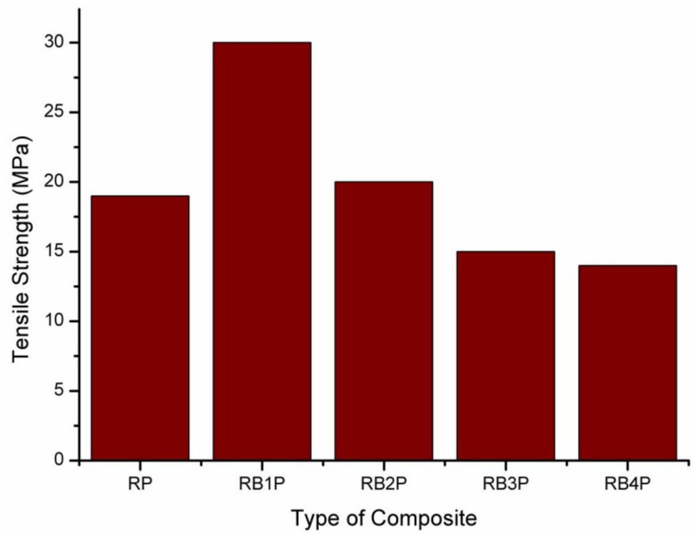
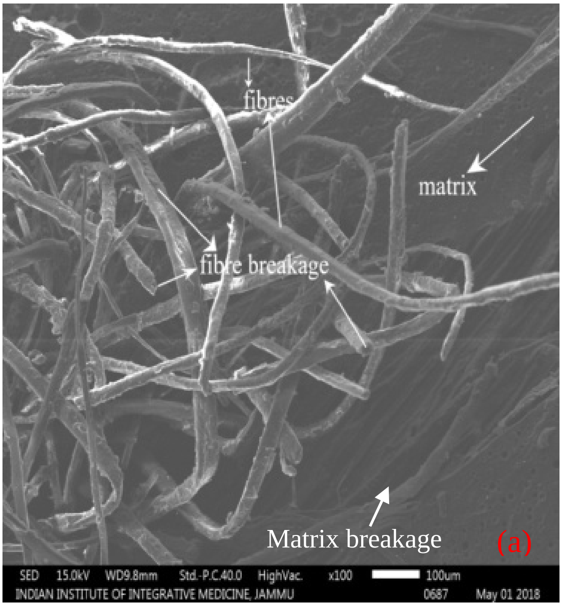


Figure 1: Tensile strength of developed composites



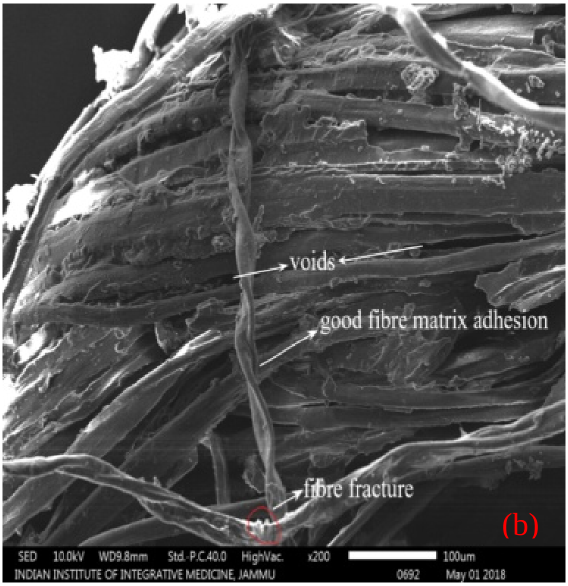


Figure 2: SEM micrographs for fractured surfaces in tensile testing for developed composites (a) RP (b) RB1P

Fractured surfaces were evaluated using SEM to observe failure mechanism. The SEM micrographs are shown in Figure 2 for RP and RB1P composites. Fibre breakage, fibre pullout, matrix breakage and voids appeared in SEM micrographs. Fibre pullout and fibre breakage were the key failure mechanism in the study. RB1P composites exhibited better fibre –matrix adhesion in comparison to RP composites. Fibre-matrix adhesion property was the governing factor for better tensile strength for RB1P composites [13].

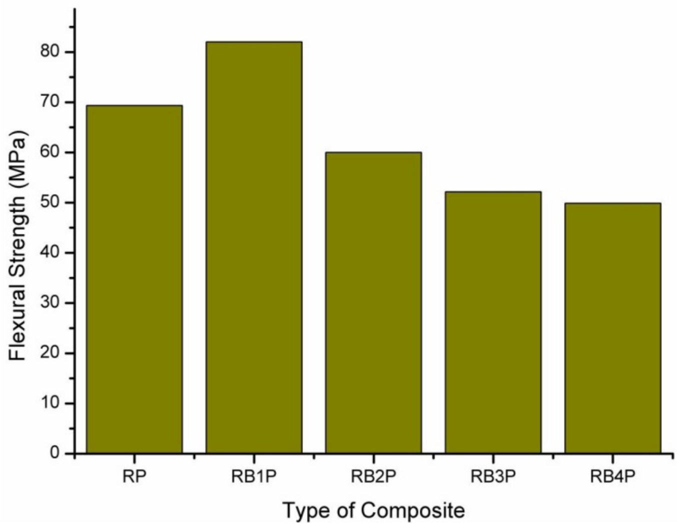


Figure 3: Flexural strength of developed composites

Flexural testing

The Flexural strength of the fabricated composites is shown in Figure 3. Flexural strength of the samples namely RP, RB1P, RB2P, RB3P and RB4P were 69.3 MPa, 82 MPa, 60 MPa, 52.16 MPa and 49.9 MPa respectively. Hybrid composites having 1 % of banana fibre (RB1P) showed maximum flexural strength among all the developed composites. An increment of 18.3 % in comparison to ramie/polyester (RP) composites was observed for RB1P composites. Further increment in banana fibre loading led to decrement in flexural strength. Fiber mechanical properties, fibre type and surface conditions have a significant influence on the flexural properties of the samples as they influence fiber-matrix adhesion [7, 12, 13].

Impact testing

Impact strength of the prepared composites is shown in Figure 4. Impact strength of the samples, RP, RB1P, RB2P, RB3P and RB4P were 4.48 KJ/m2, 4.9 KJ/m2, 3.53 KJ/m2, 3.64 KJ/m2 and 3.52 respectively. Hybrid composites having 1 % of banana fibre (RB1P) showed maximum impact strength among all the developed composites. An increment of 9.38 % in comparison to ramie/polyester (RP) composites was observed for RB1P composites. Further increment in banana fibre loading led to decrement in impact strength. The adhesion between base matrix and fibre is greatly influenced the Impact strength. With the increase in banana fibre loading poor adhesion at fibre-matrix interface due to grouping of fibres [13, 14].

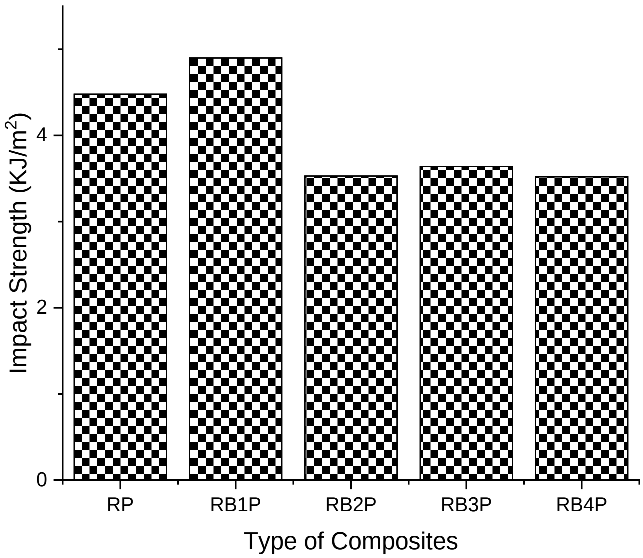


Figure 4: Impact strength of developed composites

Conclusions

In this research work, hybrid polymer composites of ramie-banana fibres were developed using hand layup technique. The weight percentage of Ramie was fixed, however there was variation in weight percentages of Polyester and Banana fibre.

Following conclusions are drawn from this work:

i) Hybrid composites of ramie-banana/polyester composites were fabricated successfully by hand layup technique.

ii) Hybrid composites with 1 % banana fibre exhibited excellent mechanical properties in comparison to other developed composites.

iii) For RB1P composites increments of 57.9 %, 18.3 % and 9.38 % in tensile, bending and impact strength respectively were observed in comparison to RP composites.

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