Influence of Sawdust Bio-filler on the Tensile, Flexural, and Impact Properties of Mangifera Indica Leaf Stalk Fibre Reinforced Polyester Composites

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Abstract. The need to have biodegradable composites is aloft in today's market as they are environment friendly and are also easy to fabricate. In this study, mangifera indica leaf stalk fibres were used as reinforcement along with saw dust as bio-filler material. Unsaturated isophthalic polyester resin was used as the matrix. The fibres were treated with 6 % vol. NaOH and neutralized with 3 % vol. of dilute HCl. Treatment of sawdust fillers was done by using 2% vol. NaOH solution. Hand layup method and compression moulding technique was used to fabricate the composite laminates. Specimens for evaluating the mechanical properties were prepared by using water jet machining. The results indicated an increase in tensile, flexural and impact strength of composites with addition of sawdust upto 3%. Further addition of the bio-filler resulted in decrease of mechanical properties.

Keywords: Mangifera indica leaf stalk fibre, Sawdust, Polyester, Handlayup, Compression Moulding, Mechanical Properties

1 Introduction

In the present scenario, wide varieties of composite products are manufactured from thermosetting polymers reinforced with synthetic fibres which are expensive, have health hazards, and are not nature friendly [1, 2]. Natural fibres are thus gaining lot of attention and extensive research is going on, as these fibres offer better strength and stiffness, low density, reduced embodied energy and possesses excellent biodegradability [3]. The abundant availability of natural fibres and flexibility in bringing about improvements in their properties by surface treatments make these fibres an excellent alternative to traditionally used synthetic reinforcements. Such composites find applications in automobile and construction industry [2, 4, 5]. Roe and Ansell [6] analysed the characteristics of polyester composites reinforced with jute fibre. The results obtained indicate that, the specific modulus shown by jute fibre is far better to the glass fibre along with the modulus per cost. Also, the specific strength per unit cost exhibited by jute fibre

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are comparable to that shown by the glass fibre. Rachchh et al. [7] examined the properties of rattan fibre polyester composites. Fibre addition improved the flexural and tensile properties up to 12.5% weight percentage after which a drastic drop in the mechanical properties was observed due to insufficient resin content. They observed reduction in density with addition of fibres indicating that such composites can be used for low strength applications.

For a proper matrix-fibre adhesion, surface of natural fibres should be chemically modified. Consequently, the hydrophilic nature of the natural fibre reduces due to partial elimination of hemicellulose content. Hill and Khalil [8] studied the effect of chemical treatment and mechanical characteristics of oil palm and coir fibre reinforced polyester composites. Acetylation and usage of silane and titanate coupling agents were considered for the study. The tensile properties increased due to stronger interfacial bonding and better wetting of the fibres. A minor improvement in impact strength was also noticed with chemically modified fibres. Naguib et al. [9] studied the physical properties of green bagasse polyester composite. Fibre treatment was performed with sodium hydroxide solution and then diluted with sulfuric acid. The authors reported an improvement in flexural strength and Young's modulus of the treated fibres. The study suggested that bagasse polyester composite can be used for various industrial applications that require bearing higher loads under mild operating conditions. Pothan et al. [10] studied the mechanical characteristics of polyester composites reinforced with short banana fibres. Silane treated banana fibres exhibited better tensile strength. The morphological images clearly showed a good adhesion between polyester and banana fibre. The impact strength showed an increasing trend with fibre loading. Kini et al. [11] investigated the effect of alkali treatment on borassus and tamarind fruit fibres. They observed that chemical treatment removes the surface impurities of the raw fibre and makes the fibre suitable for the better bonding with the matrix.

Dubey and Angnihotri [12] analysed the usage of midrib of coconut palm leaves (MCL) as reinforcement in polyester composites. Flexural and impact properties showed a significant increase with the addition of fibre reinforcement in the composite. They observed that the MCL/polyester composite was found to be superior to most of the polyester composites with regards to flexural and impact properties. Shanmugam and Thiruchitrambalam [13] examined the influence of alkali treatment on the mechanical properties (flexural and tensile strength) of palmyra palm leaf stalk fibre (PPLSF)/jute fibre polyester hybrid composites. The study confirmed that the fibre surface roughness increases with alkali treatment thereby providing more surface area leading to better fibre matrix adhesion.

To enhance the thermal and mechanical properties, fillers are added to polymer matrices. Organic fillers have added benefits over inorganic fillers such as less weight and reduced wear of the processing machinery. Marcovich et al. [14] carried out a study on composites made from sawdust and unsaturated polyester. The bending modulus showed an increasing trend up to a certain extent with the addition of filler. They concluded that saw dust composites showed satisfactorily comparable specific mechanical properties with respect to inorganic filler composites. Suarez et al. [15] analysed the tensile properties of polypropylene and malleated polypropylene (PP) coated sawdust composites. The results obtained indicated that the tensile strength of PP/MAPP sawdust composites was much superior to PP composite. Also, the micrographs revealed that the fibre pulled out is coated with the matrix and filler material indicating an effective interaction between the filler and matrix.

Many studies have been conducted to explore the use of sawdust as fillers in thermoset composites, but its usage as a filler with mangifera indica leaf stalk fibre as reinforcement in polyester has not been explored. Hence the present work aims at studying the mechanical properties of such composites finding applications in automotive and household interiors.

2 Experimental Details

2.1 Materials

Mangifera Indica leaf stalk fibres and saw dust filler were used as the reinforcements. Mangifera Indica leaves were collected from plantations within the campus in Manipal. Sawdust bio-filler was obtained from a basic workshop at our institute. Unsaturated polyester resin, its accelerator cobalt naphthalene and catalyst methyl ethyl ketone peroxide were supplied by M/s Sri Mookambika Poly Products, Udupi, Karnataka. Chemicals such as NaOH and HCl were procured from Nice Chemicals Pvt. Ltd, Kerala. Hand layup technique with compression moulding was used for fabricating the composites. The matrix properties are shown in Table 1.

Table 1. Properties of Unsaturated isophthalic polyester resin [16].

Properties	Remarks
Appearance	Pale Yellow
Density (g/cm^3)	1.15
Tensile strength (MPa)	17-21
Flexural strength (MPa)	39- 42
Viscosity at 25°C (cps)	650

2.2 Extraction and chemical treatment of the fibres

Fibres were extracted from the leaf stalk of the Mangifera Indica tree. It was sun dried for 2 days so that the sticky material on the outer surfaces loosens up. The dried leaf stalk fibres were then washed thoroughly with distilled water to remove the sticky material and greasy layers present on its surface. The fibres were later dried at room temperature for 120 h. To ensure better chemical bonding between the fibre and matrix, the fibres were subjected to mercerization treatment. The dried fibres were treated with 6 % vol. NaOH solution for 3 h at room temperature and neutralized with 3 % vol. dilute HCl. The chemically modified fibres were placed in a hot air oven at 50˚c for 4 h to dry it thoroughly. The leaf stalk and fibers being treated are shown in Fig. 1.

2.3 Preparation of sawdust bio-filler

Saw dust is a by-product formed because of machining operations carried out on wood. In the present study saw dust of teak wood was used. Approximately two kilograms of sawdust bio-filler was collected which was then sieved to size of 200 microns [17]. Sieved sawdust fillers were then treated with 2% vol. NaOH solution at room temperature for 1 h, to enhance the interfacial bonding between the polyester matrices. Post chemical treatment, the fillers were rinsed with distilled water and dried in a hot air oven for 8 h at 50˚c. The fillers were placed in a desiccator to prevent moisture absorption.

(a) (b)

Fig. 1. Mangifera Indica (a) leaf stalk (b) leaf stalk fibres undergoing chemical treatment

2.4 Preparation of composite

Chemically treated mangifera indica leaf fibre was used as reinforcement and unsaturated polyester resin used as the matrix with sawdust as filler. Composites were fabricated using hand layup followed with compression moulding technique. To ensure good quality of surface and for easy demoulding, white wax was applied over the mould surface. Fibre content of 30% by weight was kept constant while the filler content was varied from 3% to 9% by weight. A peel ply film is placed on the top surface of the mould to achieve a smooth surface before applying compressive load. Post curing was done at 50° C for duration of 3 h. The size of all the composite panels was 300 mm × 300 mm with a thickness of 5 mm. Fig. 2. shows the cured panels.

(a) (b)

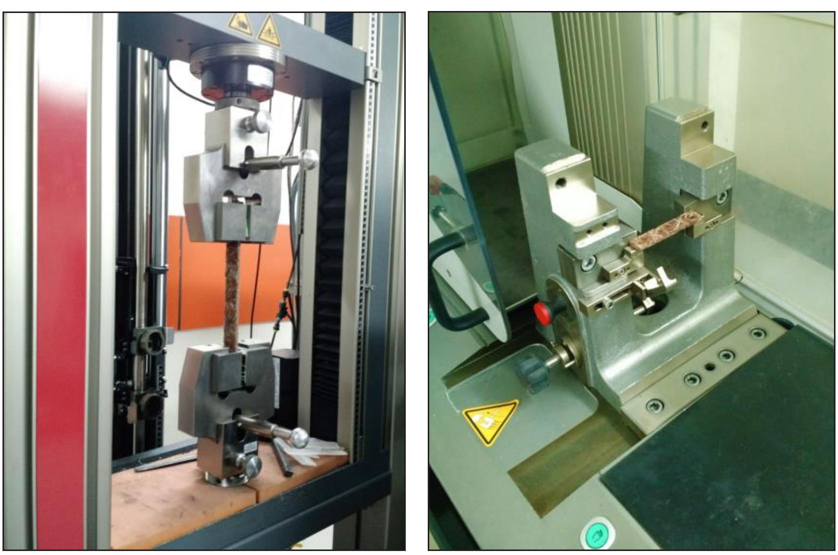
Fig. 2. Cured Composite panels with (a) 3% filler (b) 6% filler

2.5 Testing of mechanical properties of composites

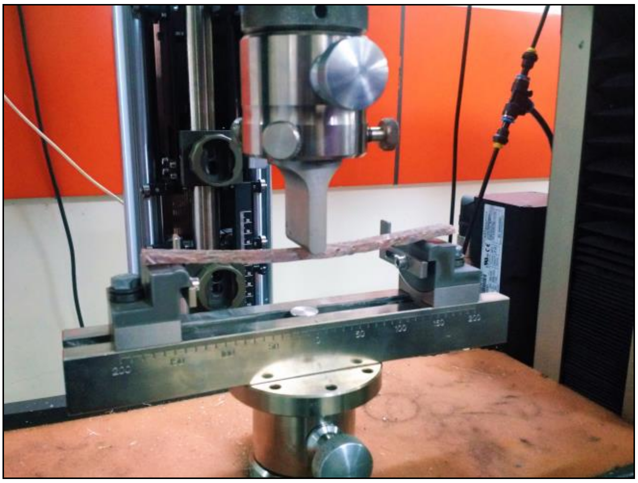
The mechanical properties of composites like tensile, flexural and impact strengths were evaluated. Tensile and flexural tests were performed on a Zwick Roell Universal Testing Machine at a cross head speed of 2 mm/min and 1 mm/min respectively, while impact testing was done on a Zwick Roell Impact tester where the specimen was subjected to an impact energy of 7.5 J. Specimens for tensile, flexural and impact tests were prepared using water jet cutting. Details of standards and specimen dimensions are shown in Table 2. Five specimens were considered for each of the above mentioned tests and average value was arrived at. Test setups are shown in Fig. 3.

Table 2. Standards and specimen dimensions [18-20].

Properties	Standard Used	Dimensions
Tensile Strength	ASTM D3039	250 mm × 25 mm
Flexural Strength	ASTM D7264	Overall Length: 120 mm; Span length: 100 mm
Impact Strength	ISO 179-1/1eu	Length 80 mm; Span length 64 mm



(a) (b)



(c)

Fig. 3. Test setups (a) Tensile (b) Impact (c) Flexural

3 Results and Discussions

Fig. 4 shows variation in tensile strength with the addition of sawdust to the composites. Treatment of fibres and fillers make them more hydrophobic resulting in improved bonding between the various constituents. When compared to neat polymer, mangifera indica leaf stalk fibre composite with no filler showed an increase of about 31% in its tensile strength. Highest tensile strength of 28 MPa was obtained for composites with 3% filler by weight, which is an increase of about 12% over composites without any filler. Further addition of saw dust to the composites resulted in reduction of tensile strength.

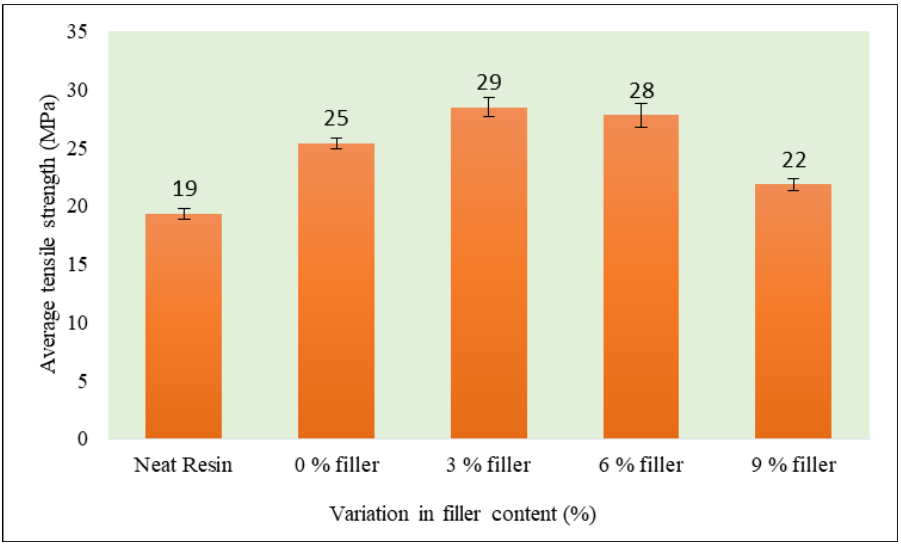


Fig. 4. Variation in tensile strength

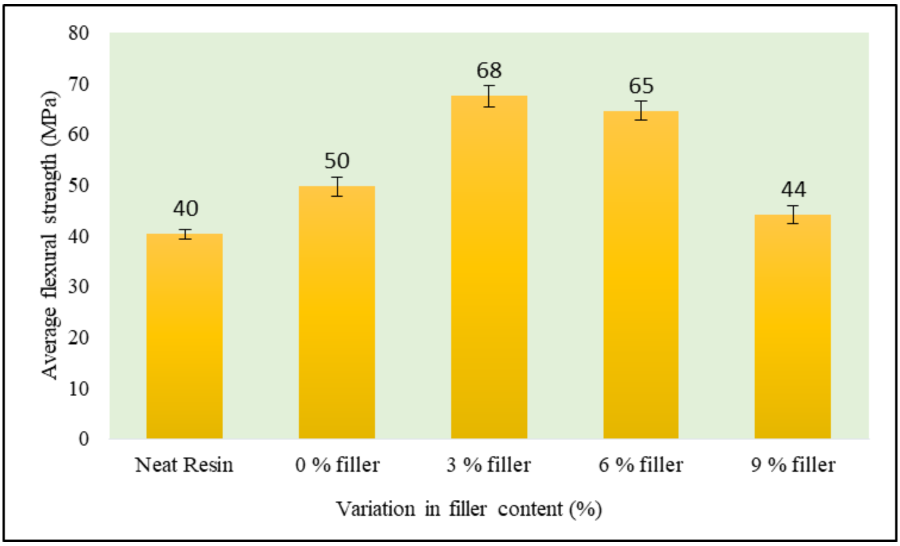


Fig. 5. Variation in flexural strength

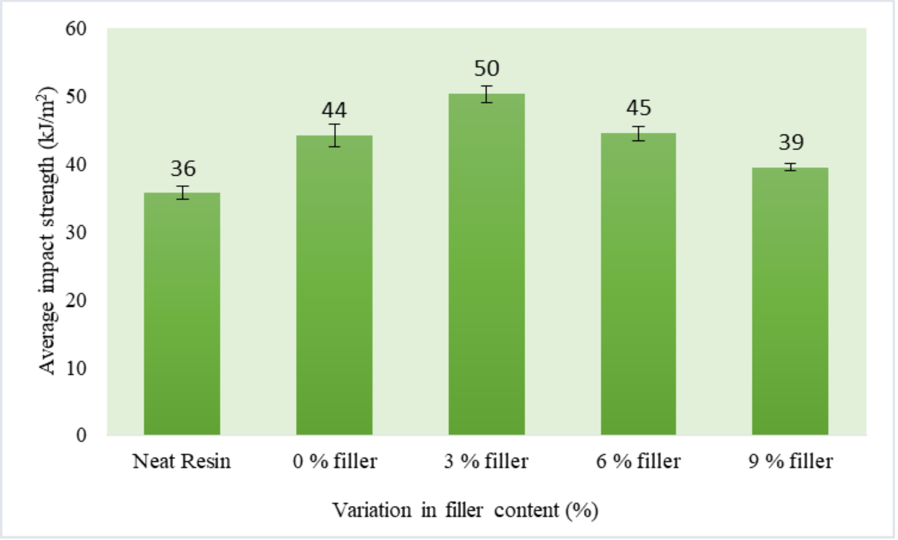


Fig. 6. Variation in impact strength

Flexural strength of the composites is presented in the Fig. 5. Addition of sawdust increased the flexural strength of the composites by about 68% when compared to neat polymer where the strength was observed to be 68 MPa which was the highest among all composites. Increase in saw dust filler to 6% and 9% resulted in lower flexural strength and the lowest strength of 44 MPa was obtained in composites with 9% saw dust filler.

The variation of impact strength is presented in Fig. 6. As seen in case of tensile and flexural tests, presence of sawdust resulted in improved energy absorption when compared to composites with only mangifera indica leaf stalk fibres as reinforcement. Increased resistance to impact loading is mainly because of the resistance provided by the fillers to the propagation of cracks [21]. Highest impact resistance of 50 kJ/m^2 is seen in composites with 3% weight filler. But with increase in filler content further reduced the ability of the composite to absorb impact load. Reduction in mechanical properties of composites beyond 3% filler content is due to reduced resin content which results in ineffective stress transfer between the various phases in composite material [7].

4 Conclusions

Composites were fabricated by varying saw dust filler content in mangifera indica leaf stalk fibre reinforced polyester matrix. Mechanical properties such as tensile, flexural and impact strengths were evaluated and compared. Significant inferences are, weight fraction of sawdust fillers have greater influence on the mechanical properties of the composites. Composites with 3% saw dust filler content showed improved mechanical properties. Increasing the filler content beyond 3% led to decrease in strength of the composites. Decrease in strength with increase in filler content is attributed to ineffective load transfer between the matrix and reinforcements. Results indicate that saw dust has a potential as filler in polymer based composites.

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