

A Review on Mechanical and Tribological Characterization of Natural Fibres Reinforced Polymer Composites

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ABSTRACT: This review paper examines the mechanical and tribological properties of natural fibres reinforced polymer composites and the various processing techniques used for the surface treatment of natural fibres. The mechanical and tribological properties of the different natural fibres composites were compared. Today natural fibres are attracting many researcher scholars due to its low cost and huge availability in nature. Also processing of these natural fibres is not difficult in comparison to the conventional fiber's production. Environmental awareness and a growing concern with the greenhouse effect have triggered the construction, automotive, and packing industries to watch out for eco-friendly materials that can replace conventional synthetic polymeric fibres. Natural fibres seem to be a good alternative because they are readily available in fibrous form and can be extracted from plants at a very affordable cost. For these reasons the natural fibres are trusted over the regular synthetic fibres.

KEYWORDS: Treatment, Natural fibres, Composite, Polymer, Mechanical properties, Tribological properties.

I. INTRODUCTION

1.1 Natural Fibres Reinforced Polymer Composites

Composite materials are macroscopic combinations of two or more distinct materials having a recognizable interface between each other. The interest in natural fibres-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants such as banana, flax, cotton, hemp, jute, sisal, Kenaf, pineapple, ramie, bamboo, etc., as well as wood, used from time immemorial as a source of lignocelluloses fibres are more and more often applied as the reinforcement of composites. Raw natural fibres of different plants are shown in figure 1.



Figure 1: Images of untreated raw natural fibres of different plants.

Their availability, renewability, low density, and price as well as satisfactory mechanical properties such as low density, high strength-to-weight ratio, high stiffness-to weight ratio, excellent durability, dimensional stability, noncorrosive nature, good thermal and electrical insulation properties and ease of fabrication make them an attractive ecological alternative to glass, carbon and man-made fibres used for the manufacturing of composites.

The natural fibres containing composites are more environmentally friendly and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling, paneling, partition boards), packaging, consumer products etc.[1] . Figure 2 shows the consumer products made from natural fibres.



Figure 2: Consumer products made from natural fibres.

1.2 Surface Treatments of Natural Fibres

The use of natural fibres in fibre-reinforced composites comes with drawbacks. They are highly hydrophilic, leading to high moisture absorption and poor interfacial adhesion in matrix-reinforcement bonds. This affects the fibres' thermal stability as well as mechanical properties, hence limiting their wider application.

The surface of a natural fibre is composed of oils, cellulose, hemicellulose, lignin, and a waxy layer, which impedes interfacial bonding. A good reinforcement-matrix bond is crucial because it ensures acceptable load transfer stress across the interface. Strong fibre-matrix adhesion is instrumental in improving the thermal and mechanical properties of the composite [2].

To address poor interfacial adhesion in natural fibres reinforced composites caused by their hydrophilic nature, surface modification treatments like alkalisation, acetylation, bleaching benzoilation, and silane have been used to enhance reinforcement-matrix interfacial adhesion by eliminating the amorphous surface layer from the fibre and enhancing the physical strength of the fibres [2].

There is a need to review how different researchers have investigated the effect of these different surface modification techniques in natural fibres and the results they attained to enhance qualities like thermal stability, mechanical properties, tribological properties as well as natural fibre hydrophobicity.

The main constituents of natural fibres are cellulose, hemicellulose, lignin, wax, and pectin. Wax and pectin are a small part of the composition of fibres compared to the other three components. Surface modification methods are used to increase the cellulose content in natural fibres to improve their fibre tensile strength; but moderation of the surface modification is necessary to avoid the cellulose being damaged in the procedure. Hemicellulose is a type of polymer found in natural fibres that is easily dissolved by an alkali, has high hydrophilicity, and can be easily hydrolysed by acid. Lignin is a component of a natural fibre which links the hemicellulose and cellulose, providing rigidity to the plant cell wall, but not mechanical properties to the same extent as cellulose does. Lignin is acid-soluble, but it cannot be hydrolysed by acids [2].

II. LITERATURE REVIEW

2.1 Mechanical behaviour of polymer composite materials

The mechanical properties of composite materials are emergent characteristics that arise from the interaction between a matrix (the binder) and a reinforcement (the strength-providing component). These materials are primarily valued for their exceptional strength-to-weight ratios, high stiffness, and ability to be tailored for specific engineering demands.

Various polymer materials, inclusive of fillers depending on the necessity of the applications are reviewed in this section. Polyester resin with glass fibre reinforced fillers have been employed to analyse the mechanical properties such as tensile strength, flexural strength and Young's Modulus for single and multiple fibres by Pothula Yamini et. al. [3] evaluated the mechanical properties of natural fibre reinforced composites. Three different types of composite were fabricated and tested under tensile, flexural, compressive, and impact conditions. It was concluded that the mechanical properties varied from fibre to fibre. Maximum tensile and flexural strength was shown by Kenaf composite and Hemp composite respectively. Kenaf + Hemp composite showed the best results for both compressive and impact tests because of more cellulose

Ya-Jung Lee et al. [4]. They have generated a numerical model from the trial information generated which in the future could be utilized for accessing the mechanical properties of laminates delivered utilizing distinctive types of fibers without additional tries. They have also concluded that GFRP laminates when subjected to flexural loading the stiffness after initial failure does not drop promptly but rather decays step by step.

Sang-Young Kim et al. [5] have used vinyl ester epoxy resin and glass fibres reinforced fillers to analyse mechanical properties such as tensile strength, compressive strength and in-plane shear properties using the vacuum infusion process and hand layup process samples and found the vacuum infusion processed GFRP samples showed better mechanical properties than the hand layup technique due to handlayup's technique increased porosity.

Mouritz et al. [6] analysed the development of fibre-reinforced polymer composites in naval ships and submarines. The high strength to weight ratio finds applications in superstructures, decks, bulkheads, advanced mast systems, propellers etc. which were meant to reduce weight and in turn increases the speed and decreases fuel costs in the long run, as well as contributes to corrosion resistance and less maintenance costs.

Selvaraju et al. [7] analysed the application of Aramid fibre reinforced polymer (CFRP) and glass fibre reinforced Polymer (GFRP) in marine applications such as naval patrol boats, submarine diesel storage tanks, lube tanks, utility tanks, low pressure pipes, cable ladders and trays with the intention of reducing weight, improving corrosion resistance and increasing the strength to weight ratio.

2.2 Tribological (Wear and Friction) behaviour of polymer composite materials

Law Mei Lin et al. [8] conducted an experimental study using epoxy resin and recycled carbon fibre, which was obtained from two conditions, as received and cryogenic treated condition. The tribological properties including the wear rate and the coefficient of friction were taken at different time intervals for both combinations and found the coefficient of friction decreased and wear resistance improved in the treated carbon fibre with epoxy resin when compared to the as received condition.

Shakuntala Ojha et al.[9] studied the wear behaviour of both raw and carbon black wood apple shell particles filled with epoxy resin. It was found the carbon black particulate composites showed a lower wear rate as compared to the raw particulate composite. The effect of wood apple shell particle concentrations with different impingement angles of 30, 45, 60 and 90o and at a constant impact velocity of 48 m/s was observed and found the maximum erosion rate occurred at 60o impingement angle. The minimum erosion rate occurred for carbon black composite at 20 wt% as compared to raw 10 wt% of filler composite.

Gai Zhao et al.[10] analysed friction and wear of polyimides reinforced with carbon, glass and aramid fibres. The research showed reinforcement improves the tribological properties of composites and the best performance was achieved by inorganic fibre reinforced composites compared to glass fiber reinforcement due to the effective load sharing between surfaces in contact.

Anu Gupta et al. [11] conducted research using epoxy resin reinforced with relatively inexpensive bamboo fibres to determine the mechanical and erosion behaviour of epoxy composites. Fibre composition ranged from 0-40 % with increments of 10% by weight. The results demonstrated the erosion wear rate improved quite significantly by the addition of bamboo fibres and mechanical properties, such as tensile strength shown maximum value at 40 wt%, flexural strength and impact strength increased with 0-20% inclusion of fibres. The test results have also shown a decrease in properties with 30 % inclusion of fibres, furthermore mechanical properties increased above 30 % inclusion of bamboo fibre reinforcement.

III. CONCLUSION

The primary advantages of using lignocellulosic fibers as fillers/reinforcements in plastics are low densities, non abrasive, high filling levels possible resulting in high stiffness properties, high specific properties, easily recyclable, unlike brittle fibres, the fibres will not fracture when processing over sharp curvatures, biodegradable, wide variety of fibres available throughout the world, would generate rural jobs increases non-food agricultural/farm based economy, low energy consumption and low cost.

Treatments of natural fibres are centred around modifying the fibre surface to remove the amorphous surface, which consists of hemicellulose and lignin. Removal of these components increases the composition of cellulose in the fibre surface which is responsible for giving strength to the fibre. This action reduces the fibre's moisture affinity and improves mechanical, tribological and thermal properties by ensuring that there is strong interfacial adhesion when the fibre is bonded to the matrix. Adequate treatment is important as insufficient treatment does not remove enough hemicellulose and lignin from the fibre surface, and over-treatment removes cellulose from the fibre surface, which is instrumental in giving stiffness to the natural fibre.

The future points to the incorporation of fibre-reinforced composites as a substitute to reduce the usage of metals in engineering industries. Physical treatment techniques like plasma treatment have gained attraction in the engineering community because of their lower production time and chemical production. The exploration of many more plant fibres is imperative to find better performing fibres to be used in composites. Currently, composites are used mostly in a non-structural capacity due to their lower fracture toughness. Future research should be focused on producing tough, thermally stable natural fibre reinforced composites that are still lightweight.

Conflicts of interest

The authors declare no conflicts of interest.

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