A Review on Chopped Jute Fibre Reinforced Composites for Advanced Aerospace Applications

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Abstract

Composites are one of the most versatile and compliant engineering materials known to men. Evolvements in the field of materials science and technology have given birth to these interesting and wonderful materials. Presently composite materials play a key role in aerospace industry, automobile industry and other engineering applications as they exhibit unmatchable strength to weight and modulus to weight ratio compared to metals and alloys. In today's world natural fibre reinforced composites are gaining importance due to their bio-degradable and non-carcinogenic nature. These composites are potential candidates for replacement of high cost glass fiber for low load bearing applications. Natural fibers have the advantages of low density, low cost, eco-friendly, lightweight, strong, renewable, cheap and biodegradable. This review paper investigates the mechanical, chemical and other properties of composites which uses various natural fibres in chopped form as reinforcement.

Keywords*: Natural Fibre, Fibre, Biodegradable, Mechanical Properties*

1. Introduction

A composite material is a combination of two or more materials that, when combined, offer superior properties compared to the individual components. Unlike metallic alloys, the components in a composite retain their distinct chemical, physical, and mechanical properties. These materials consist of a reinforcement (such as fibers) and a matrix. Composite materials are favored for their high strength, stiffness, and low density, which contribute to weight reduction in finished products. This review focuses on natural fiber-reinforced composites, which have gained increasing importance as substitutes for synthetic fibers in recent years [1].

Natural fiber composites have gained significant attention in recent decades due to their high strength-to-weight ratio and lightweight nature, making them ideal for structural and non-structural applications [2]. Among these, jute fiber stands out as a biodegradable alternative to synthetic and glass fibers, particularly where high strength isn't crucial. Jute fiber composites offer advantages like low processing costs, density, and energy consumption (2% of that for glass fiber), along with excellent mechanical properties. This paper reviews various fabrication techniques and factors influencing the mechanical properties of jute fiber-reinforced composites.

The rapid deforestation driven by the high demand for wood in furniture production poses significant environmental concerns [3]. A substantial portion of wood is used for household products, necessitating the search for sustainable alternatives. Jute composites present a viable solution, offering a biodegradable, eco-friendly option with enhanced properties such as dimensional stability, low cost, and renewability. These composites are increasingly used in applications ranging from building materials to natural fiberboards, offering structural, thermal, and environmental benefits, and are favored over synthetic fibers for their abundance and sustainability.

Natural fiber composites are made from fibers such as coir, jute, bagasse, cotton, bamboo, and hemp, all of which are derived from plants and contain lignocellulose. These fibers are known for being eco-friendly, lightweight, strong, renewable, affordable, and biodegradable. They can be used to reinforce both thermosetting and thermoplastic matrices. Thermosetting resins like epoxy, polyester, polyurethane, and phenolic are commonly employed in high-performance composite applications due to their ability to provide good mechanical properties, including stiffness and strength, at relatively low costs.

Advancements in technology and innovation have shown that jute could potentially replace wood in various applications by enhancing its mechanical, thermal, and electrical properties. Research into jute composites is extensive, with studies focusing on improving these properties. Liu et.al explored the effect of nano-SiO_2 particles on the microstructure of jute fibers, while Roy et al. investigated the combined effects of nano-clay and jute fibers in natural rubber composites. Boccardi studied jute reinforcement with various matrices, and Jha examined the erosion and mechanical behavior of hybrid composites made using the hand lay-up method.

Recent developments in natural fiber technology, particularly through genetic engineering, present significant opportunities for creating improved materials from renewable resources, supporting global sustainability. Natural fiber composites are increasingly valued for their low density and environmental benefits compared to traditional composites. They are particularly cost-effective for applications in building and construction, packaging, automotive interiors, and storage devices. These composites are considered viable alternatives to high-cost glass fibers for low-load-bearing uses due to their low density, cost, and biodegradability.

However, one major drawback of natural fiber composites is their relatively high moisture absorption. To address this, chemical treatments are applied to modify the fiber's surface properties. The properties of various natural fibers are summarized in Table 1.

Table 1. Properties of fibers [8]

Fiber	Density (g/cm^3)	Elongation	Tensile strength (Mpa)
Jute	1.3	1.5-1.8	393-773

2. Materials And Methods

2.1 Chemical treatment of fibers

Alkali treatment is a straightforward chemical method used to enhance the mechanical properties of natural fiber-reinforced composites. This treatment addresses issues like high moisture absorption, poor wettability, and inadequate adhesion by removing lignin and hemicellulose from the fibers, reducing spiral angles, and increasing molecular orientation. The process improves interfacial bonding, resulting in finer fibers, increased crystallinity, fewer defects, better bonding, and reduced moisture absorption. In the case of jute fibers, they are soaked in a NaOH solution to achieve these improvements before being used in composite fabrication.

2.2 Fabrication of composite

Alkaline-treated natural fibers will be cut to a required length of 5 mm, 10 mm or 15 mm and is used as reinforcement material. The epoxy resin with hardener is used matrix material. Handlayup technique followed by compression moulding is used for fabrication of composite. Releasing agent is applied to mould surface before fabrication. Epoxy resin and hardener are mixed along by weight ratio for 10 mins. Then chopped fibres are added to this mixture and stirred for 20 mins. Then this mixture is laid into mould of 300 mm x 300 mm x 5 mm. The mixture is distributed throughout the mould and pressed under load for uniform distribution of matrix. Composites are then allowed to cure at room temperature of 24 hrs.

3. Experimental Details

The prepared composites is subjected to hardness, tensile, flexural tests.

3.1 Tensile test

To determine the tensile strength of a natural fiber epoxy composite, the tensile test should be conducted using a Universal Testing Machine (UTM). The specimen must be prepared in accordance with ASTM D3039 standards. Once the specimen is secured in the UTM, tensile force is applied, and displacement is measured. The resulting data is used to plot force versus displacement graphs. The ultimate strength is derived from this graph, allowing for the calculation of tensile strength. The tensile strength can be estimated using the formula:

$$\sigma_t = \frac{P}{b \cdot h}$$

where:

- σ_t is the tensile strength,
- P is the ultimate load on the specimen,
- b is the initial width of the specimen, and
- h is the initial thickness of the specimen.

3.2 Flexural test

For the flexural test, also known as the three-point bending test, the procedure is carried out using a Universal Testing Machine (UTM) on specimens prepared according to ASTM D790 standards. The flexural strength is calculated using the formula:

$$\sigma_f = \frac{3PL}{2bh^2}$$

where:

- σ_f is the flexural strength,
- PPP is the maximum load applied to the specimen (in Newtons),
- L is the span length of the specimen,
- b is the width of the specimen, and
- h is the thickness of the specimen.

3.3 Hardness test

The hardness test is performed with a ball indentor 1/16’’ with an applied load of 100 kg. Rockwell hardness scale chosen was M scale. As M-scale is mostly used to measure the hardness for plastics and soft materials. changes in resins have no considerable effect on the hardness of the composite and it mainly depends on the type of fiber used as the reinforcement.

Water Absorption

The water absorption ability of jute fiber composites significantly affects their mechanical properties. Jute composites tend to absorb more water compared to biopolymers, which impacts their strength. However, surface treatments like fluorocarbon and hydrocarbon treatments can reduce water absorption, thereby enhancing the mechanical properties of the composites. The extent of water absorption is influenced by the size and flexural strength of the composites. Notably, the mechanical properties of recycled jute composites are reduced due to water absorption.

Surface Treatment

Surface treatments are employed to enhance the overall performance of jute fiber composites. Applying a 2 mm polymer film to the jute fibers significantly improves the mechanical properties of the composite. Additionally, treatments with alkali, peroxide, permanganate, and silicate modify the jute fiber surface, resulting in improved flexural and tensile properties of the composite. These treatments help in achieving better bonding between the fiber and the matrix, leading to stronger and more durable composites.

Optimization of Machining parameters

Various optimization techniques, including GRA, Taguchi, RSM, ANN, and Fuzzy-logic, have been applied to refine the machining process variables in jute fiber composites. Studies focused on drilling operations in both untreated and alkali-treated jute composites, using GRA methodology for optimization. The research shows that delamination failure tends to increase with a higher feed rate. Moreover, ANOVA results indicate that fiber treatment has a negligible impact on delamination in the fabricated composites.

4. Conclusions

A comprehensive review has been conducted, highlighting the following points: The review is to focus on fabrication, mechanical and physical properties of jute fibre reinforced composites. For better understanding and easy selection for various applications, a comparative account on properties of these fibres is presented.

- **Jute Fiber Composites**: Jute fiber composites present a viable alternative to synthetic fiber composites due to their lower cost, reduced weight, easy availability, eco-friendliness, biodegradability, and high flexural strength.
- **Fabrication Techniques**: The mechanical behavior of composites is significantly influenced by the fabrication techniques, which include variations in the size, orientation, and weight segments of the reinforced materials.
- **Surface Treatments**: Various surface treatments employed by researchers have yielded positive results in enhancing the mechanical strength of composites.
- **Moisture Content**: The mechanical properties of composites, including bending and tensile strength, are affected by moisture content. Specifically, both flexural stress and shear stress decrease as immersion time increases.
- **Research Gaps**: There is a lack of investigation into the use of micro- or nano-sized reinforced materials in jute composites. Additionally, the application of soft computing techniques to evaluate the performance of jute composites in different mechanical tests is limited. This area presents a potential opportunity for future research in jute composite fabrication.

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