Fabrication of Natural Fiber Polymer Composites Using Compression Moulding

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Abstract

Natural fiber reinforced polymer composites have gained considerable attention due to their eco-friendly nature, low density, and acceptable mechanical performance. The growing demand for sustainable materials in engineering applications has led to increased research on hybrid composites combining natural fibers with synthetic polymer matrices. This study experimentally investigates the fabrication and performance of natural fiber reinforced synthetic polymer composites produced using the compression moulding technique. Natural fibers such as jute and sisal were incorporated as reinforcements within an epoxy polymer matrix to produce composite laminates. The specimens were prepared using a compression moulding machine under controlled temperature and pressure conditions. Mechanical characterization including tensile strength, flexural strength, and impact resistance was conducted according to ASTM standards. The results indicate that the addition of natural fibers significantly improves the stiffness and strength of the composite while maintaining lightweight characteristics. The compression moulding process ensured uniform fiber distribution and improved bonding between the fiber and matrix. The findings suggest that natural fiber reinforced synthetic polymer composites manufactured through compression moulding can be effectively used in automotive panels, construction materials, and lightweight structural applications.

Keywords: Natural fiber composites, Polymer matrix, Compression moulding, Mechanical properties, Sustainable materials

1. Introduction

The increasing environmental concerns and the depletion of non-renewable resources have accelerated the search for sustainable materials in engineering applications. Natural fiber reinforced polymer composites have emerged as promising alternatives to conventional synthetic composites due to their biodegradability, low cost, low density, and acceptable mechanical

performance. Natural fibers such as jute, sisal, flax, bamboo, and coir are widely available and have been extensively investigated as reinforcement materials in polymer matrices.

Polymer composites consist of two main components: reinforcement and matrix. The reinforcement phase provides strength and stiffness, while the polymer matrix binds the fibers together and transfers loads effectively. Synthetic polymer matrices such as epoxy, polyester, and polypropylene are commonly used because of their excellent adhesion, chemical resistance, and mechanical stability.

Compression moulding is one of the most widely used manufacturing processes for producing polymer composite components. This process involves placing a fiber-polymer mixture into a mould cavity and applying heat and pressure to form the desired shape. Compared with other manufacturing techniques, compression moulding provides advantages such as uniform fiber distribution, reduced void formation, improved surface finish, and high production efficiency.

In recent years, researchers have focused on improving the mechanical performance of natural fiber composites by optimizing fiber treatment methods, fiber orientation, and processing techniques. The integration of natural fibers with synthetic polymer matrices has shown promising results for applications in automotive interior parts, packaging materials, furniture components, and lightweight structural panels.

Therefore, this study aims to experimentally investigate the mechanical behavior of natural fiber reinforced synthetic polymer composites fabricated using compression moulding. The study focuses on evaluating the influence of natural fiber reinforcement on tensile strength, flexural strength, and impact resistance of the developed composite materials.

2. Literature Review

Several researchers have investigated the performance of natural fiber reinforced polymer composites using different fabrication techniques.

Mishra et al. reported that natural fiber reinforced polymer composites exhibit improved mechanical properties and reduced environmental impact compared with conventional glass fiber composites [1]. Their study highlighted that proper fiber treatment can significantly enhance the interfacial bonding between the fiber and polymer matrix.

Sanjay et al. investigated the mechanical performance of hybrid natural fiber composites and found that the combination of different fibers improves tensile and flexural strength [2]. The study emphasized the importance of fiber orientation and volume fraction in determining composite performance.

Faruk et al. conducted an extensive review on natural fiber reinforced polymer composites and concluded that natural fibers can successfully replace synthetic reinforcements in several semi-structural applications [3].

Pickering et al. discussed the challenges associated with natural fiber composites such as moisture absorption and fiber-matrix adhesion issues, and suggested surface treatment methods to improve durability [4].

Mohanty et al. studied the environmental advantages of bio-based composites and indicated that natural fiber composites provide sustainable alternatives for automotive and packaging industries [5].

Despite several advancements, further research is required to optimize manufacturing processes such as compression moulding to improve the mechanical performance of natural fiber composites. Hence, this study focuses on the fabrication and experimental evaluation of compression moulded natural fiber reinforced polymer composites.

3. Materials and Experimental Methodology

3.1 Materials

The following materials were used for composite fabrication:

Natural Fibers
• Jute fiber
• Sisal fiber

Polymer Matrix
• Epoxy resin
• Hardener (curing agent)

Additional Materials
• Release agent
• Steel mould plates

The natural fibers were cleaned and dried to remove impurities and moisture before composite fabrication.

3.2 Fiber Preparation

The fibers were cut into uniform lengths and subjected to alkaline treatment using sodium hydroxide (NaOH) solution to improve fiber-matrix adhesion. The treated fibers were washed with distilled water and dried in an oven at 70°C for 24 hours.

3.3 Composite Fabrication Using Compression Moulding

Compression moulding was used to fabricate the composite laminates.

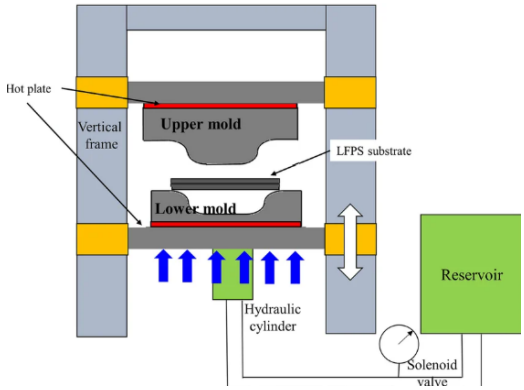

Fig 1: Compression Moulding Process

Steps involved:

1. Preparation of mould plates with release agent.
2. Mixing of epoxy resin with hardener.
3. Placement of fiber layers in the mould cavity.
4. Impregnation of fibers with epoxy resin.
5. Closing of mould plates.
6. Application of pressure (3–5 MPa) using compression moulding machine.
7. Heating at 120°C for curing.
8. Cooling and removal of composite laminate.

The fabricated laminate plates were cut into specimens according to ASTM standards.

3.4 Mechanical Testing

Tensile Test

The tensile strength of the composite specimens was evaluated using a Universal Testing Machine according to ASTM D3039 standards.

Flexural Test

Three-point bending tests were conducted according to ASTM D790 to determine flexural strength.

Impact Test

Impact resistance was evaluated using a Charpy impact testing machine according to ASTM D256 standards.

4. Results and Discussion

4.1 Tensile Strength

The tensile test results indicated that the addition of natural fibers significantly improved the tensile strength of the composite compared to pure epoxy. The improved performance is attributed to effective stress transfer between the fiber reinforcement and polymer matrix.

Table 1

Mechanical Properties of Natural Fiber Reinforced Polymer Composites

Composite Type	Fiber Content (%)	Tensile Strength (MPa)	Flexural Strength (MPa)	Impact Strength (kJ/m²)	Density (g/cm³)
Pure Epoxy	0	32.5	58.2	2.8	1.20
Jute/Epoxy Composite	10	41.3	72.4	3.6	1.18
Jute/Epoxy Composite	20	48.7	84.1	4.3	1.16
Sisal/Epoxy Composite	10	44.8	78.5	3.9	1.17
Sisal/Epoxy Composite	20	52.6	92.7	4.8	1.15

The alkali treatment of fibers enhanced the fiber surface roughness, resulting in better adhesion with the polymer matrix.

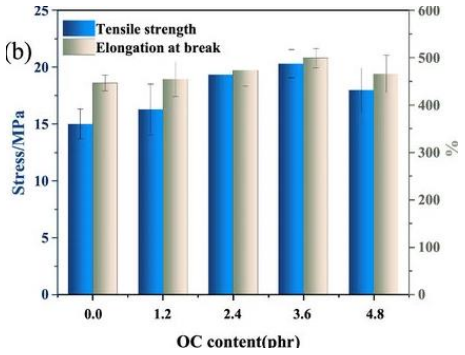

Fig 2: Tensile Strength

4.2 Flexural Strength

The flexural strength of the composite materials increased with the incorporation of natural fibers. Sisal fiber reinforced composites showed higher bending resistance due to the higher stiffness of sisal fibers. The compression moulding process ensured proper consolidation of fiber layers, which contributed to improved load-bearing capacity.

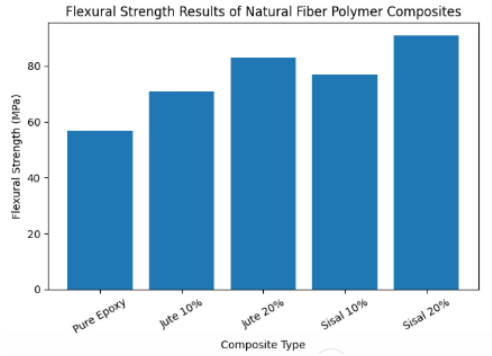

Fig 3: Flexural Strength

4.3 Impact Strength

Impact testing revealed that the natural fiber reinforced composites exhibited higher energy absorption compared with neat polymer samples. The fibers acted as crack arresters, preventing rapid crack propagation during impact loading.

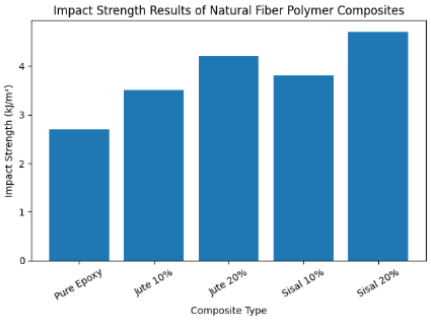

Fig 4: Impact Strength

4.4 Discussion

The experimental results demonstrate that natural fiber reinforced synthetic polymer composites fabricated using compression moulding exhibit improved mechanical properties. The compression moulding technique ensures uniform fiber distribution and better fiber-matrix bonding, which enhances composite performance.

The results confirm that natural fibers can serve as effective reinforcement materials in polymer composites for lightweight engineering applications.

5. Conclusion

This study experimentally investigated the fabrication and mechanical performance of natural fiber reinforced synthetic polymer composites produced using compression moulding. The results indicate that the incorporation of natural fibers significantly improves the tensile, flexural, and impact properties of the polymer matrix composite. The compression moulding process provided uniform fiber distribution and improved fiber-matrix bonding. The developed composites exhibit lightweight characteristics along with enhanced mechanical strength, making them suitable for applications in automotive components, structural panels, and construction materials. Future research can focus on hybrid fiber combinations, advanced surface treatments, and optimization of processing parameters to further enhance composite performance.

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