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Experimental Investigation and Analysis of Hybrid Laminates

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Abstract

Hybrid composites have gained significant attention from researchers due to their potential as reinforcement materials for composites. This is primarily because of the numerous advantages they offer, including low density, low cost, renewability, biodegradability, and environmental safety, along with mechanical properties that are comparable to those of synthetic fiber composites. In this study, hybrid composites made from natural fibers and glass fibers were fabricated using epoxy resin and a combination of the hand lay-up method and the cold press method. Specimens were cut from the fabricated laminate according to ASTM standards for various tests, including tensile, flexural, and impact tests. The woven fiberglass hybrid composites demonstrated a notable improvement in tensile strength. Consequently, these high-performance hybrid composites display enhanced mechanical characteristics and have wide-ranging engineering applications in industries such as transportation, aeronautics, naval, and automotive.

Keywords: *Hybrid composites, mechanical properties, epoxy.*

1. Introduction

Composite materials based on polymers have found widespread use in recent years, including in the automotive, sporting goods, maritime, electrical, industrial, construction, and home appliance industries. Polymeric composites are lightweight, highly resistant to corrosion, and strong and stiff. Natural fibers are abundant in the environment and can be utilized to strengthen polymers to create materials that are both robust and lightweight. There isn't much information in the literature about using banana fiber in reinforcing polymers. The ideal amount of banana fiber in polyester composites reinforced with banana fiber, according to dynamic mechanical studies, is 39%. The examination of these composites' tensile, flexural, and impact characteristics showed that banana fiber could be used as a reinforcing ingredient to create composites with good strength. Banana fiber is derived from the leftover stems or trunks of bananas, which are widely available worldwide. Natural fibers from a wide variety of plants are only one example of the many rich resources that nature continues to graciously give to humanity. However, the research and usage of natural fiber reinforced composite materials in various industries have received a lot of attention throughout the past ten years. Naturally, the comparatively high cost of synthetic N c fibers like glass, plastic, carbon, and Kevlar used in fiber-reinforced composites, as well as the health risks associated with asbestos fibers, necessitates the investigation of natural fibers like banana fibers. Important benefits of natural fiber are low density, suitable stiffness, mechanical properties that are highly renewable and disposable. Banana natural fiber is used in this project. Additionally, these banana fibers are biodegradable and recyclable. The pseudo-stem of the banana plant (Musa sepientum) yields banana fiber, a strong cellulosic fiber with comparatively good mechanical qualities. Fibrous plants are abundant in tropical nations like India, and some of them, like bananas, are grown as crops. Currently, banana fiber is a byproduct of growing bananas. Banana fiber can therefore be obtained for industrial uses without incurring any additional costs. It is observed that banana fiber provides good reinforcement.

1.2 Objectives

- Creation of a novel class of hybrid composites reinforced with banana and oriented glass fibers, based on epoxy.
- Assessment of these composites' mechanical characteristics, including micro hardness, tensile strength, and flexural strength.
- To investigate how the mechanical behaviour of the composites is affected by fiber factors like fiber and fiber loading.

1.3 Types of Composite Materials

Broadly, composite materials can be classified into three groups on the basis of matrix material. They are

- Metal Matrix Composites (MMC)
- Ceramic Matrix Composites (CMC)
- Polymer Matrix Composites (PMC)

Composites made of metal matrix Metal matrix composites provide several advantages over monolithic metals, including a lower coefficient of thermal expansion, a higher specific modulus, a greater specific strength, and improved characteristics at higher temperatures. Metal matrix composites are being considered for a variety of applications due to these characteristics, including heat exchangers, structural components, housings, tubes, cables, and combustion chamber nozzles (used in rockets and space shuttles). Composites made of ceramic matrix Increasing toughness is one of the primary goals when creating ceramic matrix composites. Naturally, it is hoped—and frequently observed that ceramic matrix composites will simultaneously increase in strength and stiffness. Composites of Polymer Matrix The most often utilized matrix materials are polymeric matrix composites. There are two explanations for this. For many structural applications, polymers' mechanical qualities are generally insufficient. Specifically, they lack the strength and rigidity of ceramics and metals. These challenges can be addressed by using polymers to reinforce other materials. Second, manufacturing polymer matrix composites does not require high temperatures or pressures. Because of this, polymer composites advanced quickly and gained popularity for structural applications quite quickly. Because the composites' overall qualities are better than those of the constituent polymers, composites made of poly are used. [1-5]

2. Experimental

2.1 Materials and Methods the Matrix

Vinyl ester, unsaturated polyester, and epoxy are the ingredients utilized to make the matrix. The most popular matrix for high-performance advanced polymer composites are epoxy resins; nevertheless, due to their high degree of cross-linking, they are also naturally brittle. The densely cross linked structures are the basis of superior mechanical properties such as high modulus, high fracture strength, and solvent resistance. However, these materials are irreversibly damaged by high stresses due to the formation and propagation of cracks. These lead to dangerous loss in the load-carrying capacity of polymeric structural engineering materials. Currently the unsaturated polyesters are the most widely used polymer in construction.

2.2 Hardener

A mixture of materials added to a plastic composition to aid in, encourage, or regulate the curing process; moreover, a material added to regulate the level of hardness of the cured film. Also see cross-linking, catalysts, and curing agents. All working times (pot life) are based upon an optimum working temperature of about 80 degrees F. Curing times are significantly impacted by temperature changes, and they can occasionally double below 65F. Other factors that affect epoxy curing can be moisture and humidity, as well as the thickness of lamination. [6-10]

2.3 Fibers of Glass

Glass fiber is the most often used reinforcement in polymer matrix composites. The majority of fibers are made of silica (sio2) with the addition of calcium, boron, sodium, iron, and aluminum oxides. Three types of glass fibers are distinguished: e-glass, s-glass, and c-glass. S-glass is meant for great strength, whereas e-glass is meant for electrical application. These days, researchers have created tools that turn glass fiber dust into powder or particle cullet using pyrolysis or calcinations and pulverization. As a result, the business was able to recycle the fiber dust for use in glassmaking. This chapter describes the materials and techniques utilized in the hybrid composites' manufacturing, sample preparation, mechanical testing, and characterisation.

- Epoxy resin
- Banana Fiber
- Glass Fiber (S-Glass)
- Hardener

Epoxy resins are available in liquid and solid forms and are cured into the finished plastics by a catalyst. They are cured at room temperatures as well as elevated temperatures of about 2750C. The erosion resin of grade LY-556 was used of density 1.1-1.2gm/cc at 298K. It having the following outstanding properties has been used as the matrix material.

- Outstanding adherence to various substances.
- Strong defense against atmospheric and chemical assault. high stability in dimensions.
- Free from internal stresses.
- Superior electrical and mechanical qualities. Tasteless, odorless, and absolutely harmless. minimal shrinking.

2.4 Banana fiber and Alkali treatment

A natural fiber with comparatively strong mechanical qualities is banana fiber. The spare tire recess on the small, second-generation Mercedes-Benz A-Class is made of a composite material that is rot-resistant and has high tensile strength. It is made of polypropylene thermoplastic with abaca and banana fibers incorporated. It is resistant to being struck by stones and exposed to environmental elements including water, sunlight, and some chemicals. Because abaca fiber uses 60% less energy to produce than regular glass fiber, using it saves energy. In order to soften the fiber and prepare it for spinning, banana fiber samples were treated with three different concentrations of sodium hydroxide (NaOH), which eliminates contaminants from the fiber surface. 0.5%, 1%, and 1.5% weight/volume were the concentrations that were employed. The sample to liquor ratio used for treatment was 1:30. The institute follows this standard practice. 200 grams of banana fibers were utilized for each concentration in this investigation. Six liters of solution were utilized in each example because the NaOH was used at 1:30. A 1% NaOH solution was used to prepare the NaOH solution.

Fibre-cell-OH + NaOH Fibre Cell-O-Na+ + H2O + impurities

One of the most adaptable industrial materials available today is glass fiber. They are readily produced from raw materials, which are available in virtually unlimited supply. All glass fibers described in this article are de-rived from compositions containing silica. They exhibit useful bulk properties such as hardness, transparency, resistance to chemical attack, stability, and inertness, as well as desirable fiber properties such as strength, flexibility, and stiffness. Glass fibers are used in the Manufacture of structural composites, printed circuit boards and a wide range of special-purpose products. Table 1 shows Properties of Banana Fiber

Table 1 Properties of Banana Fiber

Properties	Range
Cellulose (%)	63-64
Hemicellulose (%)	19
Lumen size (%)	5
Moisture content	10
Density(g/cm3)	1-1.5
Elongation at a break (%)	4.5-6.5
Young's modulus (GPa)	20
Microfibrillar angle (deg.)	11

2.4.1 Hand Layup Technique

An explanation of the hand layup method Matrixes and resins are manually infused into fibers that are bonded, knitted, sewn, or cut strands of fabric. Rollers or brushes are often used for this, although nip-roller type impregnators—which use revolving rollers and a resin bath—are increasingly being used to force resin into textiles. Under normal air circumstances, laminates are allowed to cure. Figure 1 shows Treatment of Banana Fiber.

2.5 Alkaline Treatment of Banana Fibers Protocol

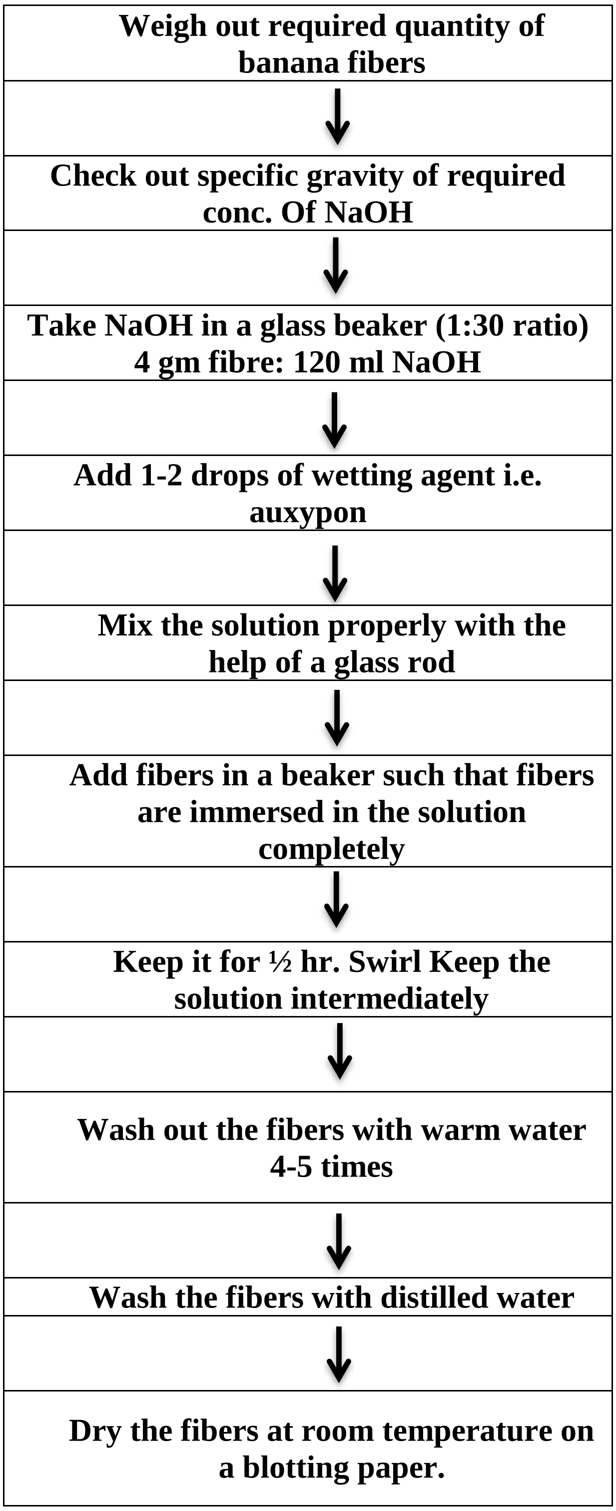

Figure 1 Treatment of Banana Fiber

2.5.1 Options for Materials Resins

Epoxy, polyester, vinyl ester, phenolic and any other resin. Fibers: Glass, Carbon, Aramid and any other reinforcement, although heavy aramid fabrics can be difficult to wet-out by hand. Cores: Any core materials can be used provided that should be compatible with resin system, i.e. polystyrene core cannot be used with polyester or vinylester resin system. [11-14]

2.5.2 Advantages

- Low capital Investment.
- Simple principles to fabricate the part.
- Low cost tooling, if room-temperature cure resins are used.
- Wide choice of suppliers and material types.

The banana fiber and glass which is taken as reinforcement in this study is collected from local sources. The epoxy resin and the hardener are supplied. Wooden moulds having were first manufactured for composite fabrication. The banana fiber and S- Glass fibers are mixed with epoxy resin by simple mechanical stirring and the mixture was poured into various moulds, keeping in view the requirements of various testing conditions and characterization standards. The composite samples of nine different compositions (S-1 to S-4) are prepared. The composite samples S-1 to S-4 are prepared in three different percentages of Glass and banana fibers (15 wt % and 30 wt %). This is accomplished while maintaining a set percentage of epoxy (50–60 weight percent).While maintaining a constant length of glass fiber, the same lengths of banana fiber are employed. Table 5 displays the specific composition and identification of composites. To make it easier to remove the composite from the mold after curing, a releasing agent is applied to the mold release sheets. A sliding roller is used to carefully remove any trapped air bubbles, and the mold is then closed for curing at 30°C for 24 hours while maintaining a continuous weight of 50 kg. Following curing, specimens of the appropriate size are cut in accordance with ASTM requirements using a diamond cutter for mechanical testing. The following table lists the designation and composition of the composites made for this investigation. In order to prepare the samples, the two fibers' lengths and loadings were varied. Curing at high temperature has the added advantage that it actually increases the end mechanical properties of the material. And many resin systems will not reach their ultimate mechanical properties unless the resin is given this 'Postcure'. This posture process involves increasing the laminate temperature after the initial room temperature cure, which increase the amount of cross linking of the molecules that can take place. To some degree this posture will occur naturally at warm room temperatures, but higher properties and shorter posture times will be obtained if elevated temperatures are used

3. Results and Discussion

3.1 Tensile Test

One of the most crucial and frequently measured characteristics of materials used in structural applications is their resistance to breaking under tensile stress. The ultimate tensile strength, also known as tensile strength at break, is the force per unit area (MPa or psi) needed to break a material in this way. Tensile characteristics show how a material will respond to tension-induced pressures. A tensile test is a basic mechanical test in which a meticulously prepared specimen is loaded under strict control while the applied load and the specimen's elongation over a certain distance are measured. The modulus of elasticity, elastic limit, elongation, proportional limit, area reduction, tensile strength, yield point, yield strength, and other parameters are all determined via tensile tests. The following table lists the designation and composition of the composites made for this investigation. In order to prepare the samples, the two fibers' lengths and loadings were varied Figure 2 shows Tensile Test; Table 2 shows Tensile Strength.

3.1 Flexural Strength

The ability of a material to withstand deformation under load is known as flexural strength, which is sometimes referred to as modulus of rupture, bend strength, or fracture strength. The most common test is the transverse bending test, which uses a three-point flexural test procedure to bend a rod specimen with a circular or rectangular crosssection until it fractures. The maximum stress felt by the material at the point of rupture is represented by the flexural strength. It is measured in terms of stress, here given the symbol. When an object formed of a single material, like a wooden beam or a steel rod, is bending, it experiences a range of stresses across its depth. At the edge of the object on the inside of the bend (concave face) the stress will be at its maximum compressive stress value. At the outside of the bend (convex face) the stress will be at its maximum tensile value. These inner and outer edges of the beam or rod are known as the 'extreme fibers'. Most materials fail under tensile stress before they fail under compressive stress, so the maximum tensile stress value that can be sustained before the beam or rod fails is its flexural strength. and loadings were varied Figure 3 shows Flexural Test, Table 3 shows Flexural Strength

Figure 2 Tensile Test

Table 2 Tensile Strength

S.No.	Length (mm)	Width (mm)	Thickness (mm)	Tensile strength (Mpa)
1	60	12	4.00	56
2	60	12	3.80	34.12
3	60	12	3.90	55.50
4	60	12	3.90	35.16

Figure 3 Flexural Test

Table 3 Flexural Strength

S.No.	Span Length (mm)	Thickness (mm)	Breadth (mm)	Flexural strength (Mpa)
1	100	4.	27.02	164.20
2	100	3.30	26.80	134.20
3	100	3.80	27.80	118.60
4	100	3.90	26,80	122,60

3.2 Charpy Impact

A standardized high strain-rate test that assesses how much energy a material absorbs during fracture is the Charpy impact test, sometimes referred to as the Charpy v-notch test. This absorbed energy serves as a gauge for the toughness of a material and can be used to investigate the temperature-dependent ductile-brittle transition. Because it is simple to conduct and prepare, and because it yields fast and affordable findings, it is commonly used in industry. The fact that all outcomes are only comparative is a significant drawback. A pendulum axe swinging at a sample of material with a notch makes up the instrument. By comparing the height of the hammer before and after a large fracture, one can determine the amount of energy that was delivered to the material. The notch in the sample affects the results of the impact test, thus it is necessary for the notch to be of regular dimensions and geometry. The size of the sample can also affect results, since the dimensions determine whether or not the material is in plane strain. Impact strength = E/t×1000 ‘E’- Energy used to break (J) ‘t’ – Thickness in mm The epoxy resin and the hardener are supplied. Wooden moulds having were first manufactured for composite fabrication

Figure 4 Charpy Test

Table 4 Impact Strength

S. No.	Breadth (mm)	Thickness (mm)	Energy use to break(J)	Impact strength (J/mm)
1	10	4.	2	10
2	10	3.70	2	10.70
3	10	3.80	2	10.64
4	10	3.90	2	10.30

Conclusions

Experimental research was done on a novel kind of fiber reinforcing composite. Chemical treatment like NaOH will increases the flexural strength of the fiber up to 20-30% and removes the moisture content of the fiber. The mechanical properties of banana and glass fiber and reinforced epoxy hybrid composites have been investigated. The tensile strength and flexural strength increases with increasing fibre volume fraction. Among all the hybrid fibre composites tested, banana reinforced epoxy hybrid composites registered the highest mechanical properties whereas glass and banana fiber composites showed the highest. The mechanical properties of the natural fibre and synthetic fiber platescom-posites tested were found to compare favourably with the corresponding tensile and flexural properties increasing volume fraction of fiber percent. The volume of glass fiber dust makes it unsuitable for reuse as a raw material for glassmaking. It has been disposed of as industrial trash via land filling. However, regarding the glass fiber dust as an important resource for glassmaking the company decided to recycle it. The future scope of the project is extended by doing the experimental analysis on different proportion of coupling agents and the fiber content in the samples and performs the mechanical and thermal properties test on the specimen. And also implementation of eco-friendly fibers in the automotive parts like car panels, bumper etc. Through implementing this fiber we can achieve light weight and structural component in automotive parts, which in turn fuel efficiency is increased.

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