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# Fabrication and analysis of Jute/Hemp reinforced fiber

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***Abstract: There is a huge need for new materials in all fields of engineering, this invites the development of new materials which suits the need. Utilization of biodegradable materials i.e. natural fibers for various applications to preserve the environment from synthetic fibers invites the development of natural fiber reinforced polyester composites. In a country like India which is producing an enormous amount of agricultural solid waste (in the form of leaf, fruits, stems etc.) there is lack of marketing for the above said wastes, if this can be improved the farmers may get benefited. Natural fiber reinforced composites are preferred than conventional materials because of their advantages like low density, light weight, high strength to weight ratio, low cost, high toughness, and biodegradability. The present investigation deals with the preparation of jute, Hemp fiber and jute- Hemp fiber (Hybrid) reinforced polyester composite and to determine the tensile modulus with an increase in percentage weight fraction of the fiber and further the experimental results will be validated through ANSYS software.***

***Keywords: Natural Fibers; Hemp, Jute Fibre, Hybrid Composite, Polyester Resin, Catalyst, Accelerator.***

## 1. INTRODUCTION

The natural fibers are renewable, non-abrasive, and bio-degradable, possess a good calorific value, exhibit excellent mechanical properties and can be incinerated for energy recovery have low density and are inexpensive. This good environmental friendly feature makes the materials very popular in engineering markets such as the automotive and construction industry [1, 2]. Composite materials are composed of two or more phases one of the phases is termed as the matrix phase, which is continuous and surrounds the other phase which is often called the dispersed phase or reinforcement phase. The reinforcement is usually much stronger and stiffer than the matrix, and gives the composite good properties [3].In contrast to metallic alloys, each material retains its separate chemical, physical, and mechanical properties [4]. Jute fibres are the natural fibres light in weight and many researchers have already identified the possibilities of fully biodegradable polymers with jute fiber reinforcement [5-6].

[7] The main advantages of composite materials are their high strength and stiffness, combined with low density, when compared with bulk materials, allowing for a weight reduction in the finished part. [8] the reinforcement is usually a fiber or a particulate. Particulate composites have dimensions that are approximately equal in all directions. They may be spherical, platelets, or any other regular or irregular geometry [9]. The use of natural fibers in matrices is highly beneficial because the strength and toughness of resulting composites are greater than unreinforced plastics. So, it is found good to use natural fibres in place of plastics and other environment unfriendly materials [10]. A fiber has a length that is much greater than its diameter. The length-to-diameter (l/d) ratio is known as the aspect ratio and can vary greatly. Continuous fibers have long aspect ratios, while discontinuous fibers have short aspect ratios [11]. Natural fibers are introduced as a replacement to synthetic fibers in order to reduce the environmental impact of non-biodegradable materials [12].

Various natural fibres such as bamboo, sisal, jute, flax, hemp, Pineapple leaf fiber, coir etc. are used as a reinforcement and thermo set or thermoplastic materials are used as a matrix [13]. Continuous-fiber composites normally have a preferred orientation, while discontinuous fibers generally have a random orientation. Examples of continuous reinforcements include unidirectional, woven cloth, and helical winding while examples of discontinuous reinforcements are chopped fibers and random [14].

Continuous-fiber composites are often made into laminates by stacking single sheets of continuous fibers in different orientations to obtain the desired strength and stiffness properties with fiber volumes as high as 5 to 30 percent. [15]. Natural fibers reinforced

composite not only exhibits but also excellent mechanical and dielectric properties, contribute to environmental advantages such as recyclable, biodegradable, hence, the use of natural fibers in composite materials industry can reduce environmental pollution and waste disposal problems [16].

## 2. MATERIALS ARE USED IN THIS EXPERIMENTATION

The basic raw materials used to prepare the composites are jute and hemp fibers procured from GO Green products, 129, Cathedral Garden Road, Nungambakkam, Chennai, Tamilnadu, 600034, India.

Polyester Resin, catalyst and acceleratoris purchased from BINDU AGENCIES H.NO 59-13-34/1, Shop No. 182, City Heart Towers, Main Road, Gayathri Nagar, and Vijayawada – 520008.

### 2.1 Jute Fiber

- The industrial term for jute fibre is raw jute, the plants grow up to and 1–4 meters (3–12 feet) long in two or three-month time, and such plants are cut, tied up in bundles and kept under water for several days for fermentation.
- It is a natural fiber popularly known as the golden fiber. It is one of the cheapest and the strongest of all-natural fibers
- Jute is the second most common natural fiber, cultivated in the world and extensively grown in Bangladesh, China, India, Indonesia, and Brazil.

**Table 1: Properties of Jute Fiber**

| Fiber | Density g/cm$^3$ | Elongation (%) | Specific Modulus (Gpa) |
|---|---|---|---|
| Jute | 1.3 | 1.7 | 39 |

### 2.2 Hemp Fibre

**Table 2: Hemp Fiber Properties**

| Fiber | Density g/cm$^3$ | Elongation (%) | Specific Modulus (Gpa) |
|---|---|---|---|
| Hemp | 300-1300 | 1.6 | 3.5 |

- Hemp is an environmental “saviour”. Hemp can be used in a variety of ways; it can produce everything from clothing to paper to fuel easily, cheaply, and most of all, in an environmentally friendly fashion.
- Hemp is completely renewable as an energy source and it grows fast, too, so it’s easily replenished.
- Hemp fiber is longer, stronger, more absorbent and more insulative than cotton fiber.
- The main uses of hemp fibre were in rope, sacking, carpet, nets, and webbing.

### 2.3 Polyester Resin

- ECMALON 4411 is an unsaturated polyester resin of orthophthalic acid grade with clear colourless or pale yellow colour.
- A large number of polyester structures that have found used in industry today, displays a wide variety of properties and applications.
- Polyesters are one of the most versatile synthetic copolymers. Polyesters are produced in high volume that exceeds 30 billion pounds a year worldwide.

  Most unsaturated polyester resins consist of a solution of a polyester in styrene monomer. The styrene serves two purposes: firstly, it acts as a solvent for the resin and secondly it enables the resin to be cured from a liquid to a solid by curing with polyester resin. This curing is achieved at room temperature by adding a catalyst (or initiator), plus an accelerator (or promoter).

### 2.4 Catalyst

The catalysts used are invariably organic peroxides. Since these are chemically unstable as a class of compounds, of which some can decompose explosively in the pure form, they are mostly supplied as solutions, dispersions or pastes in a plasticiser or as a powder mixed with an inert filler to stabilise them.

This indicates that they have been made safer to handle or stabilised with a plasticiser. Since organic peroxides are hazardous materials to handle, due note should be taken of the safety recommendations.

### 2.5 Accelerator

The most commonly used accelerators are either those based on a cobalt soap or those based on a tertiary amine. Other types of accelerators may be used for specific applications and include quaternary ammonium compounds, vanadium, tin and zirconium salts. Accelerators are usually used at between 0.5 and 4% based on the resin weight.

### 2.6 Preparation and Testing of Composite Specimens

Many techniques are available in industries for manufacturing of composites such as compression moulding, vacuum moulding, pultruding, and resin transfer moulding are few examples. The hand layup process of manufacturing is one of the simplest and easiest methods for manufacturing composites. A primary advantage of the hand layup technique is to fabricate very largely, complex parts with reduced manufacturing times. Additional benefits are simple equipment and tooling that are relatively less expensive than other manufacturing processes. Different steps involved in the making of composites are a collection of fibers and resin, preparation of mould, making and extraction of the composite from the mould. Initially, the base plate (tile) has to be cleaned by scrubbing with a sand paper. Then the surface is allowed to dry after cleaning it with a thinner and the wax has to be applied to the mould (acrylate) sheet for the easy removal of the specimen. After that, the fibers are cut down as per the ASTM Standards and then take the polyester resin, catalyst, accelerator and mix in the proportion of 100:1:1 and place the fibers in the mould (acrylate) sheet and applied resin. This process is continuing up to 8-11 layers. After preparing the laminates of weight is placed on the laminates (100 kg). After 24 hours, the weight is removed, the cured specimens are removed and they are cleaned &inspected.

**Fig. 1: Specimens of Jute – Polyester- Resin for Tensile, Flexural and Impact**

**Fig. 2; Specimens Hemp Fiber – Polyester Resin for Tensile, Flexural and Impact**

**Fig. 3: Specimens of Jute-Hemp Fiber-Polyester Resin Hybrid Composite for Tensile, flexural and Impact**

## 2.7 Tests for Mechanical Properties

### Tensile Test

The tensile test has been performed on A 2-ton capacity – Electronic tensometer, METM 2000 ER-I model is used to find the tensile strength of composites. Its capacity can be changed by load cells of 20 kg, 200 kg, and 2000 kg. A load cell of 200kg is used for testing composites. Self-aligned quick grip chuck is used to hold the composite specimen. A digital micro meter is used to measure the thickness and width of the composite. Tensile strength, the tensile modulus is determined after conducting the tensile test.


**Fig. 4: Tensometer**

### a. Flexural Test

The flexural test was performed on the same electronic tensometer is as shown fig. 6. The three-point bending test was conducted. Load, deformation values are noted and Flexural modulus and flexural strength values are determined.

### b. Impact Test

The Izod impact test of composite was tested and a cross section having 45$^{o}$ V-notch and 2mm deep were used for the test. Each test is repeated three to four times and the average values are taken for calculating the impact strength

## 2.8. Finite Element Analysis

Modeling of jute and hemp fibres reinforced composite materials are carried out in Solid works and imported to ANSYS. The model was meshed using element type solid 186. Boundary conditions are applied for uniaxial tensile test conditions. Contact between fibre and matrix is assigned as bonded conditions. Material properties, obtained from experiments for matrix and for jute fibre from literature, are assigned to respective models.

In the study of the Micromechanics of fiber reinforced materials, it is convenient to use an orthogonal coordinate system that has one axis aligned with the fiber direction. The 1-2-3 Coordinate system shown in Figure 13 is used to study the behavior of the unit cell. The 1 axis is aligned with the fiber direction, the 2 axis is in the plane of the unit cell and perpendicular to the fibers and the 3 axis is perpendicular to the plane of the unit cell and is also perpendicular to the fibers. The isolated unit cell behaves as a part of a large array of unit cells by satisfying the conditions that the boundaries of the isolated unit cell remain plane.

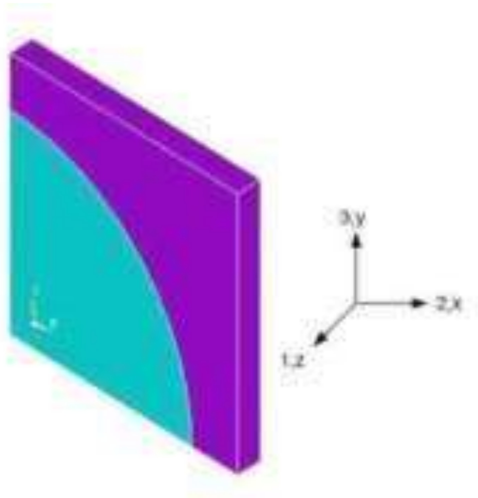


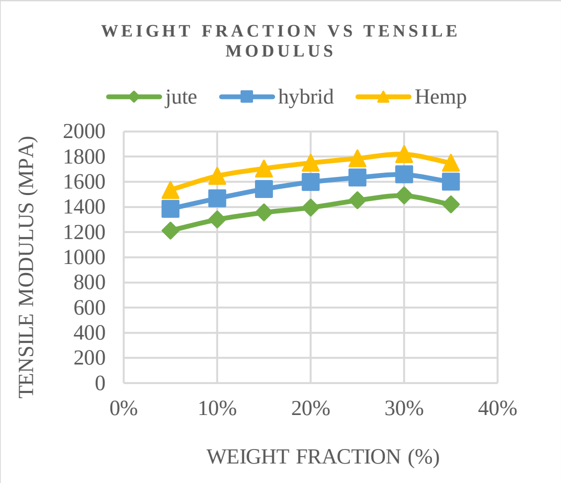

**Fig. 5: One Fourth Portion of Unit Cell**

**Due to symmetry in the geometry, material, and loading of the unit cell with respect to 1-2-3 coordinate system, it is assumed that one fourth of the unit cell is sufficient to carry out the present analysis.**

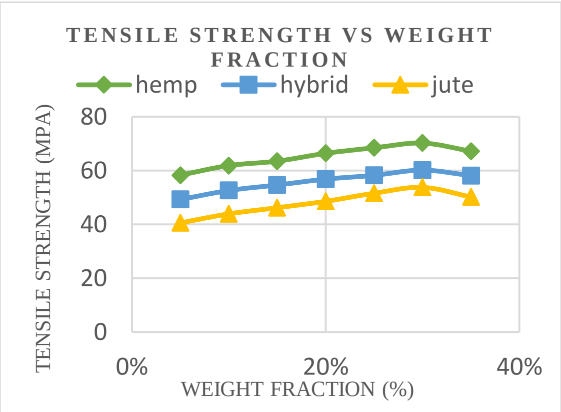
## 3. RESULTS AND DISCUSSION

### 3.1 Tensile Test

From tensile test young's modulus of jute- polyester, pineapple leaf fiber – polyester and hybrid (jute – hemp fibers-polyester) composites are determined. The specimen dimensions of tensile test are160 mm x 12.5 mm x 3 mm as per the **(ASTM D638-89)** Standard.




**Graph: 1 Weight Fraction Vs Tensile Modulus**

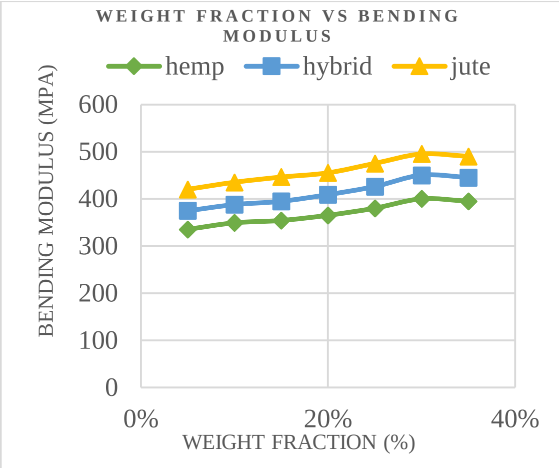



**Graph: 2 Weight Fraction Vs Tensile Strength**

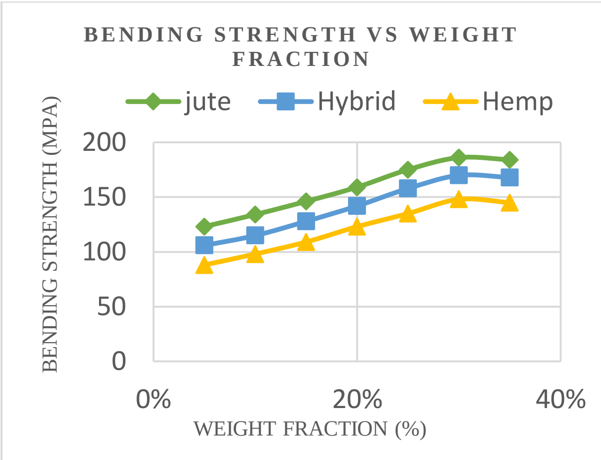
 

### 3.2 Flexural Test

By conducting the flexural test, a flexural modulus of jute- polyester, hemp fiber – polyester and hybrid (jute – hemp fibers-polyester) composite. The specimen dimensions are 100 mm x 25 mm x 3 mm as per **(ASTM D79-86)** standard.



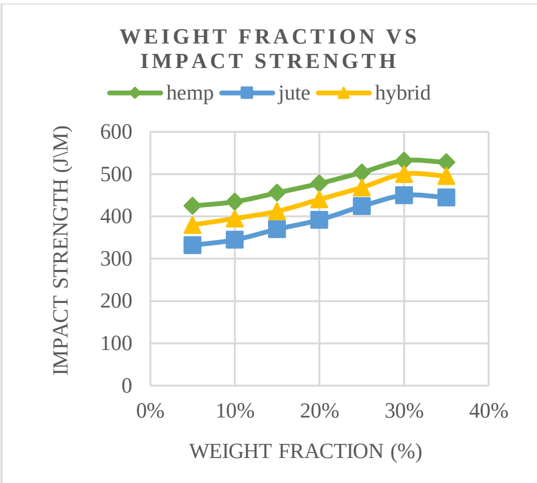

**Graph: 3 Weight fraction vs Bending Modulus**




**Graph: 4 Weight Fraction vs Bending Strength**

### 3.3 Impact Test

Impact test is conducted on jute -polyester, hemp fibre and hybrid (jute-hemp fibres -polyester) composite




**Graph: 5 Weight Fraction Vs Impact Strength**

**3. Ansys Results:**

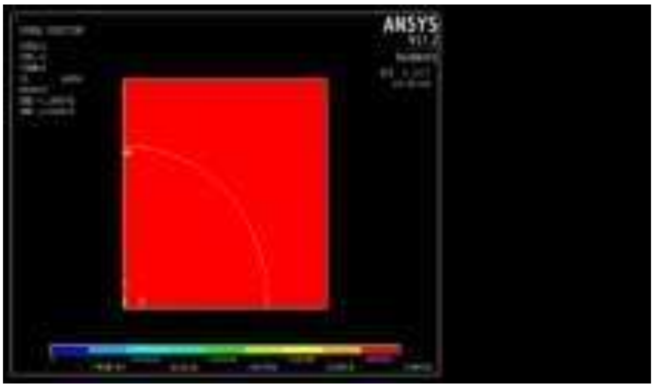


**Figure 6: Results Plot of E1 for Sample Hemp Fiber Model**

**Table 3: Comparison Values of E1 for Hemp Fibre**

| S No. | Fiber Weight Fraction | Hemp Fiber Tensile Modulus E1 (Mpa) | |
|---|---|---|---|
| | | *Experiment* | *Ansys* |
| 1 | 5% | 1534.42 | 1536.33 |
| 2 | 10% | 1645.64 | 1647.92 |
| 3 | 15% | 1705.85 | 1703.26 |
| 4 | 20% | 1750.49 | 1752.34 |
| 5 | 25% | 1786.28 | 1788.53 |
| 6 | 30% | 1820.94 | 1821.62 |
| 7 | 35% | 1754.24 | 1752.64 |

To determine impact strength as per the **(ASTMD 256-97)** standard. The specimen dimensions are 63.5mm x 3mm

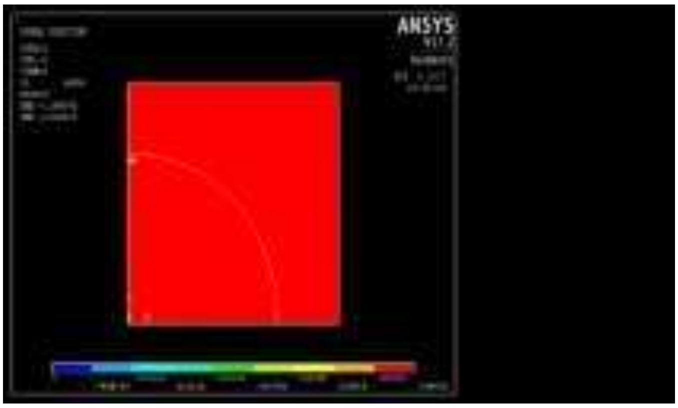


**Figure 7: Results plot of EI for Sample Jute Fiber**

**Table 4: Comparison Values of E1 for Jute Fiber**

| S No. | Fiber Weight Fraction | Jute Fiber Tensile Modulus E1 (Mpa) | |
|---|---|---|---|
| | | *Experiment* | *Ansys* |
| 1 | 5% | 1354.49 | 1357.26 |
| 2 | 10% | 1459.26 | 1548.68 |
| 3 | 15% | 1560.52 | 1562.49 |
| 4 | 20% | 1567.68 | 1565.67 |
| 5 | 25% | 1672.64 | 1670.98 |
| 6 | 30% | 1785.87 | 1783.63 |
| 7 | 35% | 1780.79 | 1781.62 |

**Table 5: Comparison Values of E1 for Hybrid Fibers**

| S No. | Fiber Weight Fraction | Hybrid Fiber Tensile ModulusE1 (Mpa) | |
|---|---|---|---|
| | | *Experiment* | *Ansys* |
| 1 | 5% | 1388.68 | 1389.49 |
| 2 | 10% | 1464.49 | 1470.65 |
| 3 | 15% | 1542.87 | 1544.82 |
| 4 | 20% | 1598.61 | 1599.62 |
| 5 | 25% | 1634.38 | 1636.49 |
| 6 | 30% | 1658.63 | 1659.74 |
| 7 | 35% | 1652.48 | 1653.96 |

## 4. CONCLUSIONS

Tensile test, bending test and impact test results, obtained from experiments, are compared with Finite element analysis results. Both results are found to be closer. Maximum load and maximum stress, as well as load versus deformation results of each cases of jute and hemp fibre hybrid polymer matrix composites with varying wait fraction % when compared with experimental and Finite element analysis results, have closer values, and From the comparison, it is concluded that further analysis can be carried out for different fibre lengths, fibre wait fractions and effect of polyester treated fibres in hybrid polymer matrix composites numerically using finite element analysis. The tensile test conducted using finite element analysis for jute and hemp fibre hybrid polymer matrix composites. Effect of polyester treated jute and banana fibre in hybrid polymer matrix composites are analysed numerically using ANSYS. Figure 8 represents the comparison of the effect of polyester treated and untreated jute and hemp fibres reinforced hybrid polymer matrix composites. It is evident from the figure that treated jute and hemp fibres carried more load when compared to untreated jute and hemp fibres for same wait fraction %.

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