# Experimental and Analysis of Polyester - Jute- Hemp Fiber Reinforced Composite

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***Abstract* - The role of natural and manmade fibres reinforced hybrid composite materials are growing in a faster rate in the field of engineering and technology due to its favourable properties. In the present unsustainable environmental condition, natural fibres are serving better material in terms of biodegradability, low cost, high strength and corrosion resistance when compared to conventional materials. The main objective of this experimental study is to fabricate the jute-hemp fibres reinforced hybrid composites and to evaluate the mechanical properties such as tensile strength, flexural strength and impact strength. There are three different types hybrid laminates are fabricated by hand lay-up method by using jute and hemp fibres as reinforcing material with polyester resin. The specimen is prepared according to ASTM standards and the experiment has been carried out by using universal testing machine (UTM).**

***Keywords* - Natural fibres; Hemp, Jute fibre, hybrid composite, Polyester resin, Catalyst, Accelerator.**

## 1. Introduction:

The natural fibers are renewable, non-abrasive, 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 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].

## 2. Materials are used in this experimentation:

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

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

- 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.

Table 2. Hemp Fiber Properties

| Fiber | Density g/cm$^3$ | Elongation (%) | Specific Modulus (Gpa) |
|---|---|---|---|
| Hemp | 300-1300 | 1.6 | 3-5 |

**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 large, 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 making of composites are collection of fibers and resin, preparation of mould, making and extraction of 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 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.

**Figure.1 Specimens of jute – polyester- resin for tensile, flexural and impact tests**

**Figure.2 Specimens hemp Fiber – polyester resin for tensile, flexural and impact tests**

**Figure.3 specimens of jute-hemp fiber-polyester resin Hybrid Composite for tensile, flexural and impact tests**

**2.7 Tests for Mechanical Properties:**

**a. 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 composite. Tensile strength, tensile modulus is determined after conducting the tensile test.


**Figure.4 Tensometer**

**b. 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.

**c. Impact Test:**

The Izod impact test of composite was tested and cross section having 45° V-notch and 2mm deep were used for 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:**

Modelling 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 behaviour of 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 large array of unit cells by satisfying the conditions that the boundaries of the isolated unit cell remain plane.

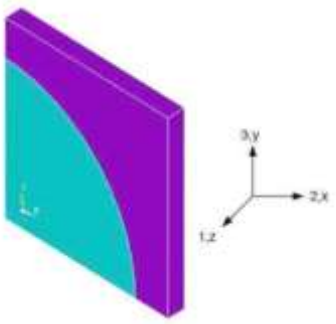


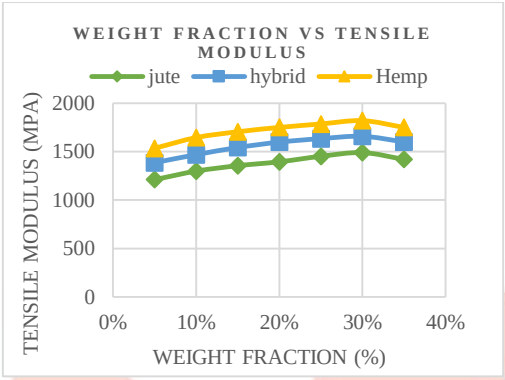

**Figure.5: One fourth portion of Unit cell**

Due to symmetry in the geometry, material and loading of 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.

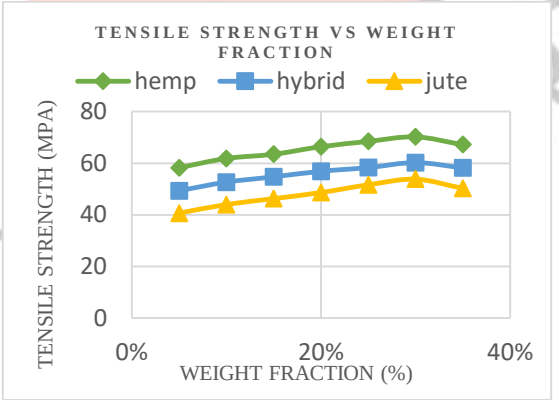
### 2.9 Results from Experimental:

#### i. 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 for tensile test are160 mm x 12.5 mm x 3 mm as per the **(ASTM D638-89)** Standard.



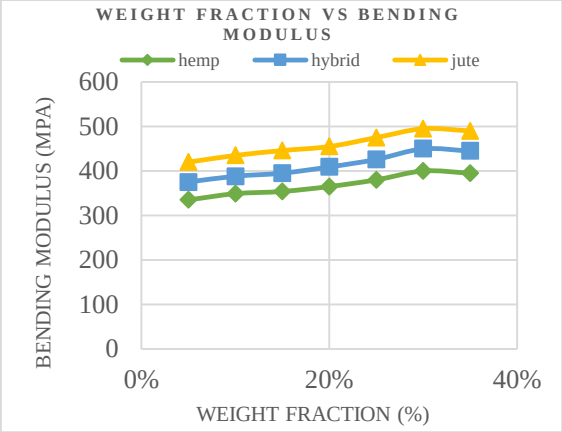

**Graph:1 Weight Fraction Vs Tensile Modulus**



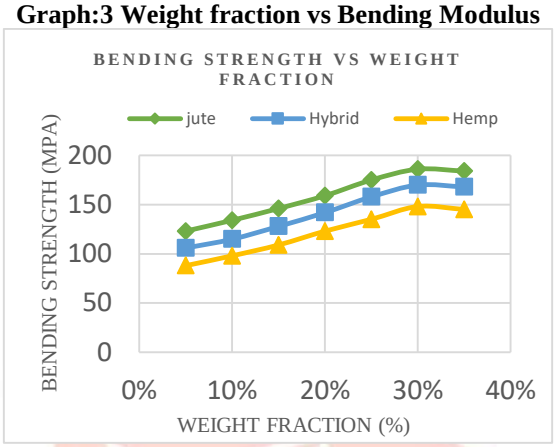

**Graph:2 Weight Fraction Vs Tensile Strength**

#### ii. Flexural Test:

By conducting flexural test, 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.



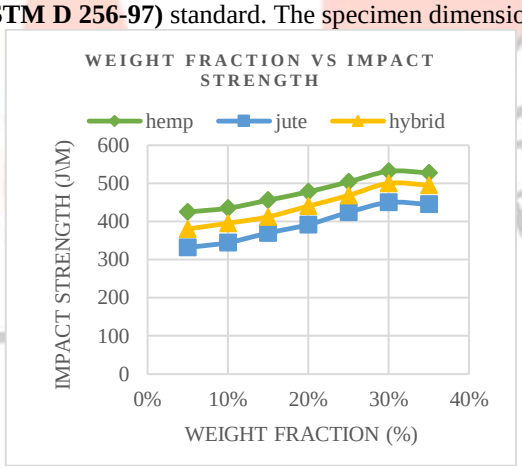

**Graph:3 Weight fraction vs Bending Modulus**




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

iii. **Impact test:**

Impact test is conducted on jute- polyester, hemp fiber – polyester and hybrid (jute – hemp fibers-polyester) composite. To determine impact strength as per the **(ASTM D 256-97)** standard. The specimen dimensions are 63.5 mm x 12.7 mm x 3 mm




**Graph:5 Weight fraction vs Impact Strength**

**3. Ansys Results:**

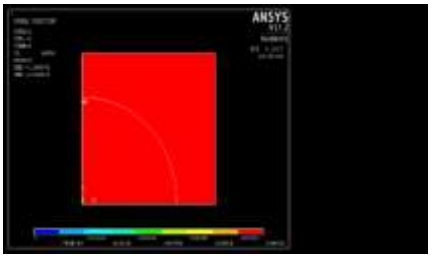



**Figure.6 Results plot of E1 for sample Hemp fiber model**

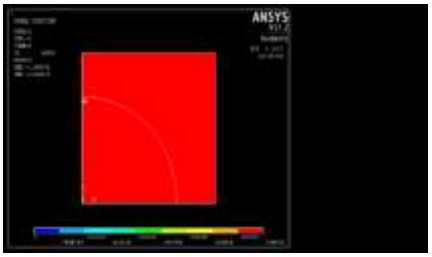
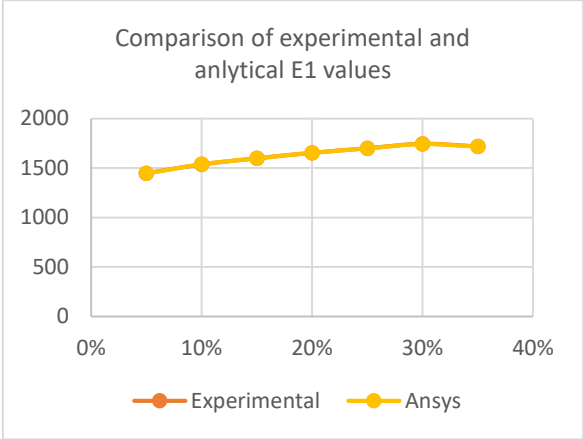



**Figure.7 Results plot of E1 for Sample Jute fiber model**




**Graph:6 Comparison of tensile modulus values determined experimentally with ANSYS results**

Table 3. Comparison values of $E_1$ for Hemp Fiber

| S No. | Fiber Weight Fraction | Hemp Fiber Tensile Modulus $E_1$ (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 |

Table 4. Comparison values of $E_1$ for Hybrid Fiber

| S No. | Fiber Weight Fraction | Hybrid Fiber Tensile Modulus $E_1$ (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 |

Table 5. Comparison values of $E_1$ for Jute Fiber

| S No. | Fiber Weight Fraction | Jute Fiber Tensile Modulus $E_1$ (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 |

**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 hemp fibre in hybrid polymer matrix composites are analyzed numerically using ANSYS. It 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 treated jute and hemp fibres carried more load when compared to untreated jute and hemp fibres for same weight fraction %.

**References**

[1]. Siregar, Januar Parlaungan, Tezara Cionita, Dandi Bachtiar, Mohd Ruzaimi Mat Rejab, and Mohd Ruzaimi. "Tensile Properties of Pineapple Leaf Fibre Reinforced Unsaturated Polyester Composites." Applied Mechanics and Materials 695 (2014): 159.

[2]. A.V. Ratna Prasad, K. Mohana Rao "Mechanical properties of natural fibre reinforced polyester composites: Jowar,sisal and bamboo". Elsevier, March2011.

[3]. Rajesh, M., Jeyaraj Pitchaimani, and N. Rajini. "Free vibration characteristics of banana/sisal natural fibers reinforced hybrid polymer composite beam." Procedia Engineering 144 (2016): 1055-1059.

[4]. M. A. Maleque*, F. Y. Bela (2007) "MECHANICAL PROPERTIES STUDY OF PSEUDO-STEM BANANA FIBERREINFORCED EPOXY COMPOSITE." Volume 32, Number 2B, he Arabian Journal for Science and Engineering.

[5]. Mehmet AKGUL, Cengiz GULER, Yalcın COPUR, (2010) "Certain physical and mechanical properties of medium density fiber boards manufactured from blends of corn ( Zea mays indurateSturt.) stalks and pine (Pinus nigra) wood." Turk J Agric For34. 197-206.

[6]. Bisen, K. B., K. Sahu, and M. M. Krishna. "Mechanical behaviour of banana and pineapple hybrid composites reinforced with epoxy resin." Int J IT, Eng Appl Sci Res 4, no. 2 (2015): 2319-4413p

[7]. Srivastava, A.K., Behera, M.K. and Ray, B.C., "Loading Rate Sensitivity of Jute/Glass Hybrid Reinforced Epoxy Composites-Effect of Surface Modifications." Int. Jou. of Reinforced Plastics and Composites, 2007, 26:851-860.

[8]. Ahmed KS, Vijayarangan S, et al. "Mechanical behaviour of isothalic polyester-based untreated woven jute and glass fabric hybrid composites." Journal of Reinforced Plastic Composites 2006; 25: 1549.

[9]. Kathleen Van de Velde and Paul Kiekens, "Thermoplastic pultrusion of natural fibre reinforced composites." Composite Structure, 2001;**54**:355-360.

[10]. Smith Thitithanasarn, Kazushi Yamada, Yew Wei Leong, Hiroyuki Nishimura and Hiroyuki Hamada, "Effect of surface treatment on thermal and mechanical performance of recycled natural fiber reinforced composites." Proceeding of the International Conference on Composite Materials 18th, 2009

[11]. David Plackett, Tom Logstrup Andersan, Walther Batsberg Perdersen and Lotte Neilsen, "Biodegradable composite based on Lpolylactide and jute fiber Composite." Science and Technology, 2003;**63**:1287-1296.
[12]. Mishra S, Mohanty AK, Drzal LT, Misra M, Parijac S, Nayak SK, et al. "Studies on mechanical performance ofbiofiber/glass reinforced polyester hybrid composites." Sci Technol 2003; 63(10):1377–85
[13]. Sreenivasan V.S., Ravindran D., Manikandan V., and Narayanasamy R. (2011). "Mechanical Properties of Randomly Oriented Short Sansevieria Cylindrical Fibre/Polyester Composites." *Materials and Design.*
[14]. Muthu Kumar, V., R. Venkatasamy, A. Sureshbabu, and D. Arunkumar. "A Study on Mechanical Properties of Natural Fiber Reinforced Laminates of Epoxy (Ly 556) Polymer Matrix Composites." International Journal of Production Technology and Management Research 2, no. 2 (2011)