Evaluation of Mechanical Properties of Polymer Composites Reinforced with Jute Mat Fiber and Egg Shell Powder for Ligaments and Tendons Replacement

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***Abstract* — In this present world scenario composite materials have a wide range of applications, but we are basically concerned over their medical applications. Fiber reinforced composite materials comprises of fiber embedded in matrix materials, which are discontinuous fiber or short fiber composites. These composites have a better bending ,buckling and good tensile properties. Of the commonly available annual crop fibers jute contains one of the highest proportions of stiff natural cellulose, approximately 75 wet %. Jute may be combined with phenolic, epoxy and polyester resins to form composite materials, and it has been laminated with glass fiber to form hybrid composites. Further to enhance then flexural strength, jute fiber is treated with urea. The composite fiber is incorporated with egg shell powder to increase the tensile strength and bending properties, because greater the filler contents higher are the properties.**

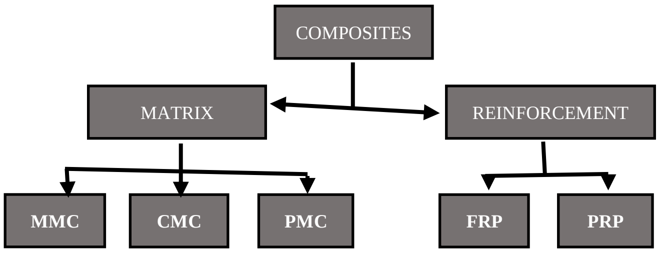
I. INTRODUCTION

Basically, when two or more than two chemically distinct materials are combined, produces synergistic effect, with a distinct separating interface of component. Due to this the component gets aggregate properties different from the component by which it is formed. The main components cannot compete with the composites in terms of properties. The component materials can be metal, ceramic or polymer etc. The use of natural or plant fiber reinforced composite is increasing with time. This is due to its advantages like low cost, ease of availability, light weight etc. The important and exclusive properties of natural composite are its renewability and biodegradability. These properties with low cost fulfil the economic interest of industries. These materials are eco-friendly and use of green materials in these composites also provides an alternative way to deal with agricultural residue. Apart from the industrial application composites have wide range of medical application and researches have been extensively carried out for their implementation. One among such application is replacement of ligaments and tendons with composite fibers whose failure is mostly common during accidents and injuries in day to day life. Composite fibers produced from naturally occurring jute fibers have extensive tensile strength and bending properties and are also safe to be embedded in human body.

1.1 DEFINITION OF COMPOSITES

A composite material is a material made from two or more constituent materials with significantly different physical or chemical properties that, when combined, produce a material with characteristics different from the individual components.

1.2 Classification of Composites



1.2.1 Basic Types of Composites

Based on Matrix

1. Metal Matrix Composites (MMC)
2. Ceramic Matrix Composites (CMC)
3. Polymer Matrix Composites (PMC)

Based on Reinforcement

1. Fiber reinforced polymer (FRP)
2. Particle reinforced polymer (PRP)

1.3 Natural Fiber Reinforced Composite

Natural fibers are used for reinforcing material. These have complicated structure, with crystalline cellulose micro fibril-reinforced amorphous lignin or/and hemi-cellulose matrix. Natural fibers are constitutes of cellulose, hemi-cellulose, lignin, waxes and some water-soluble compounds. The major component of it are cellulose (60%-80%), hemi-cellulose (5%-20%), lignin and moisture (20%). They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants such as flax, cotton, hemp, jute, sisal, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lingo celluloses fibers are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber containing

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composites are more environmentally friendly and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling, paneling, partition boards), packaging, consumer products etc.

1.3.1 JUTE FIBER

Jute is a best fiber used for sacking, burlap, and twine as a backing material for tufted carpets. It is a long, soft, shiny fiber that can be spun into coarse, strong threads. It is one of the cheapest natural fibers, and is second only to cotton in amount produced and variety of uses. Jute fibers are composed primarily of the plant materials cellulose, lignin, and pectin. Both the fiber and the plant from which it comes are commonly called jute. It belongs to the genus Corchorus in the basswood family, Tiliaceae. Jute fiber is 100% bio-degradable and recyclable and thus environmentally friendly. Jute is a natural fiber with golden and silky shine and hence called The Golden Fiber. Jute is used chiefly to make cloth for wrapping bales of raw cotton, and to make sacks and coarse cloth. Jute fibers have following properties because of which they have wide range of applications.

1.Lighter in weight	2.Use of renewable resource
3.Lesser raw material	4.Better physical properties
5.Cost economic	6.Fire, termite properties
7.Moisture resistant properties	8.Better mechanical property


Fig. 1.Raw fiber


Fig. 2.Composite fiber

1.4 HAND LAYUP PROCESS

Hand lay-up is an open molding method suitable for making a wide variety of composites products from very small to very large. Production volume per mold is low; however, it is feasible to produce substantial production quantities using multiple molds. Hand lay-up is the simplest composites molding method, offering low cost tooling, simple processing, and a wide range of part sizes. Design changes are readily made. There is a minimum investment in equipment. With Skilled operators, good production rates and consistent quality are obtainable.

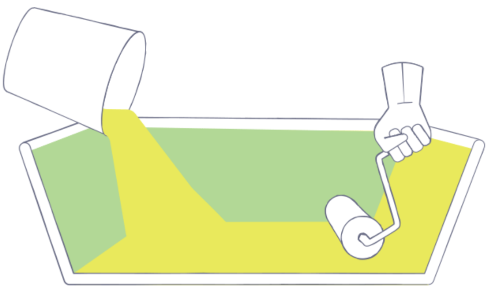
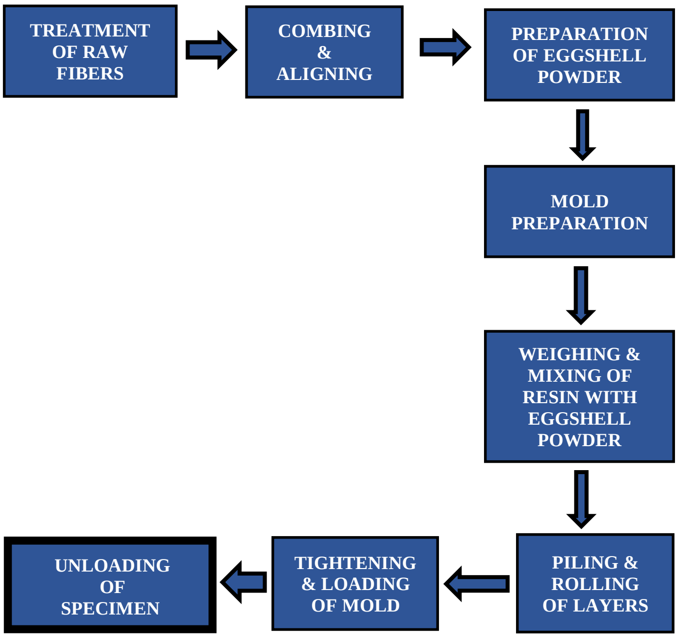


Fig. 3.Hand Layup Process Schematic View

II. EXPERIMENTAL WORK

2.1 Process Flow Chart



2.2 Preparation of Composites

- Treatment of Fiber: Long jute fibers are carefully soaked in distilled water mixed in proper proportion of NaOH pallets, for about 24 hours after which they are washed with cold running water and dried under sunlight for 20 minutes also dried in the ambient environment for 24 hours.
- Combing & Aligning: The dried fibers are carefully examined for presence of moisture and further are combed using combs of various teeth width and lengths, followed by fine combing using combs of minute fine teeth. The finely combed jute fibers are aligned over a sheet of paper having the same dimensions to that of the mold cavity.
- Preparation of Eggshell Powder: Egg shells are collected and dried thoroughly for about 3 to 4 days under sunlight and cleaned for the removal of any foreign particles if present. This process is followed by breaking of eggshells into smaller fragments manually and then finely powdering them to obtain the talc form of eggshell powder.
- Mold Preparation: Using emery paper the mold and die cavity is polished to remover surface entities. Mold is thoroughly cleaned using cloth dipped in acetone. Mold wax is applied throughout the mold box and die cavity and is dried for about 5 to 10 minutes.
- Weighing & Mixing of Resin: Epoxy resin (LY556) is mixed with hardener (HY951) and eggshell powder in suitable proportion according to the composition chosen.
- Piling & Rolling of Layers: Carefully a layer of jute fibers which are pre-aligned is placed in die cavity, resin mixture is poured over the fiber layer and are rolled using a roller having die cavity dimensions, This process is carried on for further layers until suitable thickness of layer is obtained.
- Tightening & Loading of Mold: After the suitable thickness is obtained the mold is closed and tightened using Allen keys for screws and bolts. Load is applied on the mold using weights and bricks as per requirement.
- Unloading of mold: After 24 hours the mold is unloaded and the screws and bolts are removed to obtain final specimen.

2.3 COMPOSITION OF SPECIMENS

Sl. No	Percentage of epoxy + hardener	Percentage of jute fiber	Percentage of egg shell powder
1 (A)	66% + 10%	20%	4%
2 (B)	62% + 10%	20%	8%
3 (C)	58% + 10%	20%	12%

TABLE. 1. VARIOUS COMPOSITION OF COMPOSITE FIBERS

Sl. No	Testing Type	ASTM – A370	Length	Width	Depth
1	Tensile	638	165	20	3
2	Bending	790	80	12.7	3

TABLE. 2. ASTM STANDARD DIMENSIONS OF TEST SPECIMENS

2.4 EXPERIMENTAL PROCEDURE

- The final specimen obtained is carefully examined for presence of blow holes or minute pores which initiates cracks during testing or application of load.
- After examining the specimen is cut according to ASTM standards for tensile, bending and hardness tests.
- Filing is done using diamond, round files in order to attain dimensional tolerance as per the ASTM standards.
- Surface and edge finishing is given for the test specimen and dimensions are accurately measured using suitable measuring instruments.
- Testing is carried out in a sophisticated laboratory for tensile, bending and hardness tests and results are tabulated.
- The results obtained are compared with strength of a ligament and tendon as it has to be replaced with the same for which the results must satisfy the requirements.
- For Water Absorption or Moisture Content Test the specimens are dried in over (preheating) at 60*C for 4 to 5 hours and then weighed W_o before soaking them in distilled water. After the soaking is done the specimen is dried using absorbent paper before weighing it again after the test W_f. Further weight gain W_g due to water absorption was calculated as follows:

$$Wg = (W_{f\,-} W_o / W_f)*100\%$$

III CALCULATIONS

***3.0.1** Density of Egg Shell Powder*

Density : Mass / Volume

$= 0.2645\times10 / 2.1205$

$= 1.24\times10^{-3}\ gm/mm^3.$

***3.0.2** Volume of Die or Specimen*

$V_C = L\times B\times T$

$= 180\times90\times4$

$= 64800\ mm^3.$

Calculations for 72:20:8 composition

3.0.3 Density of composite

$$\rho_C = \rho_{E\,/}\,W_E + \rho_{M\,/}\,W_M + \rho_F / W_M$$

$$\rho_C = \frac{1.17*10-3}{0.72} + \frac{1.46*10-3}{0,2} + \frac{1.17*10-3}{0.08}$$

$$\rho_C = 1.1224\times10^{-3}gm/mm^3.$$

3.0.4 Calculation for Weight of Composite (72:20:8)

$W_C = \rho_C \times V_C$

$W_C = 1.1224\times10^{-3}\times64800$

$W_C = 79.32mm.$

***3.0.5** Volume*

Volume of fiber, $V_F = 0.2\times64800 = 12960mm^3.$

Volume of matrix, $V_M = 0.726\times4800 = 46656mm^3.$

Volume of eggshell powder, $V_E = 0.08\times64800 = 3184mm^3.$

***3.0.6** Weight*

Weight of fiber, $W_F = 1.46\times10^{-3}\times12960 = 18.92gm.$

Weight of matrix, $W_M = 1.17\times10^{-3}\times46656 = 34.59gm.$

Weight of eggshell powder, $W_E = 1.24\times10^{-3}\times5184 = 6.43gm.$

Calculations for moisture absorption test

***3.0.7** Weight gain*

$w_g = (w_f - w_o / w_f)\times100$

$w_g = (3.746 – 3.64 / 3.746)\times100$

$w_g = 6.45\%.$

IV RESULTS & DISCUSSION

4.3 COMPARISION OF RESULTS

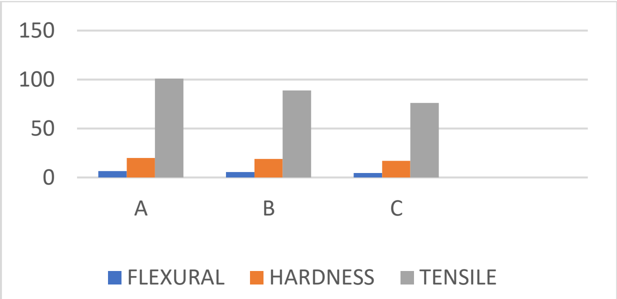


Fig. 4. Graph depicting the variation Specimen for various Test

Sl. No	Tensile Strength in MPa	Flexural Strength in MPa	Hardness Number	Moisture absorbed or Weight Gain in %
1	101.2	5.6	20	8.5
2	89.2	4.6	19	6.45
3	75.6	6.3	17	5.15

TABLE. 3. Results of various Tests for specimen of different composition.

4.2 DISCUSSION

- The results obtained are satisfying the requirements as the average tensile strength of a human ligaments is found to be 50 to 100 MPa.
- It is also clearly seen that composite fibers can replace them as they are not absorbing the moisture for a greater extent as well which depicts even during the blood flow inside the body the fibers are not much affectd from the flow or presence of moisture.

- Composite fibers used in the experimental work are naturally occurring raw fibers which are also safe to be embedded or replaced inside human body.

V CONCLUSION

After the experimental work the following conclusions are drawn after carefully examining the results:

- The polymer composite specimens were produced according to ASTM standards and different mechanical characterization were analyzed and examined.
- A Polymer composite that has the ability to replace ligament and tendons in human body is obtained.
- Properties of the composite fiber has been enhanced by adding egg shell powder to the resin mixture.
- The maximum Tensile strength is seen in Specimen A with (76:20:4) composition which is about 101.2 MPa.
- Specimen C with (68:20:12) composition has maximum Flexural strength of about 6.3 MPa.
- Moisture content absorbed or weight gained by the Specimen A is found to be higher than that of other specimens with 8.5% weight gain.
- Hardness value of all the specimens are satisfactory.
- Considering all the results preferably Specimen B is found to give the best results when implemented.

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