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Investigation on Basic Mechanical Properties of Jute Reinforced Polyester Composites for Patellar Implant Application

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ABSTRACT

In this study, Polyester resin matrix was reinforced with Jute fibers in different compositions and orientations. The polymer composites were prepared using Hand layup technique. Mechanical tests such as tensile test, compression test and bending test were conducted on the samples prepared to the standard dimensions. Also compared with the properties of UHMWPE, which is the presently used material.

Thus it is concluded that Jute reinforced polymer composite is a low density material and the induced stresses are within the permissible range. So, existing implants can be replaced by polymer composite implants based on strength properties.

Keywords*—Implantation, Polyester, Jute fibers*

I. INTRODUCTION

A Biomaterial is defined as any systemically, pharmacologically inert substance or combination of substances utilized for implantation within or incorporation with a living system to supplement or replace functions of living tissues or organs [1].

In the area of materials science, corrosion of biomaterials is of paramount importance as biomaterials are required for the survival of the human beings suffering from acute heart diseases, arthritis, osteoporosis and knee joint and other joint complications [2,4]. Metals and their alloys are usually used as implants, but with metals there are concerns regarding stress shielding, corrosion, wear etc. The possible metallic candidates, tantalum and the noble metals do not have suitable mechanical properties for the construction of most orthopedic tools and implants, while zirconium is in general too expensive. Today, titanium, cobalt chrome, zirconium, stainless steel 316 and titanium alloys are the most frequently used biomaterials for internal fixation devices because of a favorable combination of mechanical properties, corrosion resistance and cost effectiveness when compared to other metallic implant materials [3,5]. The knee has three compartments: an inside (medial), outside (lateral), and a front (patellar) compartment for the kneecap. Generally, a unicompartmental (or partial) knee arthroplasty is performed when only one compartment is affected by arthritis, and total knee arthroplasty is performed when 2 or 3 compartments are affected [6]

One area of potential in this development is composites. In composites a conglomeration produces material properties which are unavailable from individual constituent materials.

Therefore in the present research work polymer composites are prepared using economical, low density and stable material. The Polyester resin matrix was reinforced with Jute fibers in different compositions and orientations. The strength of the prepared composites is analyzed by basic experimental tests namely tension, compression, Bending. Also wear studies on all selected materials have been carried out to ensure wear resistance of the implant.

II. PREPARATION OF POLYMER COMPOSITES

Materials

Raw materials used in this experimental work are: Polyester resin (with Hardener) as matrix and Jute fibers (long fiber and mat) as reinforcement, the properties of the constituents are shown in table below. In the present work HY 951(araldite) Hardener is used. This has a viscosity of 10-20 poise at 250^{o}C.

Table 1: Properties of materials

Property	Density (Kg/m3)	Elastic Modulus (Gpa)	Tensile Strength (Mpa)	Compressive Strength (Mpa)
Polyester	1200- 1500	2 - 4.5	40 - 90	90 – 250
Jute	1460	20-50	400-800	10-30
UHMWPE	934	0.827	21.37	13.78

Fiber Preperation

The Jute stalks are cut off close to the ground. The stalks are tied into bundles and retted (soaked) in water for about 20 days. The fibers are then stripped from the stalks in long strands and washed in clear, running water. After 2-3 days of drying, the fibers are tied into bundles. Jute is graded (rated) according to its colour, strength, and fiber length. The fibers are off-white to brown, and 1-4 m long, shown in fig. 1. It is 100% bio-degradable & recyclable and thus environment friendly. Jute fiber presents a high tensile strength, low extensibility, low thermal conductivity and acoustic insulating properties.

Figure 1: Jute long fiber, Jute mat fiber

Processing technique

Hand Lay-up Technique was selected for the preparation of the polymer composite. First the mould of size 300 x 300 x 3 mm was considered. Then, three OHB sheets are placed in the floor and wax is applied to the sheets for easy removal of the composites after curing. The matrix is prepared by mixing Polyester and Hardener in the Ratio of 10:1. The mixed matrix is poured on the OHB sheets. The fiber mat is kept as a first layer and rollers are used for spreading the matrix uniformly across the mold. Again the mixed matrix is applied on the first layer of fiber and rolled properly. Then second layer of fiber mats are kept above the first layer and apply mixed matrix and again rolled properly. Similarly the consecutive layer can be formed up to required thickness. Then the laminates are allowed for curing in atmospheric condition for 2 days. This attachment is slowly and gently hammered on the boundary of its attachment when the glass and the composite separate out. The Test samples were prepared by cutting the laminates as per ASTM standards.

Table 3: Composition of prepared composites

COMPOSITES	ORIENTATION	COMPOSITION		Density
		POLYESTER (Weight %)	JUTE (Weight %)	Kg/m3
C1	Long fiber	90	10	1378
C2	Long fiber	80	20	1387
C3	Mat	90	10	1378
C4	Mat	80	20	1387

Figure 2: Casting process

III. EXPERIMENTATION

Mechanical tests such as tensile, Compression and flexural test, and wear tests were conducted on the specimens prepared as per the ASTM standards. Minimum of three samples for each combination were tested to account for statistical scatter and arrived at mean values. All the tests were carried out at room temperature.

Tensile test

Static tensile properties of flat composite materials are determined according to ASTM D 3039 standards, shown in figure 4. A compliant and strain-compatible material (usually aluminum or glass fiber reinforced epoxy materials) is used for making the end tabs to reduce the stress concentrations in the gripped area and thereby promote tensile failure in the gage section. The tensile test Sample was cut into flat shape (250x25x3) mm, in accordance with ASTM standards D3039.[7]

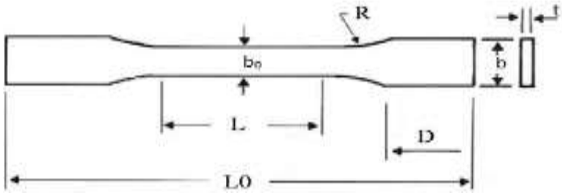


Figure 4: ASTM D3039

Figure 5: Tensile test specimen

Figure 6: Tensile Specimen before and after braking

Compression test

In-plane static compressive properties can be determined using either D 3410 test methods. D 3410 is recommended only for unidirectional, or cross-plaid fiber-reinforced polymer composites. The compression test samples were cut in to flat shape (150x25x3) mm, in accordance with ASTM standards D3410[8], shown in Fig.7.

Figure 7: Compression test specimen

Bending test

Static and fatigue flexural properties are determined by ASTM D 790 test method. In this test, a composite beam specimen of rectangular cross-section is loaded in either a three-point or a four-point bending mode. In either mode, a large span (L) to thickness (t) ratio of 16, 32, 40, or 60 is usually recommended to minimize interlaminar shear deformation. The flexural test sample was cut into flat shape (20x150x5) mm, in accordance with ASTM standards D790 [9], shown in fig.9.

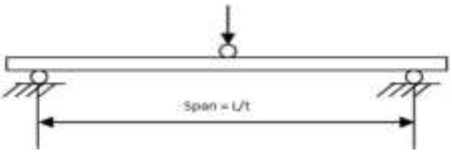
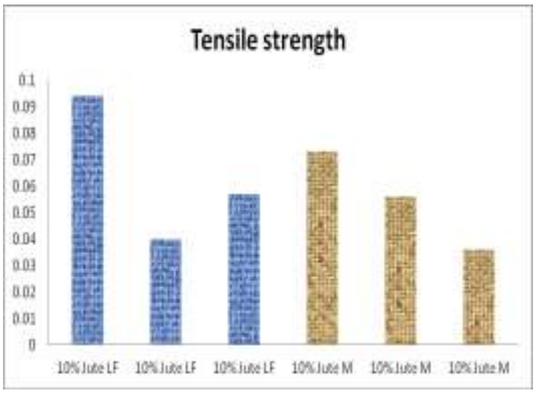


Figure 8: ASTM standards D790

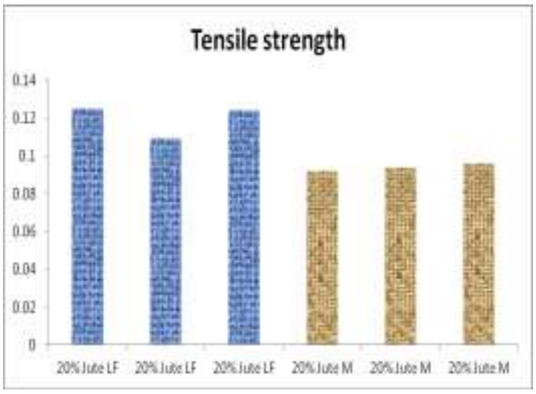
Figure 9: Bending specimen

IV. RESULT & DISCUSSION

Tensile strength

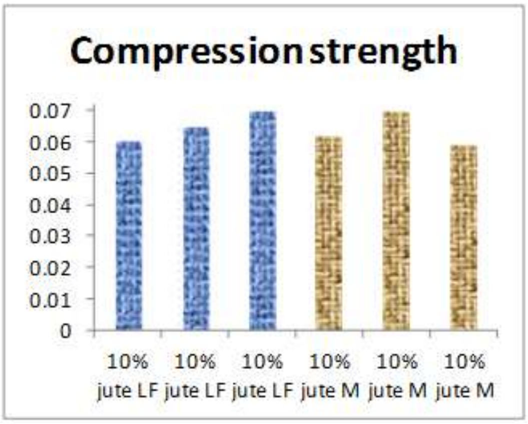


Graph 1: Tensile Strength(GPa) vs 10% Jute fiber

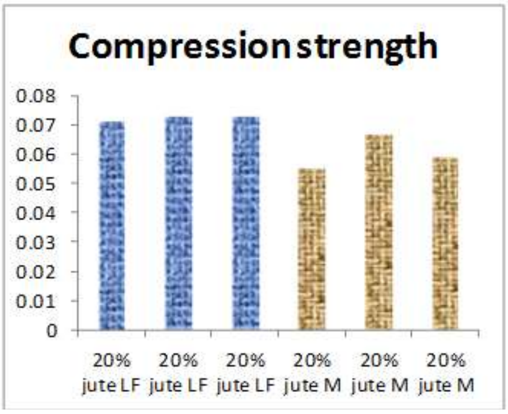


Graph 2: Tensile Strength(GPa) vs 20% Jute fiber

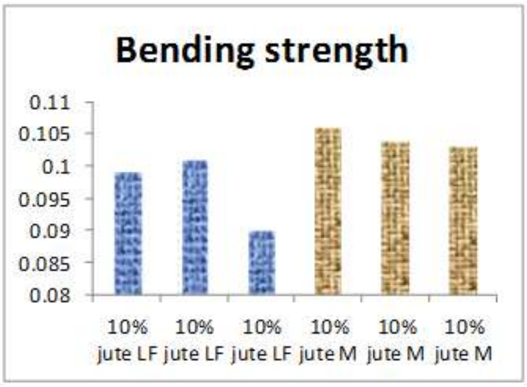
Compression Strength



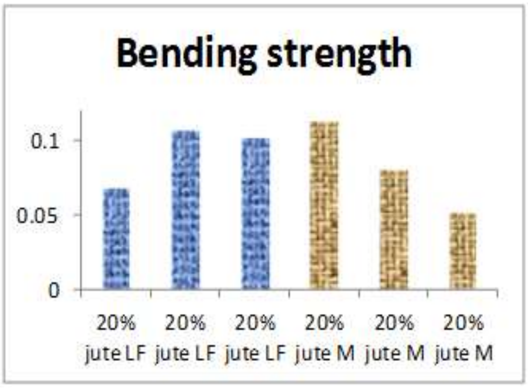
Graph 3: Compression Strength(GPa) vs 10% Jute fiber



Graph 4: Compression Strength(GPa) vs 20% Jute fiber



Graph 5: Bending Strength(GPa) vs 10% Jute fiber



Graph 6: Bending Strength(GPa) vs 20% Jute fiber

The graphs 1-5 have been drown for test results of tensile, compression and bending preparing three specimen of each configuration and the results are observed to appreciable.

V. CONCLUSION

The tensile strength and Compressive strength of the jute reinforced polyester composite with long fiber are observed to be more compared to other orientations in this work and also compared to UHMWPE.

Bending strength of the jute mat reinforced polyester composite is better than the jute long fiber reinforced composite

The density of both jute mat and jute long fiber polyester material is approximately 1378 Kg/m^3 and it is matching the density of bone (1000 to2000 Kg/ m^3).

With the above observations based on strengths, it is concluded that the jute long fiber reinforced polyester composite will be one of the best alternative materials for knee patellar implant material compared to UHMWPE.

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