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Design and Analysis of Artificial Limb using Fiber Reinforced Polymeric Composites - A Research Paper

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Abstract: Composites made with natural fibers are finding applications in a wide variety of engineering fields due to their low cost and eco-friendly nature. The fabricated composite samples are tested to investigate the various mechanical and wear properties. This research work deals with hybrid composite materials made of natural fibres namely kenaf and flax fibres. Glass fibre reinforcement polymer (GFRP) is used for lamination on both sides. The test result shows that hybrid composite has far better properties than single fibre glass reinforced composite. The mechanical and wear properties of the fibers are evaluated under different combinations as per ASTM standards, and the analysis are compared with a software analysis using ANSYS software.
Keywords: Natural Fiber Reinforced Composites, Matrix, Fibers, Hardener, Ansys.

I. INTRODUCTION

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. The individual components remain separate and distinct within the finished structure, differentiating composites from mixtures and solutions.The new material may be preferred for many reasons: common examples include materials which are stronger, lighter, or less expensive when compared to traditional materials.

A. Overview

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly. Modern composite materials constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective.

B. Classification of Composites

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

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

C. Fiber Reinforced Composite

Common fiber reinforced composites are composed of fibers and a matrix. Fibers are the reinforcement and the main source of strength while matrix glues all the fibers together in shape and transfers stresses between the reinforcing fibers. The fibers carry the loads along their longitudinal directions.

Sometimes, filler might be added to smooth the manufacturing process, impact special properties to the composites, and /or reduce the product cost.

D. Matrix

The role of matrix in a fiber-reinforced composite is to transfer stress between the fibers, to provide a barrier against an adverse environment and to protect the surface of the fibers from mechanical abrasion. The matrix plays a major role in the tensile load carrying capacity of a composite structure. The binding agent or matrix in the composite is of critical importance. Three major types of matrices have been reported: Polymeric, Metallic and Ceramic. Most of the composites used in the industry today are based on polymer matrices.

Polymer resins have been divided broadly into two categories:

1) Thermosetting
2) Thermoplastics.

E. Fibers

Fibers are the principal constituent in a fiber reinforced composites. They occupy the largest volume fraction in a composite structure and share the major load acting on it. Proper selection of the fiber type, fiber volume fraction, fiber length, and fiber orientation is very important incomposites.

Fiber influence the following characteristics of composite structure

1) Density
2) Tensile strength and modulus
3) Compressive strength and modulus
4) Fatigue strength and as well as fatigue failure mechanisms
5) Electrical and thermal conductivities

F. Objectives

1) A composite material is a combination of two materials with different physical and chemical properties. When they are combined they create a material which is specialised to do a certain job, for instance to become stronger, lighter or resistant to electricity. They can also improve strength and stiffness.
2) In a composite, the fiber, held in place by the matrix resin, contributes tensile strength, enhancing performance properties in the final part, such as strength and stiffness, while minimizing weight.
3) Typically, the goal is to improve strength, stiffness, or toughness, or dimensional stability by embedding particles or fibers in a matrix or binding phase.
4) The device, which is called a prosthesis, can help us to perform daily activities such as walking, eating, or dressing.

II. LITERATURE SURVEY

A. Natural Fiber Reinforced Composites

The mechanical properties of a natural fiber-reinforced composite depend on many parameters, such as fiber strength, modulus, fiber length and orientation, in addition to the fiber-matrix interfacial bond strength. A strong fiber-matrix interface bond is critical for high mechanical properties of composites. A good interfacial bond is required for effective stress transfer from the matrix to the fiber whereby maximum utilization of the fiber strength in the composite is achieved. Modification to the fiber also improves resistance to moisture induced degradation of the interface and the composite properties.

B. Mechanical Properties Of Composites

Tensile and flexural strengths of coconut spathe and spathe-fiber reinforced epoxy composites were evaluated to assess the possibility of using it as a new material in engineering applications. Samples were fabricated by the hand layup process (30:70 fiber and matrix ratio by weight). Tensile and flexural strengths for the coconut spathe-fiber- reinforced composite laminates ranged from 7.9 to 11.6 MPa and from 25.6 to 67.2 MPa respectively, implying that the tensile strength of coconut spathe- fiber is inferior to other natural fiber such as cotton, coconut coir and banana fibers. The tensile strength on the pseudo-stem banana woven fabric reinforced epoxy composite is increased by 90% compared to virgin epoxy. The flexural strength increased when banana woven fabric was used with epoxy material. The results of the impact strength test showed that the pseudo-stem banana fiber improved the impact strength properties of the virgin epoxy material by approximately 40%. Higher impact strength value leads to higher toughness properties of the material. The banana fiber composite exhibits a ductile appearance with minimum plastic deformation.

III. MATERIALS AND METHODS

A. Materials

This chapter describes the details of processing of the composites and the experimental procedures followed for their mechanical characterization. The raw materials used are :

1) Flax fiber
2) Kenaf fiber
3) S-glass fiber
4) Epoxy resin
5) Hardener

B. Methods

1) Hand Layup Technique

The hand layup technique is one of the oldest and most commonly used methods for manufacture of the composite parts. The infrastructural requirement for this method is less. The processing steps are quite simple. In the beginning a liquid paraffin is sprayed on the mould surface toavoid the sticking of fiber to the mould surface. Thin plastic sheets are used at the top and bottom of the mould to get good surface finish of the product. The fibers which are in the form of woven mats are cut as per themould size and placed at the surface of mould. Then the liquid form epoxy resin and the prescribed hardner (polymer) is mixed thoroughly in suitable proportion with a ratio of 10:1 and it is poured on to the mould surface where the fiber is placed. The polymer is uniformly spread with the help of roller. Second layer of the fiber is then placed on the polymer surface and a roller is moved with a mild pressure on the fiber- polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and fiber, till the required layers. After placing the plastic sheet, liquid paraffin is sprayed on the inner surface of the top mould plate which is then kept on the stacked layers and the pressure is applied.

2) Combination of Fibers

In this research, we are going to fabricate 3 different variants using the natural fibers in between the synthetic fibers. We are using different combinations to determine the best combination based on the test results.

Fig. 3.1 Sequence of Laminates

S.NO	SEQUENCE OF LAMINATES	S1	S2
1	Top layer	E-Glass fiber 1 nos	S-Glass fiber 1 nos
2	Second layer	Kenaf fiber 1 nos	Kenaf fiber 1 nos
3	Third layer	E-Glass fiber 1 nos	S-Glass fiber 1 nos
4	Fourth layer	Flax fiber 1 nos	Flax fiber 1 nos
5	Fifth layer	E-Glass fiber 1nos	S-Glass fiber 1 nos

3) Ansys

ANSYS is a general purpose software, used to simulate interactions of all disciplines of physics, structural, vibration, fluid dynamics, heat transfer and electromagnetic for engineers. So ANSYS, which enables to simulate tests or working conditions, enables to test in virtual environment before manufacturing prototypes of products. Furthermore, determining and improving weak points, computing life and foreseeing probable problems are possible by 3D simulations in virtual environment. ANSYS software with its modular structure as seen in the table below gives an opportunity for taking only needed features. ANSYS can work integrated with other used engineering software on desktop by adding CAD and FEA connection modules. ANSYS can import CAD data and also enables to build a geometry with its "preprocessing" abilities. Similarly in the same preprocessor, finite element model (a.k.a. mesh) which is required for computation is generated. After defining loadings and carrying out analyses, results can be viewed as numerical and graphical. ANSYS can carry out advanced engineering analyses quickly, safely and practically by its variety of contact algorithms, time based loading features and nonlinear material models .ANSYS Workbench is a platform which integrate simulation technologies and parametric CAD systems with unique automation and performance.

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IV. RESULTS AND DISCUSSIONS

A. *Mechanical Test Results of Composites*

Table 4.1 Mechanical Test Results of Laminates

LAMINATES	TENSILE STRENGTH(MPa)	FLEXTURAL STRENGTH(MPa)	IMPACT STRENGTH(JOULES)
S1	110	146.83	4
S2	98	134.38	3.33

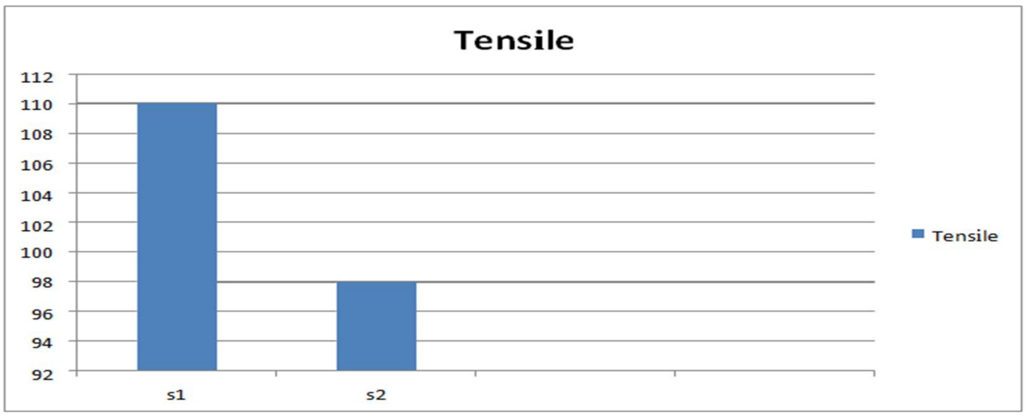

Fig. 4.1 Tensile Test of Laminates

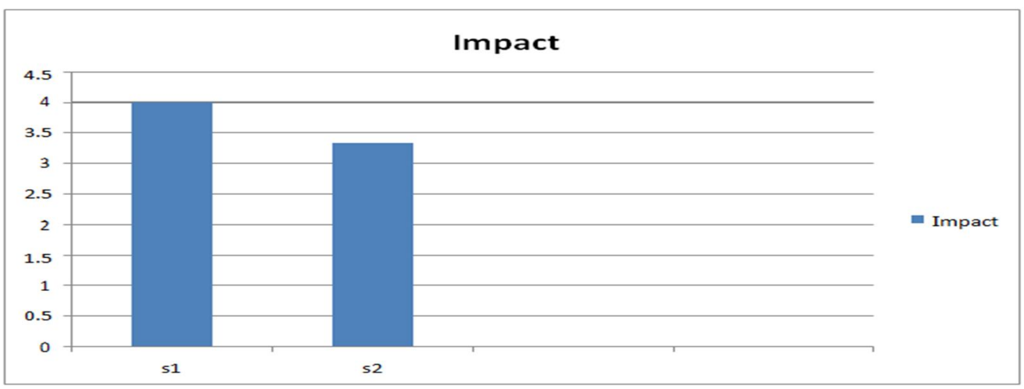

Fig. 4.2 Impact Test of Laminates

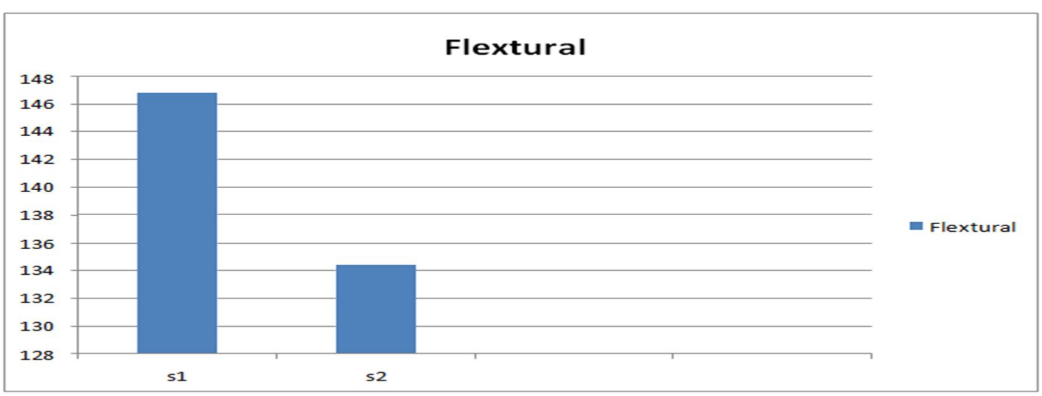

Fig. 4.3 Flextural Test of Laminates

Table 4.2 Wear values of Combination

S.No	RPM	Time Taken	Co-Efficient of Friction	Specific Wear Rate	Wear Loss
1	159	13	6.5480	0.5036	0.1025
2		17	6.5480	0.3851	0.0784
3		20	6.4014	0.32007	0.0651
4	318	13	6.4009	0.4923	0.1002
5		17	6.3142	0.3714	0.0756
6		20	6.3138	0.3156	0.0642
7	478	13	6.5394	0.5030	0.1024
8		17	6.5391	0.3846	0.0783
9		20	6.5391	0.3269	0.0665

B. Analysis using Ansys

Using ANSYS APDL , we are analyzing the acting on the different fiber combinations , a constant load of 981N is applied at on the product and the stresses acting on them is evaluated.

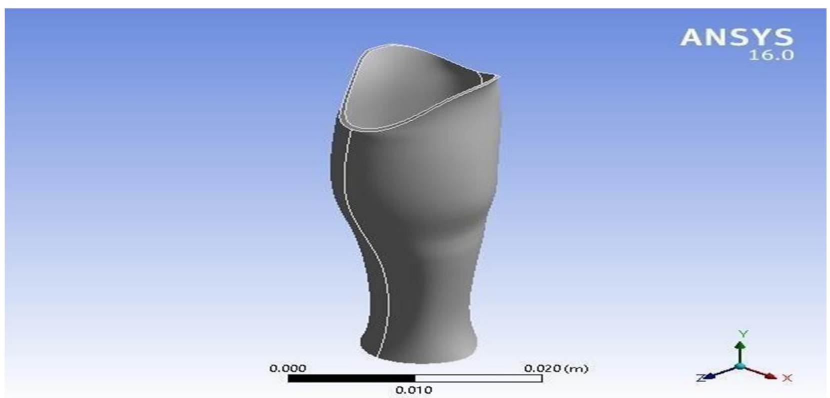

Fig. 4.3 Design of Artificial Limb

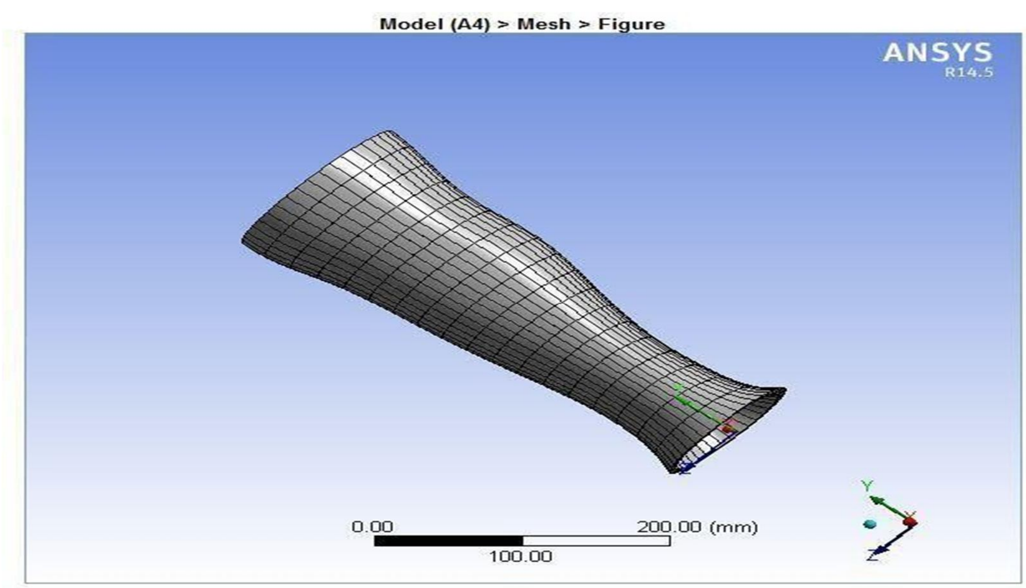

Fig. 4.4 Total Meshing

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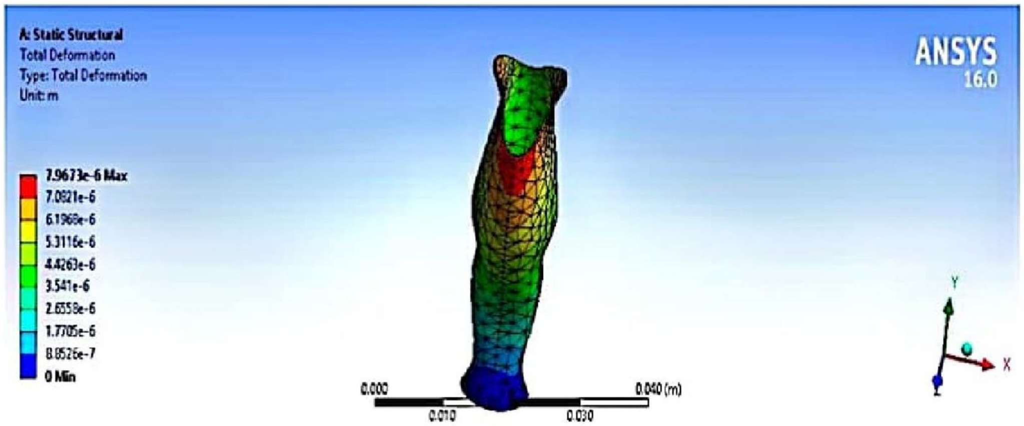

Fig. 4.5 Total Deformation in Side View

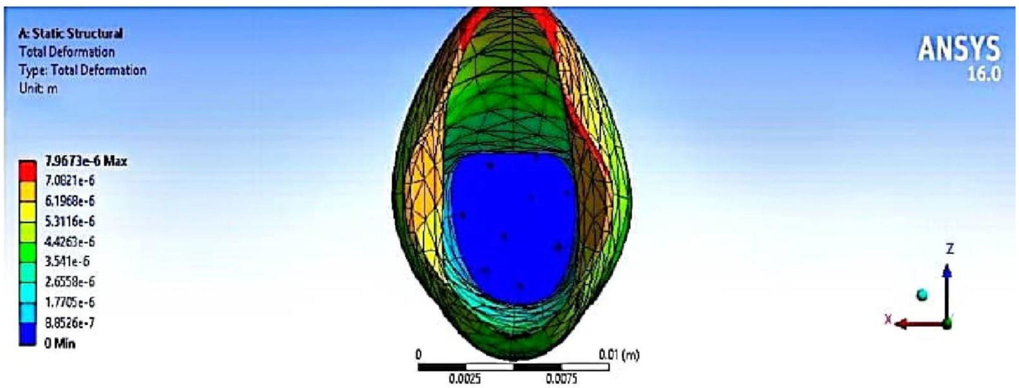

Fig. 4.5 Total Deformation in Top View

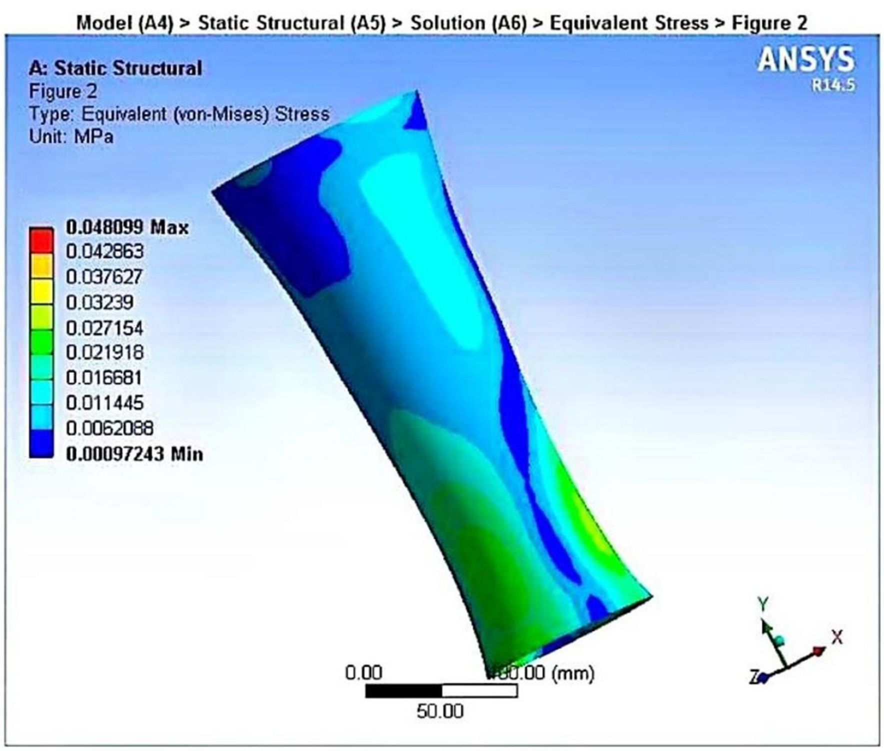

Fig. 4.6 Equivalent Stress

V. CONCLUSION

The Experimental results from testing the different composite combinations under static loading condition the impact strength and the wear properties are calculated. Multi layered hybrid composites were fabricated for the main objective of minimization of weight and improve the physical properties of the material. The objective was to find wear characteristics and analyze the specimens with minimum weight which is capable of carrying given static external forces by constraints limiting stresses and displacement. From the test results, we conclude that the combination S1 has a higher impact strength compared to S2 combinations. On the other hand, the combination S1 has better wear properties when tested under normal conditions, and better stress distribution when analyzed using ANSYS APDL software.

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