

Experimental Investigation and Comparison of Fatigue Behavior of E-Glass, Carbon Fiber and Jute Fiber Reinforced Polymer Matrix Composite used as Implants

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Abstract—This research paper constitutes the Fatigue behavior of E-glass fiber carbon and jute fibre reinforced polymer composite and study of 10% weight fraction E-glass fiber carbon and jute fibre reinforced polymer composite fabricated by using Hand Layup fabrication technique According to the ASTM Standard Fatigue test was conducted ie ASTM D3479 / D3479M - 19 and ASTM D-3039 Standard the specimen is fabricated by using the Epoxy resin- LY556 as the matrix material and the Hardener-HY 951 with the 10% E-glass fiber carbon and jute fibre as the reinforcement material with fiber weight fraction, 0+/- 90° fiber orientation. By using the Hand Layup fabrication technique the specimens are prepared and the fatigue tests conducted on E-glass fiber, carbon and jute fibre polymer composites fatigue strength evaluated. The tests are conducted under static tension and cyclic tension with mean fatigue stress equal to 10% of the E-glass fiber, carbon and jute fibre polymer composites tensile strength. The experimental results show the Gradually the cyclic load is applied for the 10% E-GFRP carbon and jute fibre Specimen, From the experimental results the cyclic load @40243 CYCLES with 182.4MPa the E-Glass fibre polymer Composite at Failure ie 100% amount of E-Glass fibre cracks/delimitation takes place or fibre At Failure. Similarly Jute polymer Composite Fails at 23809 Cycles with 19.86 MPa and Carbon Fibre Composites Fails At 10° cyclic Load with 1100 MPa and compare with human Tibia bone.

Keywords— *Tension-Tension Fatigue of Polymer Matrix Composite Materials, E-GFRP, carbon and jute fibre, tibia bone.*

1. INTRODUCTION

The development of composite materials and related design and manufacturing technologies is one of the most important advances in the history of materials. Composites are multifunctional materials having unprecedented mechanical and physical properties that can be tailored to meet the requirements of a particular application. Many composites also exhibit great resistance to Fatigue loading. Fatigue is the Phenomena of material failure or it may be structural damage

occurs when subjected to reparative loading or cyclic loading. In this paper elaborative study is done on the failure behavior of Carbon /E-glass/Jute fiber Reinforced Polymer Composites by tensile-tensile fatigue tests under a sinusoidal waveform loading at two different loading frequencies, 5 and 30 Hz, using a load amplitude control mode, and a ratio between minimum and maximum stress (R) of 0.1.

The research is carried out to predict the fatigue life of the patient's lower leg bones along with identifying the regions of the bones which are weaker in terms of strength of Tibia and Fibula bones of a patient suffering from lower leg pain [2]. Failure phenomena occur with increasing stress levels and duration, which can lead to material damage or degradation. The Mean Stress, Amplitude and orientation of the varying load with respect to fiber direction decide the characteristic of fibre cracks/delimitation[3]. The stress-controlled tensile fatigue behavior at a stress ratio of $R = 0.1$ were performed on GFRP composites, The fatigue life of the GFRP composite was increased by about three to four times due to the silica nanoparticles[4]. The influence of compressive, zero, and tensile mean strains on fatigue life and on the stress strain histories during fatigue were examined on cortical bone specimen from human femora, The total number of cycles to fatigue failure was influenced only by the total strain range and was not affected by mean strain[5]. Fatigue failure of hybrid polymer which is prepared with the mixture of cashew nut shell liquid (CNSL) resin and polyester resin was analyzed to optimize the composition parameters and for the improvement of biocompatibility [6]. The effect of load interruptions on the fatigue behavior of $(\pm 45)_2s$ angle-ply glass/epoxy composite laminates was investigated. Constant amplitude fatigue experiments were performed at different stress levels, The specimens loaded under interrupted fatigue exhibited longer fatigue live than those continuously loaded until failure [7]. The experimental results of the influence of water ageing on Glass fiber and Kevlar-fiber composites

shows that the residual stiffness and residual strength decreased when the immersion time and cycle number of fatigue increased, indicating that the studied composites have experienced some forms of mechanical damage[8]. It was observed that moisture saturation has a detrimental stress-dependent effect on the fatigue strength of the epoxy/E-glass composite. The stiffness during the fatigue cycles was similar for both dry and water-saturated coupons [9]. Tension- Tension fatigue tests were performed on woven jute fibres with epoxy matrix composites with a constant fatigue stress ratio ($R=0.1$) and results obtained from the tests were used to plot S-N Curve [10].

2. MATERIALS AND TEST METHODS

This chapter describes the details of processing of the composites and the experimental procedures followed for their characterization and fatigue evaluation. The raw materials used in this work are: E-glass fiber, carbon jute fibre and Epoxy resin.

2.1. METHODOLOGY

Characterization is carried out using Epoxy resin -LY556 as a matrix material, hardener -HY 951 and (a)10% Carbon fibres as the reinforcement material (with fiber weight fraction, 0 ± 900 orientation ie orthotropic material) (b)10% Jute fibres as the reinforcement material (with fiber weight fraction, 0 ± 900 orientation ie orthotropic material) (c)10% E-Glass fibres as the reinforcement material (with fiber weight fraction, 0 ± 900 orientation ie orthotropic material) by using Hand lay up technique.

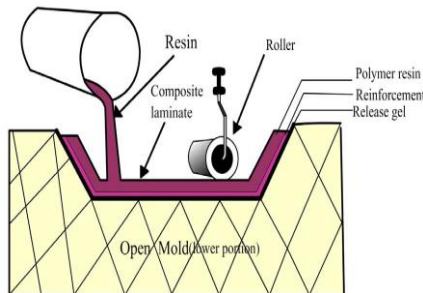


Figure: 2.1 Hand Lay Up Method

2.2. OBJECTIVE The objective of the present study is:

1. To study the Fatigue behaviour E-GFRP, carbon and jute fibre composites implants.
2. To report Fatigue behaviour with cyclic loads results.

3. EXPERIMENTAL PROCEDURE

3.1. PROPERTIES OF jute fibre

Table 3.1: Properties of jute fibre

Table 3.1: Physical and mechanical properties of Natural Fibers [60-61]

Fiber	Density (g/cm ³)	Elongation (%)	Tensile Strength (MPa)	Elastic Modulus (MPa)
Jute	1.3	1.5-1.8	393-773	26500
Hemp	1.47	2-4	690	70000
Sisal	1.5	2.0-2.5	511-635	9400-22000
Banana	1.3	3-3.2	540-549	29000-32000

3.2. PROPERTIES OF E-GFRP3.1.

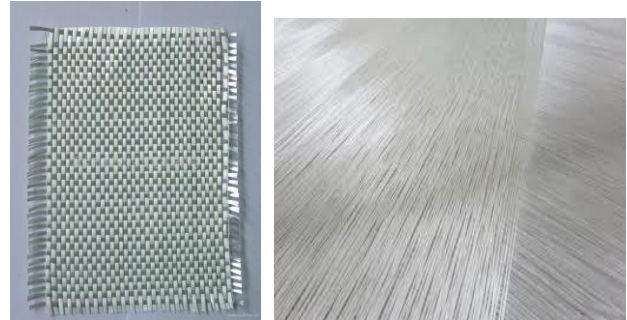


Fig:3.1 E-glass fibers

Table 3.2: Mechanical properties of E-GLASS FIBER

PROPERTY	E-GLASS FIBER
Density [g/cm ³]	2.58
Tensile strength [N/mm ²]	1950 -2050
Compression Strength [N/mm ²]	4000-5000
Young's modulus in N/mm ²	73
Poisson's ratio	0.21
Shear modulus in N/mm ²	5600

Table 3.3: Mechanical properties of Carbon Fiber

PROPERTY	CARBON FIBER
Density [g/cm ³]	1.298
Tensile strength [N/mm ²]	600
Compression Strength [N/mm ²]	570
Young's modulus in N/mm ²	113.0
Poisson's ratio	0.320
Shear modulus in N/mm ²	3200

3.4. Specimen preparation

After fabrication of E-GFRP Laminates, jute fibre Laminates, carbon fibre Laminates, These laminates are cut according to ASTM D3039 Standards by using a Trotec Speed300@ laser device in the fibre direction. - Specimens of 250 mm in length and 25 mm in width 2.5 mm in thickness were prepared for tensile monotonic and fatigue testing. These dimensions are in agreement with the ASTM D3039 recommendations. After surface preparation (sanding then cleaning with acetone), tabs made with the same composite materials (40 mm in length, 15 mm in width and 1 mm in thickness) were bonded to the test specimens used a Loctite Super Glue 3 Gel adhesive.



Fig 3.2: Specification of the Tensile Test Specimens as Per the ASTM D-3039 Standard.

3.5 Digital-Fatigue-Testing-Machines FTG-8D:-

This is rotating beam type machine in which load is applied in reversed bending fashion. The standard specimen is held in special holders at its ends and located such that it experiences a uniform bending moment. The specimen is rotated at 4200 rpm by a motor. A complete cycle of reversed stresses in all fibres of the specimen is produced during each revolution. The bending moment is applied with the lever system and can be easily changed by moving a weight over the lever. Total number of revolution at which the specimen fails is recorded by a mechanical counter.



Fig3.3 universal hydraulic fatigue testing machine



Fig3.4(a),(b),(c) Flat Fixture to hold the specimen according to ASTM D-3039 Standard and Fixing the Fixture for Flat Specimen.

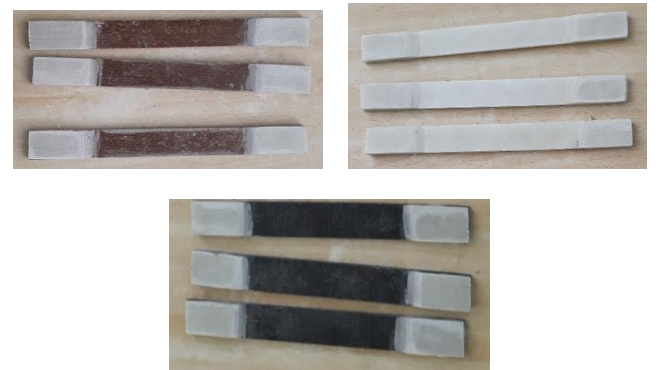


Fig3.5 (a) Jute fibre composite (b) E-Glass fibre composite (c) Carbon fibre composite as Per the ASTM D-3039 Standard

TECHNICAL SPECIFICATIONS.MODEL FTG -8(D):-

Maximum bending movement kg cm ; Bending movement adjustable kg cm ; Ranges I & II kg cm 25 – 200kg cm 125 – 200; Gripping dia of specimen mm 12; Testing dimension of specimen mm--250X25X3mm Rotating speed rpm 4200; Accuracy of applied bending movement; Digital counter No. of digits 8; Power required HP 0.5 Main supply 3hp, 440,V,50 Hz, A.C; Overall size (approx) mm 1000L.X.; Weight (approx) kg 120

3.6 Procedure of Tensile Fatigue Tests:- The tensile-tensile fatigue tests were performed under a sinusoidal waveform loading at two different loading frequencies, 5 and 30 Hz, using a load amplitude control mode, and a ratio between minimum and maximum stress (R) of 0.1.

The experimental configuration (loading machine, specimen shape and preparation) was similar to monotonic tensile tests. Fatigue tests were performed in the fibre direction. Six levels of maximum stress were applied. The levels were 100,150,200,250,and 280 N for three replicates were tested at each stress level. Tests were stopped at failure. At 30 Hz, A complete cycle also recorded with fatigue load



A. Fig3.6 Fatigue Test On Jute polymer Composite ---- Failure @23809 Cycles



B.



Fig3.7 Carbon Polymer Composites Slipped From Jaw @57646 CYCLES At Failure And Also Continued The Experiment The Carbon Fibre Composites Fails At 10⁶cyclic Load.



Fig3.8 Fatigue test on JUTE polymer composite @40243 CYCLES At Failure

3.7 Types of Tests with ASTM Standards:

Fatigue experiments were performed by applying two types of loading patterns.

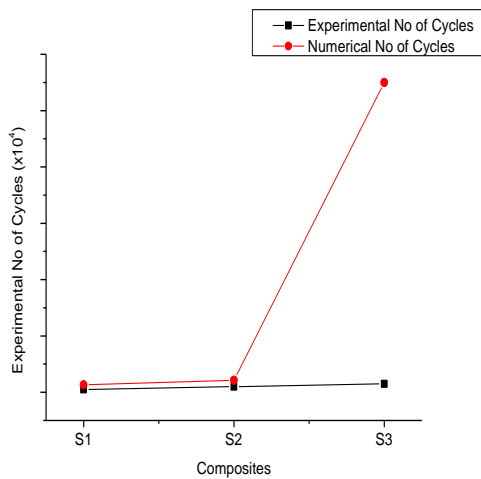
- 1.Constant amplitude fatigue experiments were performed at different stress levels to derive base line fatigue data.
- 2.In addition, interrupted-fatigue experiments were performed by removing the cyclic loading for two hours repetitively
- 3.After cycling for 20% of the fatigue life achieved under continuous loading at the same maximum cyclic stress level. The specimens loaded under interrupted fatigue exhibited longer fatigue live than those continuously loaded until failure.

Table 3.4: Tensile -Tensile fatigue test Results.

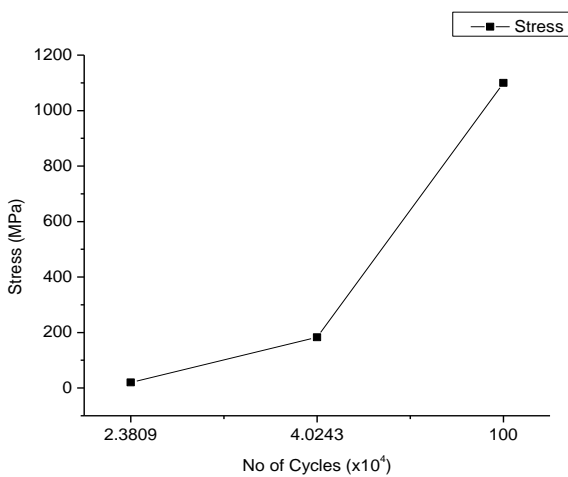
specimen	stress	Various cyclic load	Status of Fibre delamination property	Conclusion
Jute polymer Composite (S1)	19.86 MPa	Failure @23809 Cycles	100% amount of fibre cracks/delamination takes place or fibre At Failure	100% Failure
E-Glass fibre polymer Composite (S2)	182.4 MPa	cyclic load Starting Point @00000 CYCLES	Zero amount of fibre cracks/delamination takes place	0% Failure
		Cyclic load @10220 CYCLES	little amount of fibre cracks/delamination takes place	40% Failure
		Cyclic load @30388 CYCLES	80% amount of fibre cracks/delamination takes place	80% Failure
		Cyclic load @40243 CYCLES fibre At Failure	100% amount of fibre cracks/delamination takes place or fibre At Failure	100% Failure
Carbon Polymer Composites (S3)	1100 MPa	Carbon Polymer Composites Slipped From Jaw @57646 CYCLES At Failure And Also Continued The Experiment The Carbon Fibre Composites Fails At 10 ⁶ cyclic Load	100% amount of fibre cracks/delamination takes place or fibre At Failure	100% Failure

Table 3.4: Consolidated Tensile -Tensile fatigue test Stress, No of Cycles compared with Tibia Bone Fatigue Strength

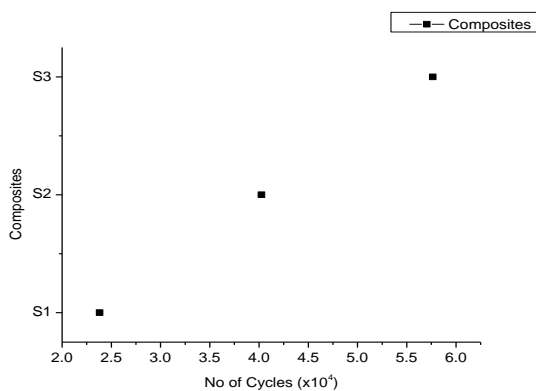
Material Properties	Experimental In No of Cycles	Stress	Tibia Bone Fatigue Strength [2]
Jute /Epoxy(S1)	23809	19.86 MPa	18593 Cycles of life for Diseased
E-glass /Epoxy(S2)	40243	182.4MPa	
Carbon /Epoxy(S3)	>10 ⁶	1100 MPa	



Graph 3.1:-shows Composites vs No of Cycles.



Graph.3.2:shows Stress vs No of Cycles.



Graph.3.3:shows Composites vs No of Cycles

4. CONCLUSION

1. According to experimental results, 10% Carbon fibers Polymer Composite Material of Fatigue test has Fatigue strength of 1100 MPa for specimen S3 ,10% E-Glass fibers Polymer Composite Material of Fatigue strength of 182.4MPa for specimen S2 and 10% Jute fibers Polymer Composite Material of Fatigue strength of 19.86 MPa From these results it is found that Tibia Fatigue strength of 18593cycles of life for Deseaed.
2. 10% Carbon fibers Polymer Composite Material of Highest Fatigue strength of 1100 MPa compare to other two specimen S1 and S2.Hence based on Fatigue strength recommending to the medical field.
3. From the experimental results the cyclic load @40243 CYCLES with182.4MPa the E-Glass fibre polymer Composite at Failure ie 100% amount of E-Glass fibre cracks/delamination takes place or fibre At Failure similarly. Jute polymer Composite Fails at 23809 Cycles with 19.86 MPa and Corbon Fibre Composites Fails At 10⁶cyclic Load with1100 MPa and compare with human tibia bone ie 18593cycles of life for Deseaed.
4. At Failure ie 100% amount of Jute fibre, E-Glass fibre, Corbon Fibre cracks/delamination takes place or fibre At Failure and also Under both loading patterns, failure was observed in the form of fiber pull-out; however, in specimens loaded continuously failure occurred with considerable necking. At low stress levels, failure with predominant fiber breakage under both loading patterns was observed the fiber stretching

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