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► **To cite this version:**

Shivanand N. Pujar, K. R. Dinesh, Jagdish S.P, Shiva Kumar Gouda. Evaluation Of Mechanical, Biodegradable & Microstructure Analysis of Epoxy-Based Glass, Carbon and Jute Fiber Reinforced Bio-Composites Used as Orthopedic Implants [Human Bone]. Journal of Scholastic Engineering Science and Management, 2021, 1 (3), pp.32-47. hal-03284138

HAL Id: hal-03284138

<https://hal.science/hal-03284138>

Submitted on 23 Jul 2021

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“Evaluation Of Mechanical, Biodegradable & Microstructure Analysis of Epoxy-Based Glass, Carbon and Jute Fiber Reinforced Bio-Composites Used as Orthopedic Implants [Human Bone]”

¹Shivanand N. Pujar, ²Dr. K.R. Dinesh, ³Dr. Jagdish S.P, ⁴Dr. Shiva Kumar Gouda

¹Research Scholar, ²Professor and Head, ³Associate Professor, ⁴Associate Professor

^{1,2,3,4}Department of Mechanical Engineering

¹Research Scholar, VTU RRC, Belagavi, Karnataka, India, ²Government Engineering College, Hassan, India, ³R.Y.M Engineering College, Bellary, Karnataka, India, ⁴Deputy Dean CIII, SDMCE-Dharwad, Karnataka, India.

Email: snpujar007@yahoo.com, dineshkrpet@gmail.com, spjagadish11@gmail.com, ursshivu@gmail.com

ABSTRACT

The aim of the present research work is experimental investigation to evaluate various physical, Mechanical and Corrosion Test Properties and concentrates on the progress of biomaterials in the field of orthopedics especially for Tibia bone an effort to utilize the 10% JPCM(S1), 10% EPCM(S2) and 10% CPCM(S3), and fabricated the bio composites materials. The present invention focuses on the enhanced properties of 10% JPCM(S1), 10% EPCM(S2) and 10% CPCM(S3) as Tibia bone implant material. It is a challenge to the creation of better materials for the improvement of quality of life and Economical one suggests to use Tibia Bone Prosthesis (Rods, Plates etc.,) and also Characterization is carried out using Epoxy resin -LY556 as a matrix material and hardener -HY 951 with 10% Carbon fiber, E-Glass fiber and Jute fiber reinforced composite material with 0+/-90 Degree orientation. by using hand layup fabrication technique the specimens are prepared as per biomaterials ASTM standards for Tensile Tests specimens are prepared by ASTM D-3039, For Compression Tests specimens are prepared by ASTM D-3410 and for Bending Tests specimens are prepared by ASTM D-790 , Wear by G-99, Fatigue test was conducted i.e. ASTM D3479 / D3479M - 19 and ASTM D-3039 Standard also Moisture ,Impact and Corrosion test was also carried out according to ISO standard for the same specimen to know the biocompatibility.

Keywords: *Glass/Carbon/Jute Fiber reinforced, Epoxy, Tibia Human Bone, Rule of mixture, Biodegradable, Ph values, SEM*

1. INTRODUCTION AND OBJECTIVE OF THE RESEARCH WORK

Intention of this research includes the develop three different polymeric matrices i.e., Jute-natural fibers, Carbon fiber and E-Glass fiber composite material and characterized to evaluate mechanical properties to match the requirements. According to bio material ISO (International Standards Organization) and ASTM (American Society for Testing and Materials) standards Specimen will be prepared to conduct experiments like Tensile, Compression, Bending, Wear, Corrosion, Fatigue and Impact. The Human Tibia Bone Fractures depends on negligence in driving, it leads to accident and also during working hours the person moves from one place to other places. Slippery may happen during sports activities, the people may injure in case of football, cricket etc. In case of athletics Gymnastics people may injured during Jumping, dancing, Running, Gating and Scatting activities. Lower extremity injuries are a frequent outcome of automotive accidents. They Investigated and evaluated the patient Safety, it related to organic assessment of medicinal apparatus and these devices must undergo biocompatibility test and they conducted the degradation test for High-density polyethylene, nonreactive plastic, synthetic Polymer. Ceramics etc, out of these materials which are having very good PH value or biocompatibility property and suggested to use for medical application^[1]. They investigated composite material in Aeronautical and automobile and so on and stated that composite material can also use for medical application and critical issues i.e. problem faced in composite are used as biomedical describe generally human having different types of bone and tissues ligaments and teeth's etc, from this also they have stated that various material are used for Biomedical filed^[2] They have investigated about the Human Bone with Various ages of human and found out the Fatigue strength of human Cortical Bone^[4], They have conducted the Experiments on CF/PEEK to implant materials, they have found out there is tissue reaction or reaction found by the medical or Doctor Examination also compared with titanium material and study shows the bonding between CF/PEEK is very good used for Implantation^[5]. This paper review the organic attitude of paste positioned dents component, this paper also discuss the traditional as well as advanced technique used for bio composites appraisal of dents material and proved the biocompatible material paste positioned dents components show that there are incompatible data obtained from in vitro and in vivo tests, in vivo tests adequate conclusion are achieved with in vitro tests^[7]. this paper results that to compare the natural fiber (Agave sisalana fiber, Musasapientum fiber and Hibiscus sabdariffa fiber) reinforced polymer composite bone plates to orthopaedic alloy plates (stainless steel, titanium, cobalt chrome and zirconium) and these palates are utilized in humorous ruptures^[11]. They Investigated the Fatigue strength of SFR PEEK material and Fatigue Behaviour of by Considering cyclic creep and fatigue damage by uniaxial fatigue test^[12] They investigated the consequence of medians on account of Various pH on strength and shear of zirconia-based ceramics to resin cements. Finally recommended the Panavia F2 [cements] and Unicem demonstrated satisfactory performance in media with different pH. Calibra failed in bonding to Cercon ceramic and is not recommended for this purpose^[14].

2. METHODOLOGY

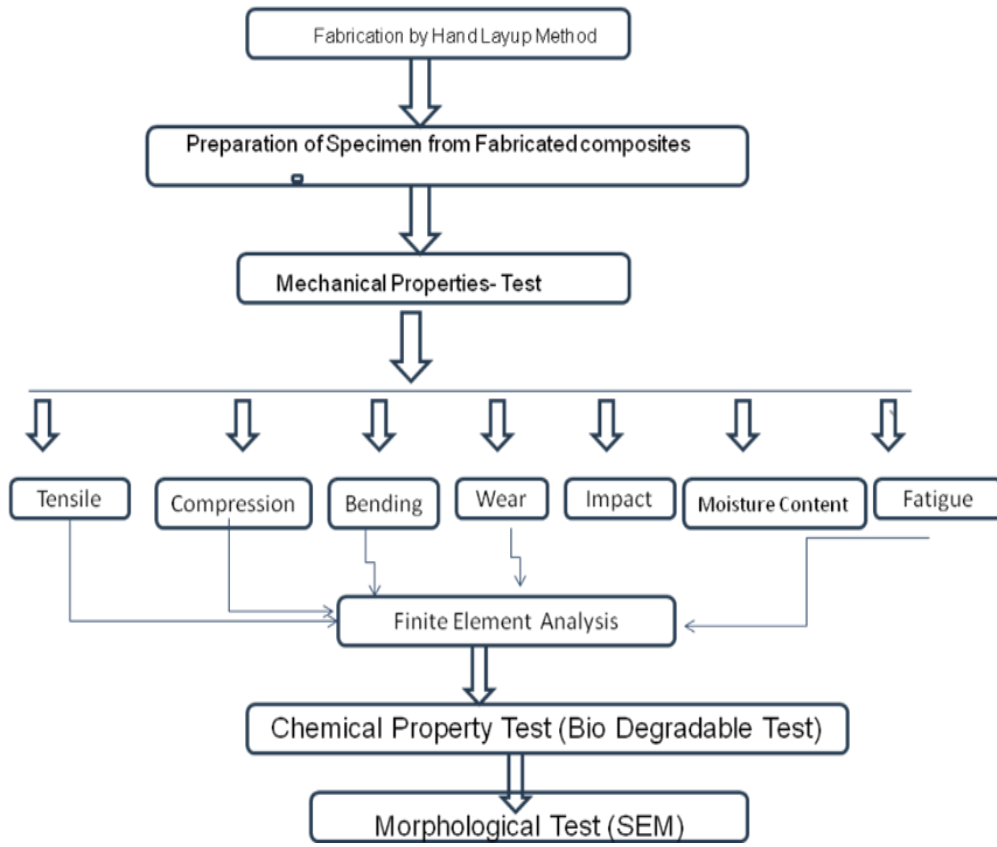


Fig.1.0: Flow Chart for Methodology and Experimentation of Composite materials

2.1. Matrix Material

Matrix substantial utilized in the present work is Epoxy resin LY556 along with hardener LY991 as shown in Figure 1.1. From literature survey the Epoxy resins mechanical, physical, properties are tabulated in the Table 1.



Fig.1.1: Epoxy LY55

Table 1: Properties of typical thermoset polymers used in Carbon fiber, E-Glass fiber and Jute-natural fiber composites

Polymer	Density (gm/cm ³)	Modulus of Elasticity (MPa)	Ultimate Tensile strength (MPa)	Crushing Strength (MPa)	Elongating (%)	Cure Shrinkage (%)
Epoxy Resin	1.100-1.400	3000-6000	35-100	100-200	1-6	1-2

2.2. Reinforcement (Jute, E-Glass and Carbon)

Reinforcement materials used in the present work are natural fibers like Jute, Carbon fiber, and E-Glass fiber. Their properties are discussed as follows.

- **Jute Fiber:** It is a natural fiber, and long shining fiber, it belongs to genus Corchorus in the basswood family, it is basically plant material composed of Lignose, Celluloses and pectin and it is cheapest one natural fiber compares to other fibers. The material property is shown in Table 2.

Table 2. Material Property of Jute Fiber

Fiber	Ultimate Tensile Strength (MPa)	Modulus of Elasticity (MPa)	Densities (g/cm ³)	Expansion (%)
Jute	393-773	26500	1.3	1.5-1.8

- **E-Glass Fiber:** Synthetic fiber consists of fine fibers of glass, Glass fibers can also occur naturally, as Pele's hair, it is much cheaper and significantly less brittle when used in composites. Glass fibers are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fiber-reinforced-polymer (FRP) composite material called glass-reinforced plastic (GRP).
- **Carbon Fiber:** The material properties of Carbon fiber are as follows: corrosion resistance, high strength to weight ratio, Withstand high temperature & conductivity. Carbon fiber components are used in structural, automotive, sporting goods, surgical implant elements energy production systems, power transmission systems etc. The material property of E-Glass and Carbon is shown in Table 3.

Table 3. Material Property of E-Glass /Carbon Fiber

Properties	E-Glass Fiber	Carbon Fiber
Density [g/cm ³]	2.58	3200
Tensile strength [N/mm ²]	1950 -2050	1.298
Compression Strength [N/mm ²]	4000-5000	0.320
Young's modulus in N/mm ²	73	113.0
Poisson's ratio	0.21	570
Shear modulus in N/mm ²	5600	600

2.3. Preparation of the composites

Selection of Materials and its Composition used in the research work to manufacture the Hybrid polymer composite material are as follows the compositions of polymer composites with Carbon fiber, E-Glass

fiber and Jute - natural fibers as listed in the Table 4.

Table 4. Compositions of polymer composites

Composites	Naming Of Materials	Epoxy Resin Weight %	Jute (0+/-90 ⁰) Weight %	E-Glass (0+/-90 ⁰) Weight %	Carbon (0+/-90 ⁰) Weight %
S1=Average (A1, A2, A3)	10%JFRCM	90	10	10	10
S2=Average (B1, B2, B3)	10%EFRCM	90	10	10	10
S3= Average (C1, C2, C3)	10%CFRCM	90	10	10	10

- **To Fabricate Natural fiber composite Compression Specimen by weight fraction method the following calculations were done.**

$$\text{Volume of the die} = 300 \times 300 \times 2.5 = 225000\text{mm}^3 = 225\text{cm}^3$$

$$1. \text{ Density of the Jute fibers} = 1.46 \text{ g/cm}^3 \quad 2. \text{ Epoxy Resin} = 1.2 \text{ g/cm}^3$$

$$V_c = V_{\text{Epoxy}} + V_{\text{Jute}}$$

$$m_c/\rho_c = m_{\text{Epoxy}}/\rho_{\text{Epoxy}} + m_{\text{Jute}}/\rho_{\text{Jute}}$$

$$1/\rho_c = 1/\rho_{\text{Epoxy}}(m_{\text{Epoxy}}/m_c) + 1/\rho_{\text{Jute}}(m_{\text{Jute}}/m_c)$$

$$1/\rho_c = (0.88/1) (1/1.2) + (1/1.46) (0.04/1)$$

$$1/\rho_c = 0.73 + 0.03 = 0.818 \text{ cm}^3/\text{gm}$$

$$\rho_c = 1.29 \text{ g/cm}^3 \text{ (For 10\% Natural Fiber polymer Composite material)}$$

Similarly calculated for 10% Carbon Fiber and 10% E-Glass polymer Composite material

$$(f) m_c = \rho_c \times V_c \dots m_c = 1.29 \times 225 = 290.25\text{gms.}$$

3. EXPERIMENTATION, RESULTS & DISCUSSIONS

Fabrication Process for JFRCM (S1), E-FRCM (S2), CFRCM (S3), is carried out by means of Hand Lay-Up approach about 10% proportion by weight by applying Rule of Mixture. After curing the laminates, the laminations are slice(cut) in accordance with ASTM regulations to carry out mechanical tests namely, Tensile, Compression, Bending, Wear, Corrosion Impact and Fatigue.

3.1. Tensile Test

Tension trials on intricate testimonies have been conducted in accordance with **ASTM-D 3039** standards (250x25x3.2mm) for S1, S2 and S3 specimens to assess Ultimate tensile strength and Maximum Displacement of the performance of S1, S2 and S3specimens under load. In accordance with the experiment the results the Ultimate Tensile Stress (KN/mm²) and Displacement with the SEM have been recorded and compared with Human Tibia bone tensile property. It is noted that from that, ultimate tensile strength of all specimens is matching against the minimum requirement of Tibia Bone tensile strength of 141 to 192 N/mm². From the experimental results it is found that S2 and S3 have good mechanical property compare to S1, hence SEM images S1, S2 and S3 have taken and it is observed that very good interface binding amongst the fibers and the matrix, fibers fracture, matrix fracture, fibers pull-out is very less.

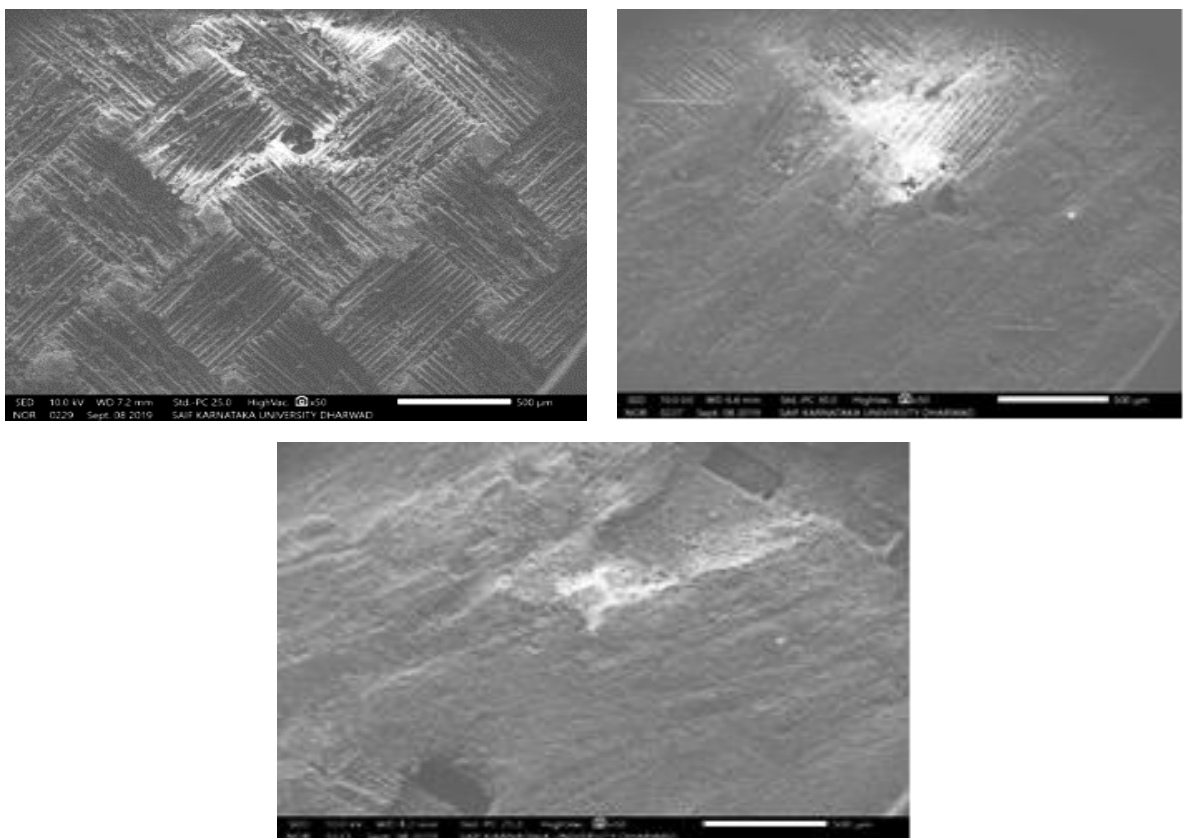
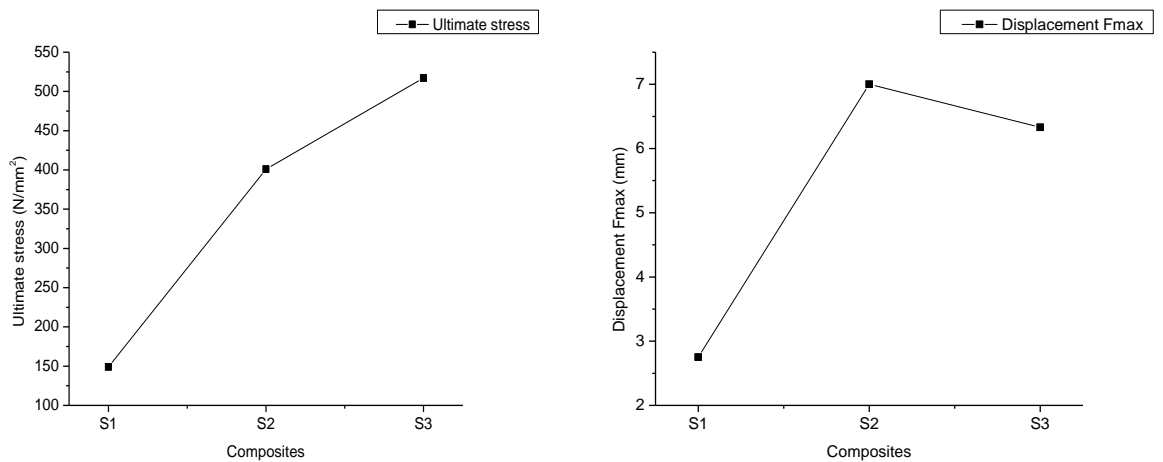


Fig.1.2: SEM [Magnification 500µm] S1 (10% Jute), S2 (10% E-Glass), S3 (10% Carbon)

3.2. Compression Test

Compression trials on intricate testimonies have been conducted in accordance with **ASTM-D-3410** standards (155x25x3.17mm) to assess compressive strength and modulus of elasticity for S1, S2 and S3 specimens under load. Compressive strength (PKL/Area) (KN/mm²) and displacement values With the SEM have been discussed and compare with Human Tibia bone compressive property.

Compression strength all specimen is not matching the minimum requirement of Tibia bone Compression strength of 151MPa. From the experimental results S1, S2 and S3 specimens will have good mechanical property, S3 specimen dominating other two specimens, hence SEM images have taken and discussed and it is observed that very good interface binding amongst the fibers and the matrix, fibers fracture, matrix fracture, fibers pull-out is very less for all specimens.

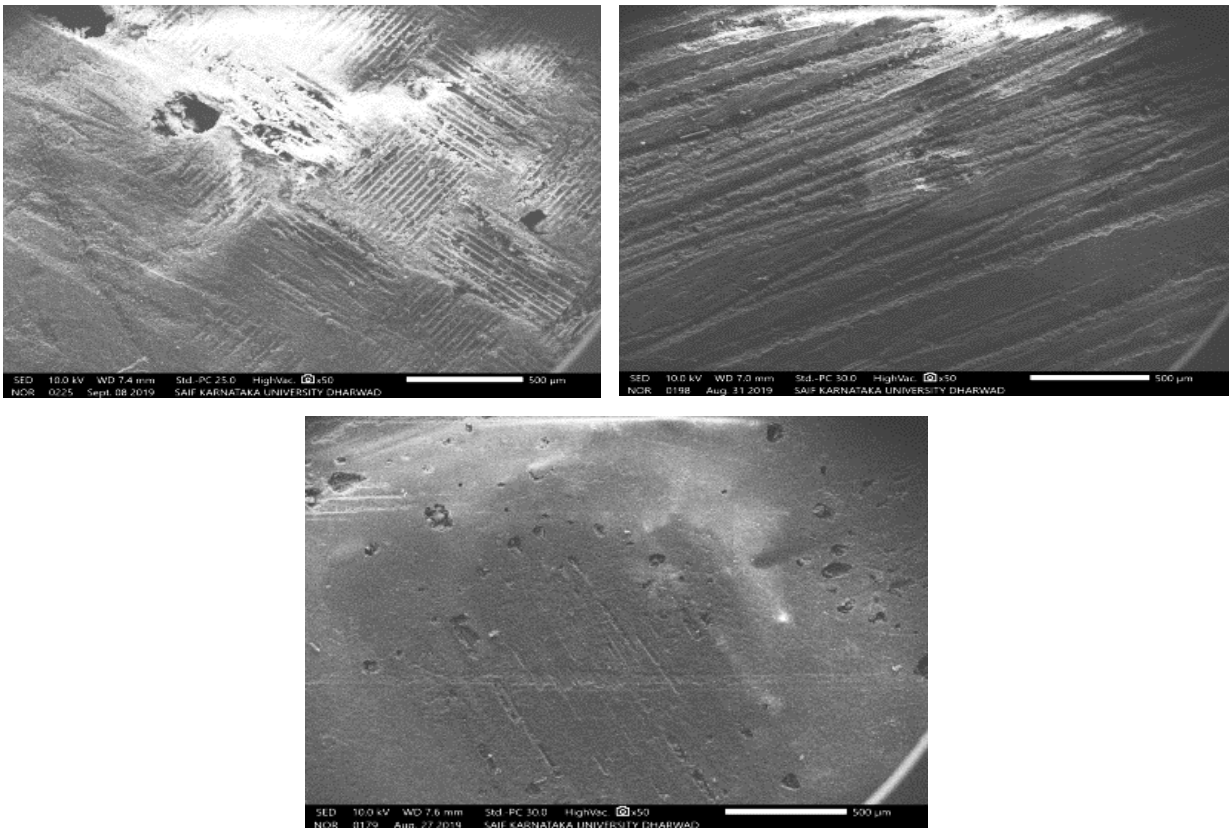
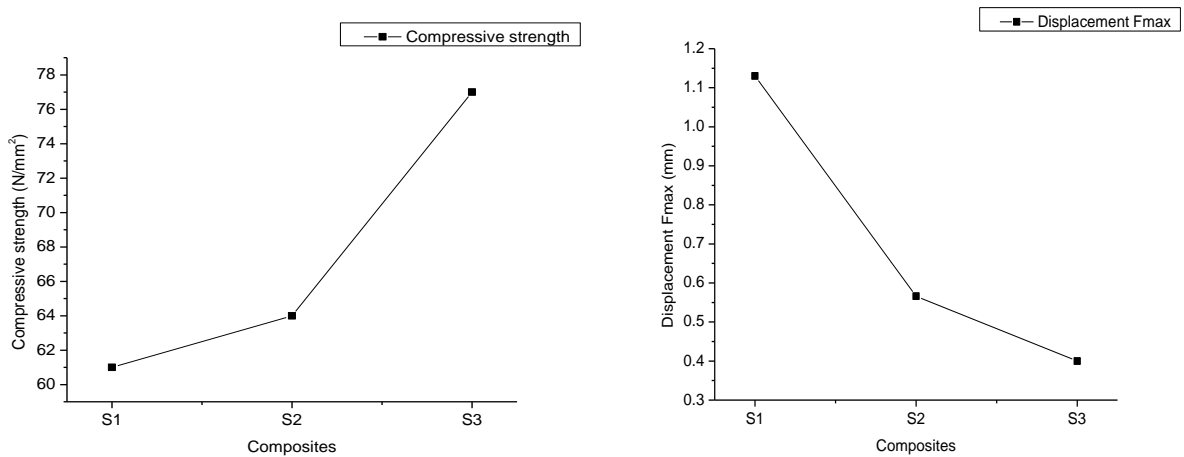


Fig.1.3: SEM [Magnification 500µm] S1 (10% Jute), S2 (10% E-Glass), S3 (10% Carbon)

3.3. Bending Test

Bending trials on intricate testimonies have been conducted in accordance with **ASTM-D 790** standards (127x12.7x3.2) mm to assess Bending strength for S1,S2 and S3 specimens to observe the behaviour of S1, S2 and S3 specimens to determine Bending strength(PKL/Area)(KN/mm²) and Displacement With the SEM have been discussed and compare with Human Tibia bone bending property and it is observed that very good interface binding amongst the fibers and the matrix, fibers fracture, matrix fracture, fibers pull-out is very less for all specimens.

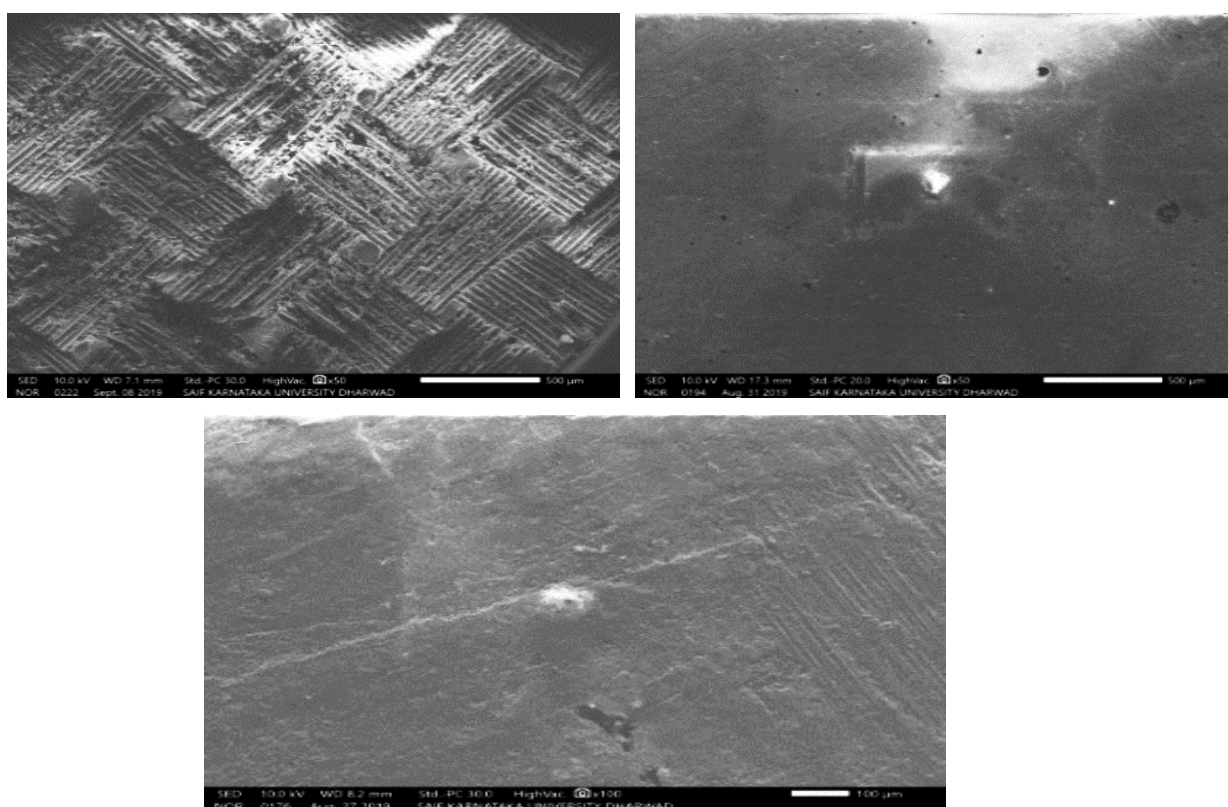
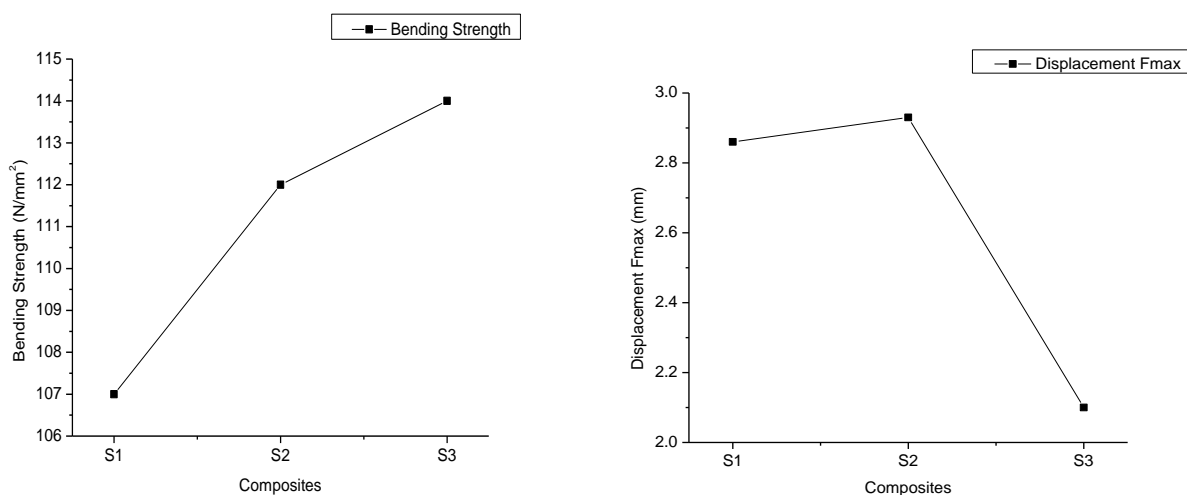


Fig.1.4: SEM [Magnification 500µm] S1 (10% Jute), S2 (10% E-Glass), S3 (10% Carbon)

3.4. Wear Test

The wear result is based on the test condition like Load (N), Speed (rpm), Wear track diameter (mm), Sliding distance (Km). In this wear experiment the Speed, Track diameter, sliding speed has been kept constant and Normal Load(100N) test is conducted for certain duration (1800 sec), The wear of the pins was measured by a vertical height loss as a function of time. Frictional force (F) and frictional coefficient (μ) were also reported. Pin-on-disc measurements were conducted using a commercial Wear & Friction monitor TR-20LC by **ASTM G-99**. In that way we can find how much wear has been obtained by weight loss method. In this test we use one types pin specimens of viz: S1, S2 and S3 of diameter 10, Like this it is discussed on coefficient of friction, Wear rate mm, Frictional force (N), abrasive wear mechanism.

From the graphs it is concluded that the wear rate of S3 specimen is less compare to S1 and S2



specimen. This result shows that S3 is specimen Withstand the Wear at different load conditions and it is observed or found that very good interface binding amongst the fibers and the matrix, fibers fracture, matrix fracture, fibers pull-out is very less for all specimens.

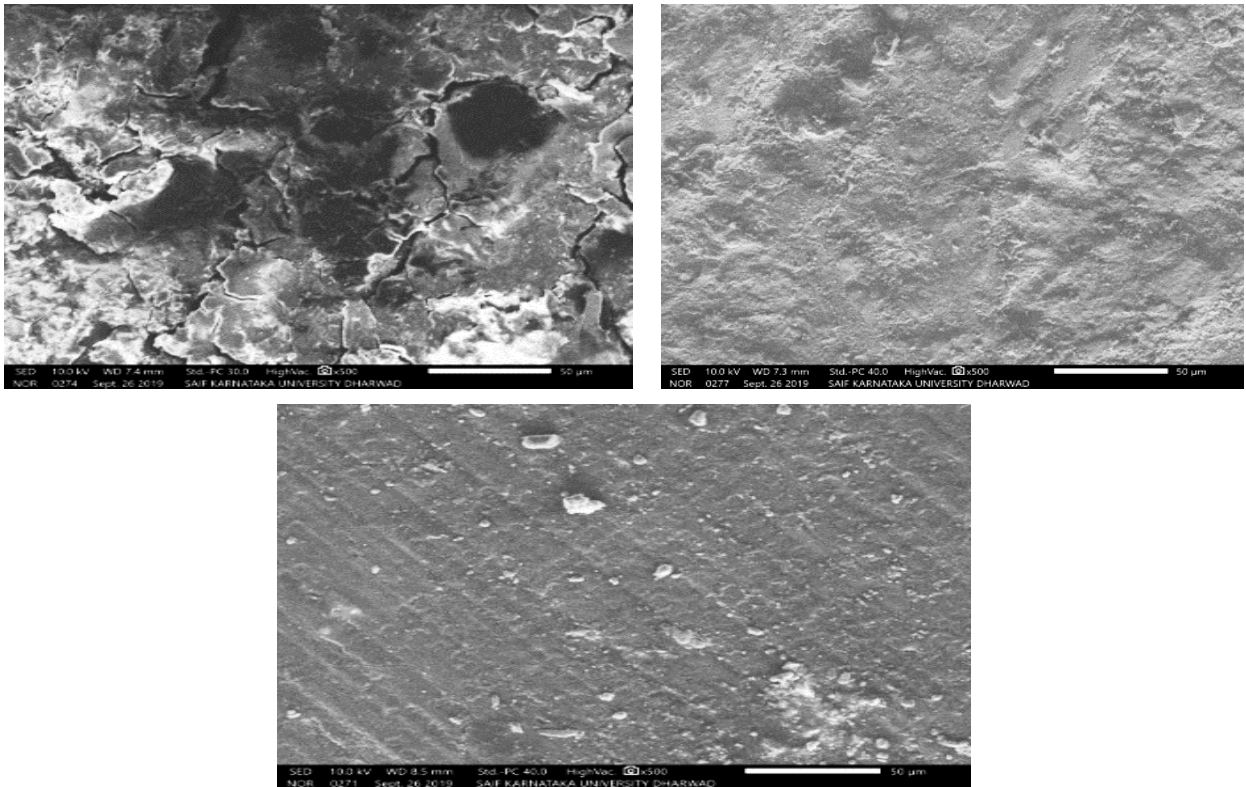
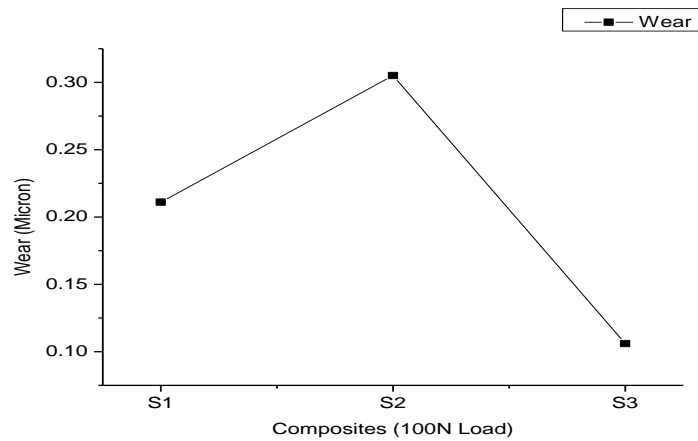


Fig.1.5: SEM [Magnification 500 μ m] S1 (10% Jute), S2 (10% E-Glass), S3 (10% Carbon)

3.5. Bio Compatibility Test

To conduct Corrosion/Bio-compatibility test on polymer composite material ISO10993-12 is used For Medical Application and hence OXIDATIVE DEGRADATION test is conducted by using Fenton's Reagent solution [For oxidation degradation, the subsequent solvents are prepared; Water and hydrogen peroxide, e.g., 3% hydrogen peroxide solution, pharmacopoeia grade. Fenton's reagent (mixture of dilute hydrogen peroxide solution and iron salts, e.g.100 μ mol Fe² and 1 μ mol H₂O)], a slight increase in the weight of composite material S1, S2 and S3 is observed, And also it is S3 will have very good pH value i.e. nearest to neutral value compare to others hence it is suggested to use TIBIA bone as implant material .After corrosion test the SEM images have taken for the different material to know the microstructure of the material the following images shows the SEM images of different specimen after corrosion test with Magnification of 50 μ m, from this it is observed that very less corrosion or chemical interaction between

the fibers and resin for all specimens.

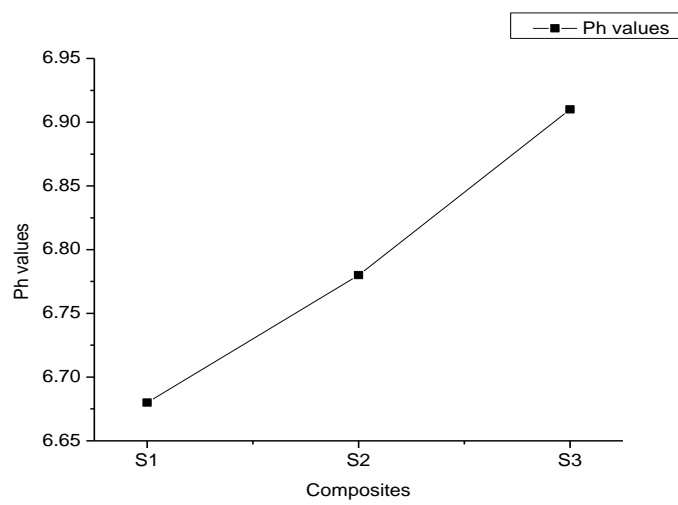


Fig.1.6: pH -meter instrument with Fenton's reagent solution and specimen

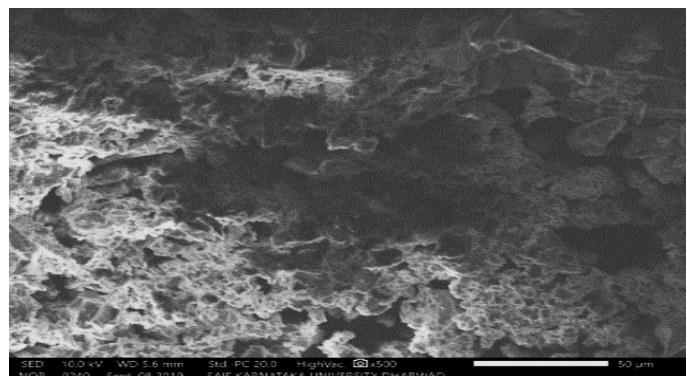
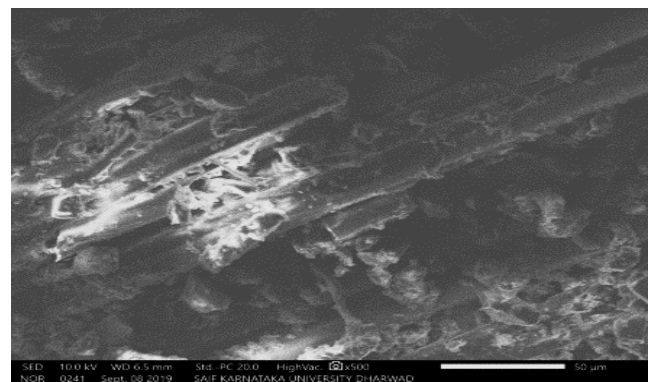
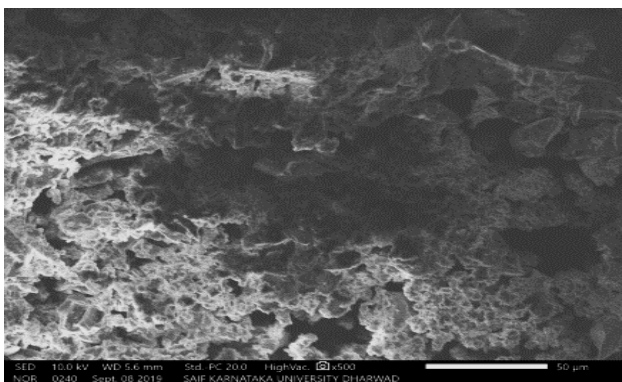


Fig.1.7: SEM [Magnification 500μm] S1 (10% Jute), S2 (10% E-Glass), S3 (10% Carbon)

3.6. Impact Test

Impact test is of two types namely Izode Test and Charpy Test conducted on S1, S2 and S3 specimens the experimental values of Izode/Charpy Test of three different S1, S2 and S3 materials as indicated in the below graphs, it is concluded from the graphs that S3 specimen having highest Izode/Charpy Strength and Energy Absorbed is more compare to S1 and S2 specimen it is concluded that S3 is the good material compare to S1 and S2 specimen.

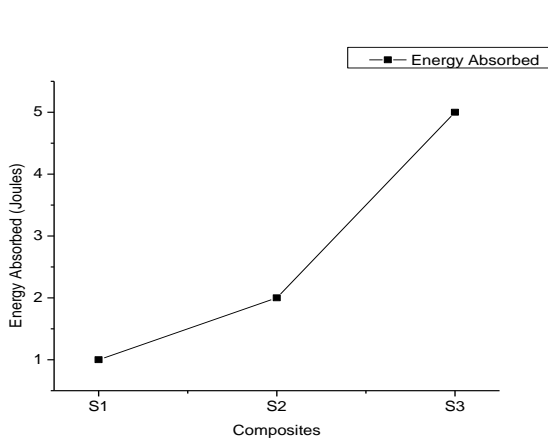


Fig.1.8: Izod Test

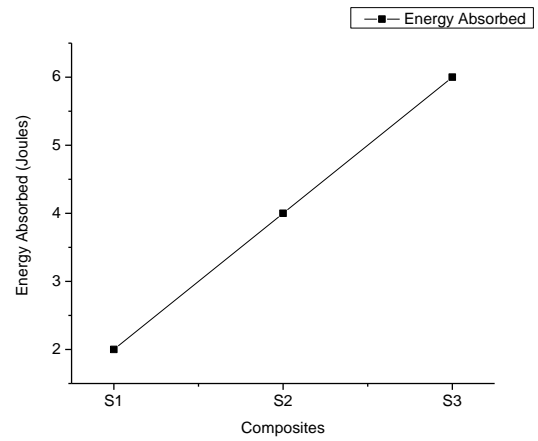
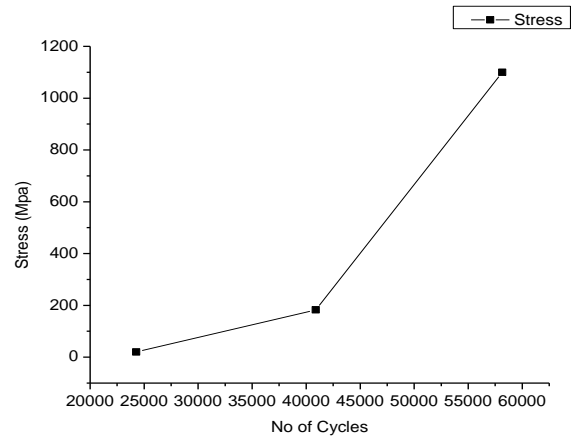
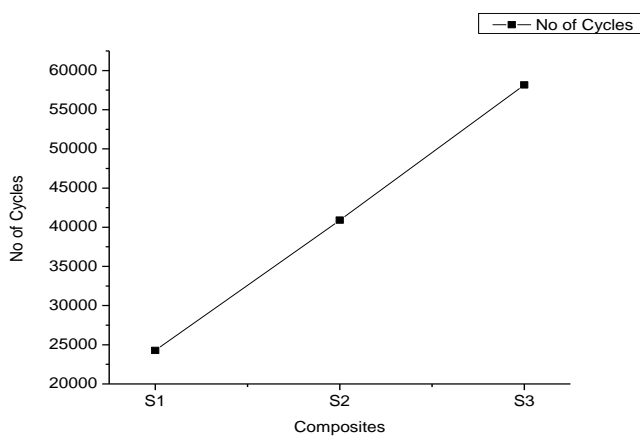


Fig.1.9: Charpy Test

3.7. Fatigue Test

Fatigue trials on intricate testimonies shave been conducted in accordance with ASTM D3479/D3479M-19 and D3039/D3039 standards with (250x25x3.2mm) to conduct Tension-Tension Fatigue of Polymer Matrix Composite Materials with tension-tension variable amplitude loading to understand the fatigue behaviour of composites subjected to tensile cyclic loading for S1, S2 and S3 specimens to assess Fatigue Strength, stress life (S-N) or strain-life (ϵ -N) curves and to notice the performance of S1, S2 and S3 specimens under load. In accordance with the experiment the ie Fatigue Strength and compared with Human Tibia bone fatigue property.

From the graph it is concluded that S3 specimen having good Fatigue Strength dominating other S1 and S2 specimen it is concluded that S3 is the good material compare to S1 and S2 specimen.



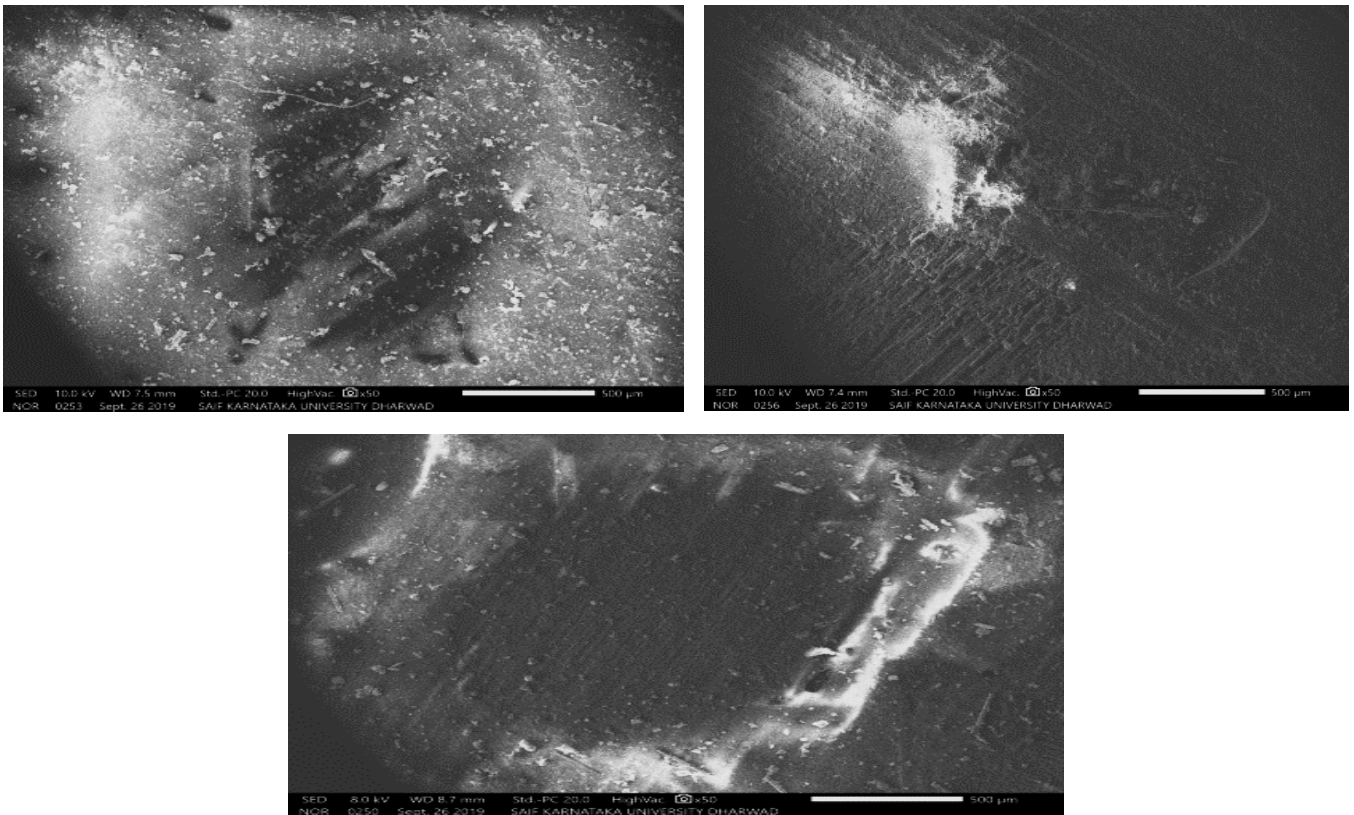


Fig.2.0: SEM [Magnification 500 μ m] S1 (10% Jute), S2 (10% E-Glass), S3 (10% Carbon)

3.8. Moisture Content Test

Moisture absorption capacity for S1, S2 and S3 specimens has been found out by hygrometric principle. For moisture absorption capacity test disc type specimens were prepared with standard size (50 mm diameter and thickness 4 mm for 5-ply and 2.5 mm for 3-ply laminate) according to ASTM standard. Two specimens were prepared from 3-ply as well as 5-ply hybrid composites as shown in Figure. The dry weight of both specimens was taken by an electronic balance. Then specimens were allowed to soak in the water for 24 hours shown in Figure. After that the specimens were taken out and clotting papers were used to absorb extra water contents on the outward surface. Then the weights were noted down and the gain in weight was calculated and tabulated in the table.



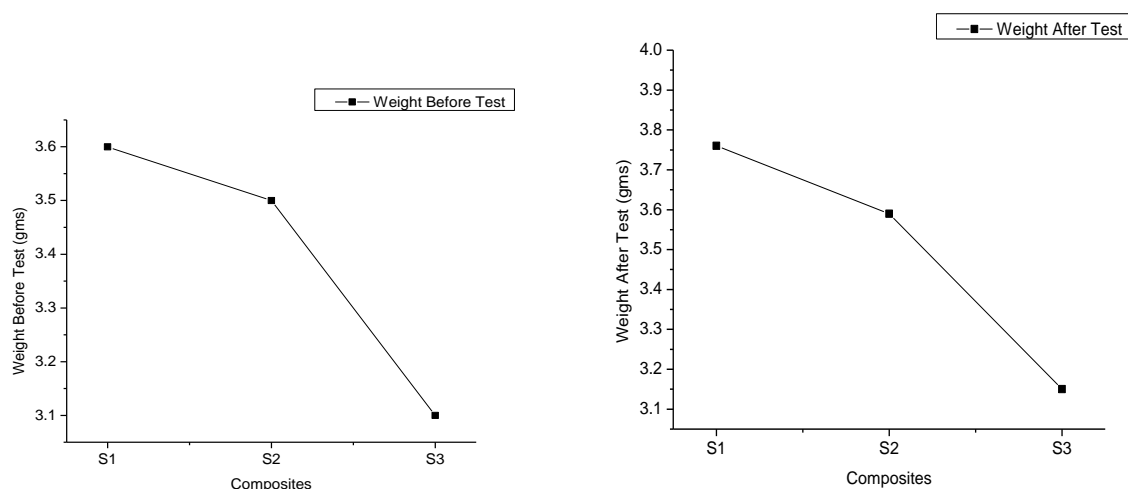


Fig.2.1: SEM [Magnification 500 μ m] S1 (10% Jute), S2 (10% E-Glass), S3 (10% Carbon) (a) Weight before Test in Grams Vs Composite materials (b). Weight after Test in Grams Vs Composite materials

It is concluded that the specimen S1 will absorb more amount of water and hence moisture content is more compare to other specimen S2 and S3 and also from the graph S3 will have less amount of abortion of water compare to other specimens S1 and S2.

4. CONCLUSION

It is observed that appreciable improvements in Tensile, Compression, Bending Corrosion, wear, Fatigue, Moisture and Impact properties of the 10% CPCM(S3) shows very good mechanical property and dominating other composite materials 10% EPCM(S2) and 10% JPCM(S1).

- It is concluded that increase in weight fraction of fibers, density of composite material also increases.
- Wear property also increases with increase in weight fraction of fibers.
- It is observed that corrosion property also improved which is a part of bio compatibility of material.
- It is found that pH value of 10 %CPCM (S3-Specimen) is neutralised with temperature from Oxidation degradation test.
- From the Tensile, Compression, Bending, wear Fatigue, Moisture and Impact Experimental test results it is found that 10% CPCM(S3) shows very good mechanical property and dominating other composite materials 10% EPCM(S2) and 10% JPCM(S1).
- Overall graph test results 10% CPCM(S3) will match the Tibia bone mechanical properties and which is having good mechanical properties and high Density when compare to other Hybrid composites. But when come to the point of economical one 10% JPCM(S1) composite material suggestible.

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