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"Analysis of mechanical properties of carbon fiber polymer Composite materials used as orthopaedic implants".

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ABSTRACT: This research paper constitutes the analysis of mechanical properties of Carbon fiber polymer composite material with +/- 0° to 90^0 orientation used as implant material. From this research work Characterization of 10% weight fraction of carbon fiber as reinforcement with epoxy resin as matrix and ceramic powder as a filler material and the composite materials are manufactured by using Vacuum bag moulding method and specimens are prepared according to ASTM standards and mechanical tests are carried out for these specimens and compare with femur bone prosthesis and finally we will suggest this material for Bio medical field application.

***Keywords**:-* Carbon fiber composite material, vacuum bag moulding method, orthopaedic Implants.

I. INTRODUCTION

While the use of metal plates and intramedullary nails remains the mainstay of internal fracture fixation, we have found CFRP plates particularly helpful in managing a number of difficult fractures. Currently, they cannot match their 'rigid' metal counterparts in terms of versatility, but they have been valuable when dealing with unusual problems. Semi-rigid plates have been constructed from epoxy resin reinforced with carbon fibre[1]. These have been used in animal trials and also for internal fixation of 20 fractures of the human tibia. The results are generally very satisfactory and support the view that semi-rigid fixation is not only desirable theoretically, but also works in practice. However, the results are from preliminary trials only and it is emphasized that further experience is necessary before widespread use of such plates can be advocated [2]. The surface chemistry of the carbon fibres may have an influence on the tissue response. The surface of the carbon fibres is affected by the oxidative treatment which is applied routinely during production and whose purpose is to aid bonding to the surroundings when these fibres are used to reinforce plastics. The surface chemistry of all types of treated carbon fibres (whether normal or high modulus) is likely to be similar, with their characteristic-of biocompatibility dominated by the presence of reactive

- Oxide side-groups [3] and following are the Properties of Biomaterials i.e. Biocompatibility. Appropriate Design and Manufacturability of Implants, Mechanical and Biological Stabilities.Corrosion Resistance. Resistance to Implant Wear and Aseptic Loosening. [4].
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II. Fig2.1:-FEMUR BONE [5]

The Femur is the longest and strongest bone in the skeleton is almost perfectly cylindrical in the greater part of its extent. Femur fracture to occur, either a large force must be applied or something is wrong with the bone. The most common procedure is to insert a metal rod down the center of the thigh bone. This procedure reconnects the two ends of the bone, and the rod is secured in place with screws both above and below the fracture According to literature survey femur bone outside layer will have thick surface i.e., compact bone, inside of femur layer will have thin surface i.e., Cancellus bone, from these bone we have to collect the mechanical properties like tensile, Compression, Bending strength and Wear properties of the bone. In this project work Characterizing the 10% (Weight fraction) carbon fabric material with Epoxy resin LY-556 and compare the Experimental results with orthopedic field /Femur bone [6]

MECHANICAL PROPERTIES OF FEMUR BONE [7][8]

Mechanical Tests	**≤ 30 Years (13)**	**31 – 50 Years (13)**	**51 – 70 Years (15)**	**≥ 70 Years (14)**
Tensile Strength	43.44±3.62	39.82±4.29	33.16±6.43	30.16±7.09
Compression Strength	155.8±9.53	142.37±12.12	124.44±15.40	115.29±12.94
Bending Strength	84.03±9.91	75.22±11.61	61.89±10.81	43.57±11.74
Shear Strength	55.41±4.56	49.54±7.11	39.61±8.39	32.62±8.35

III. METHODOLOGY

Characterization is carried out using Epoxy resin -LY556 as a matrix material, hardener -HY 951 and filler material as ceramic powder(Al_2O_3) with 10% Carbon fibres as the reinforcement material (with fiber weight fraction, 0 ± 90^0 orientation ie orthotropic material) by using Vacuum bag moulding methodology fabrication technique and the specimens are prepared as per ASTM standard .

IV. OBJECTIVE

The objective of the present study is:

1. To study the bio mechanical behaviour corbon fiber implants.
2. To report tensile, compression and Bending results.
3. To study tensile, compression and bending properties of biomaterials.

I. EXPERIMENTAL PROCEDURE

A. PROPERTIES OF CARBON

Table 3.1: Properties of carbon. [9]

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/mm2	113.0
Poisson's ratio	0.320
Shear modulus in N/mm2	3200

B. CUTTING OF CARBON FIBERS

The carbon fibers are cut according to the specified dimensions and are according to the ASTM standards to prepare the required specimens

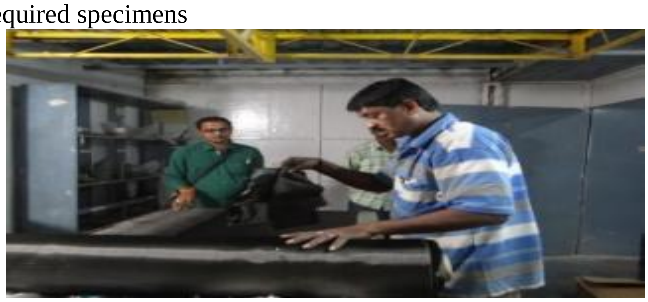


Fig3.1: Carbon fiber

C. MATERIALS USED FOR FABRICATION WORK

1. Selection of Matrix material: Matrix material selected is Epoxy resin LY556 and HY-951 as binder for the resin.
2. Reinforcement of Carbon fibers
3. Requirements for the Fabrication of Composites- Epoxy resin, Hardener, ceramic powder(Al_2O_3), Weighing Machine, Vacuum bag, Acetone, white cover, Oven or Furnace to dry the specimen.

D. MOULD PREPARATION AND FABRICATION PROCESS FOR TESTS.

Fig3.2 (a) **fig3.2 (b)** **fig3.2 (c)**



3.2 (d) **3.2 (e)** **3.2 (f)**



3.2 (g) **3.2(h)**


Fig3.2 (a): Cutting of carbon fibers according to ASTM Standards.
Fig3.2 (b): Cleaning the surface of the mould.
Fig3.2 (c): Weighing the mixture of Epoxy resin, hardener and ceramic powder according to the calculations made.
Fig 3.2(d): Placing up of carbon fibers according to the orientation.
Fig3.2 (e): Applying of epoxy resin hardener and ceramic powder mixture on to the mould surface.
Fig 3.2(f): Covering the layers with the Teflon cover and white covers.
Fig3.2 (g): Pressure setting to 680 bar.
Fig3.2 (h): Furnace used for annealing process

E. WEIGHT FRACTION OF THE FIBER:- The weight of the matrix was calculated by multiplying density of the matrix and the volume (volume in the mould). Corresponding to the weight of the matrix the specified weight percentage of fibers is taken. The carbon fiber is placed in the orientation of 0 ± 90^0 which describes the high strength the purpose of filler Al_2O_3 is to increase strength and hardness of the material.

F. SPECIMEN:- Mixing the Epoxy resin LY556 and the hardener HY-951 with a ratio of 10:1 with the filler agent as a ceramic powder(Al_2O_3). This solution is used as Matrix and the carbon fibers are used as a reinforcement The carbon fibers are used in weight percentages of 10%

II. EXPERIMENTAL TESTS

A. CUTTING THE TENSILE SPECIMEN TEST INTO SAMPLES OF DESIRED DIMENSION
A Wire Hacksaw blade was used to cut each specimen into pieces, according to the **ASTM D-3039/D-3039M-00** flat shape (250×25×2.5) mm. The No. of the test specimen.

Fig4.1:- 10% CARBON FIBER TENSILE SPECIMEN

B. CUTTING THE COMPRESSION SPECIMEN TEST INTO SAMPLES OF DESIRED DIMENSION
A Wire Hacksaw blade was used to cut each specimen into pieces, according to the **ASTM D-3410/D-3410M-03** flat shape (150×25×3.17) mm. The No. of the test specimen.

Fig4.2:-10% CARBON FIBER COMPRESSION SPECIMEN

C. CUTTING THE BENDING SPECIMEN TEST INTO SAMPLES OF DESIRED DIMENSION
A Wire Hacksaw blade was used to cut each specimen into pieces, according to the **ASTM D-790** flat shape (127×12.7×3.2) mm. The No. of the test specimen.

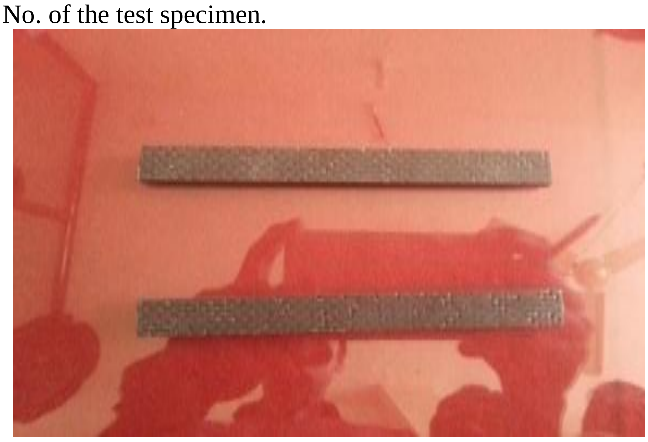


Fig4.3:-10% CARBON FIBER BENDING SPECIMEN

D. fig4.4UNIVERSAL TESTING MACHINE [10]

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength, compressive strength and bending strength of materials. It is named after the fact that it can perform many standard tensile and compression tests on materials, components, and structures. The specimen is placed in the machine between the grips and an extensometer if required can automatically record the change in gauge length during the test. If an extensometer is not fitted, the machine itself can record the displacement between its cross heads on which the specimen is held. However, this method not only records the change in length of the specimen but also all other extending / elastic components of the testing machine and its drive systems including any slipping of the specimen in the grips.

Once the machine is started it begins to apply an increasing load on specimen. Throughout the tests the control system and its associated software record the load and extension or compression of the specimen.

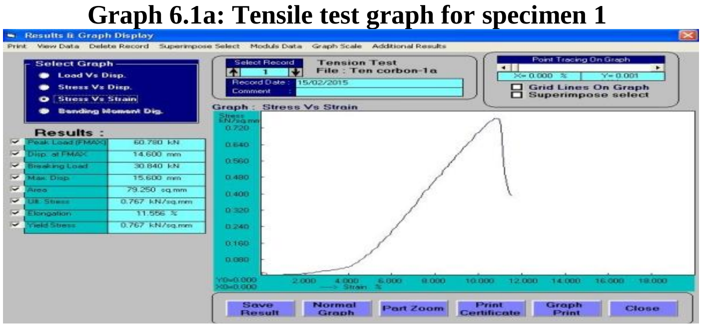
DATA ACQUISITION: The varying load signal is displayed in real time on a PC Screen. Data can be viewed as it is logged for the entire specified test duration, which can be recalled later for detailed analysis.

PURPOSE: Records the max load applied and the graph is applied according to the varying load

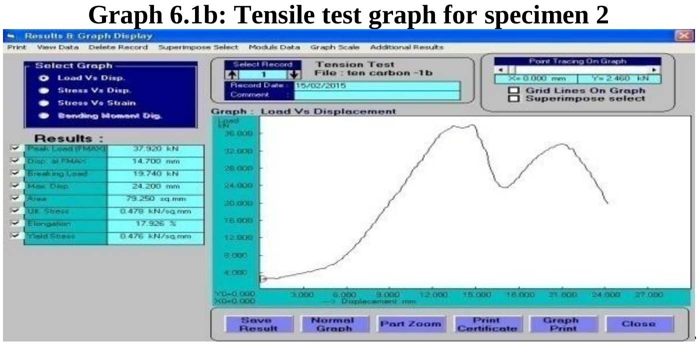
III. RESULTS AND DISCUSSION

6.1 TENSILE TEST RESULT FOR 10% WEIGHT FRACTION COEFFICIENT

Graph 6.1a: Tensile test graph for specimen 1



Graph 6.1b: Tensile test graph for specimen 2



6.2 COMPRESSIN TEST RESULTS FOR 10% WEIGHT FRACTION COEFFIECENT

Graph 6.2aCompression test graph for specimen 1.

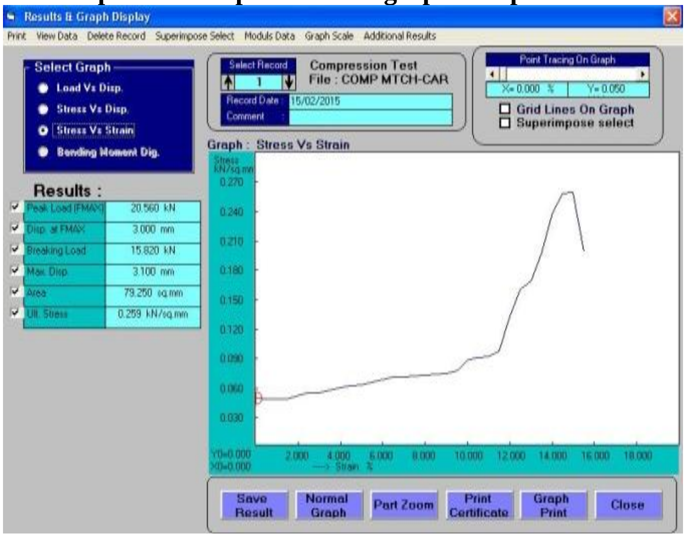
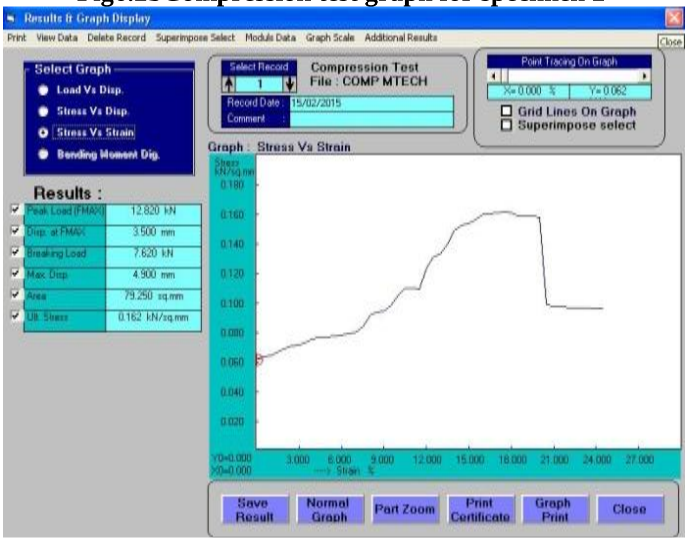


Fig6.2bCompression test graph for specimen 2



6.3 BENDING TEST RESULT FOR 10% WEIGHT FRACTION.

Fig6.3aBending test graph for speciman 1

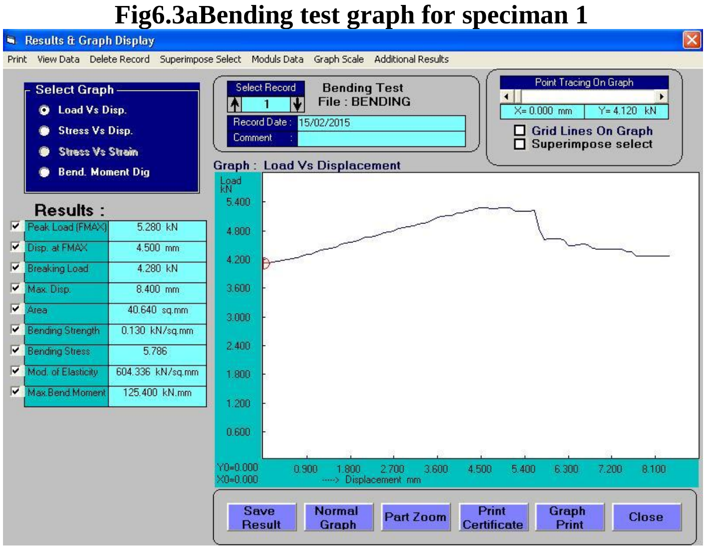


Fig6.3bBending test graph for specimen 2

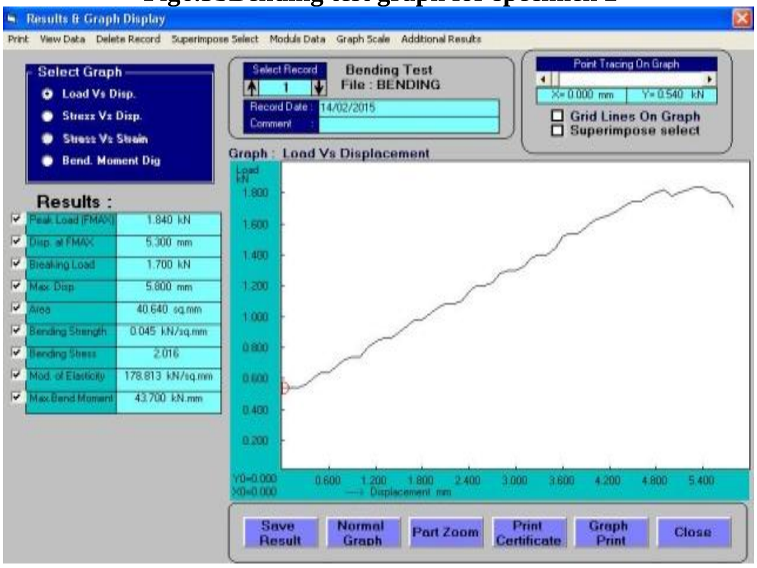


Table 6.1: Tabulated results of Tensile specimen

Sl no	Peak load (Fm ax) kN	Displacement Fmax (mm	Breaking load (kN)	Max Displacement (mm)	Area mm2	Ultimate stress (kN/mm 2)	Elongation %	Yield stress (kN/m m2)	Femur Bone tensile strength
1	60.80	14.60	30.80	15.66	79.25	0.767	11.56	0.767	43.44±3.62 Mpa or 0.04344±0. 00362 (kN/mm2)
2	37.50	14.20	19.74	24.22	79.25	0.478	19.92	0.476	

Table 6.2: Tabulated results of Compression Specimen

Sl no	Peak load (Fm ax) kN	Displace ment Fmax (mm	Breakin g load (kN)	Max Displac ement (mm)	Area mm2	Compressive strength (PKL/Area) (kN/mm2)	Femur Bone Compressive strength
1	20.56	3.00	15.82	3.100	79.25	0.259	115.29±12.94(Mpa) or 0.11529±0.012 94 (kN/mm2)
2	12.82	3.500	7.62	4.900	79.25	0.162	

Table 6.3: Tabulated results of Bending Specimen

Sl no	Peak load (Fm ax) kN	Displa cemen t Fmax (mm)	Break ing load (kN)	Max Displac ement (mm)	C/S Area mm2	Bending Strength (kN/m m2)	Bendin g Stress (kN/ mm2)	Modu lus of elastic ity (kN/m m2)	Max bending Strength kN.m m	Femur bone bending strength
1	4.78	11.10	4.500	13.4	40.64	0.118	5.23	221.8	113.5	84.03±9. 91 (Mpa) or 0.084± 0.00991(kN /mm2)
2	4.60	10.70	4.32	12.80	40.64	0.113	5.040	221.2	109.2	

IV. CONCLUSION

1. According to experimental results, 10% Carbon fibers Polymer Composite Material of tensile test has yield strength of 0.767kN/mm^2 for specimen 1 and yield strength of 0.476 kN/mm^2 for specimen 2. From these results it is found that Tensile strength of femur bone 0.04344±0.00362 kN/mm2 both the specimens' results will match.
2. According to experimental results, 10% Carbon fibers Polymer Composite Material of compression test has compressive strength of 0.259KN/mm^2 for specimen 1 and compressive strength of 0.162 KN/mm^2 for specimen 2. From these results it is found that Compressive strength of femur bone 0.11529±0.01294kN/mm2. 1st Specimens results will match.
3. According to experimental results, 10% Carbon fibers Polymer Composite Material of Bending strength test has Bending strength of 0.118KN/mm^2 for specimen 1 and bending strength of 0.113 KN/mm^2 for specimen 2. From these results it is found that bending strength of femur bone 0.084± 0.00991kN/mm2. both the specimens results will match.

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