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"Wear Study on Hybrid Natural Fiber Polymer Composite Materials Used As Orthopaedic Implants"

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ABSTRACT

This paper constitutes the wear study of 2%, 24% and 36% of Hybrid Fiber (Natural fiber- Sisal, Jute and Hemp) polymer composite material used as Bio-material. Characterization of 12%, 24% & 36% Hybrid Natural fiber polymer composite material with the low density, economical for prosthetic bone with respect to biocompatibility and the mechanical behaviour of long human bones, such as Femur Bone. According to the ASTM Standard G-99 the specimen is fabricated by using the Epoxy resin- LY556 as the matrix material and the Hardener-HY 951 with the 12%, 24% and 36% of the Natural Fibers (Sisal, Jute and Hemp) as the reinforcement material with fiber weight fraction, randomly continuous long fiber orientation. By using the Hand Layup fabrication technique the specimen are prepared.

The wear tests were conducted on the varying percentage standard samples prepared. The study was conducted by using a pin-on-disk apparatus and is issued under the standard ASTM G- 99. For the PIN-ON-DISK wear test conducted in this research, the specimens were a pin with a rounded tip, which is positioned perpendicular to a flat circular disk. It is found that appreciable improvements in tribological properties of the 36% Hybrid Natural fiber polymer composite material when compared with 12% and 24% Hybrid Natural fiber polymer composite material. This study suggests 36% Hybrid Natural fiber polymer composite material can be used for different applications in the human body bone replacement or orthopedic implant.

Keywords—Hand layup Fabrication Technique, Wear Resistance, Bio-Material, 12%, 24% and 36% of Hybrid Natural fiber polymer composite material, orthopaedic Implants.

INTRODUCTION

The use of plants fibre reinforced composites has been continuously increased during recent years. Their low density, higher environmental friendliness, and reduced cost proved particularly attractive for low-tech applications [1]. Natural fibres have special advantage in comparison to synthetic fibre in that they are abundantly available, form a renewable resource and also biodegradable [2]. Natural fibres represent an environmentally friendly alternative by virtue of several attractive attributes that include lower density, lower cost, non-toxicity, and ease of processing, renewability and recyclability [3-5], Sisal Fiber Reinforcement epoxy resin composite material used for orthopaedic implants [6] and Biocomposites materials based on biopolymers and natural fibers used as bone implants [7], Much of natural product obtained from plants having own medicinal values such as biologically active photochemical are normally present in leaves, roots, barks and flowers [8], Natural fibers present important advantages such as low density, appropriate stiffness and mechanical properties and high disposability and renewability. Moreover, they are recyclable and biodegradable [9]. Natural fiber reinforced polymer composite materials which are less rigid than metals may be good alternatives because of properties closer to bone mechanical properties. It was found that they help to avoid stress shielding and increase bone remodelling [14, 15]. Orthopaedic surgeons have been using metallic bone plates for the fixation of humerus bone fractures. Apparently, metallic prosthesis, which are generally made of stainless steel and titanium alloys, because some problems like metal incompatibility, corrosion, magnetism effect, anode-cathode reactions, including a decrease in bone mass, increase in bone porosity, and delay in fracture healing [10, 11, 12]. The Femur is the longest and strongest bone in the skeleton is almost perfectly cylindrical in the greater part of its extent [13]. Fabrication of (Hybrid) natural fiber reinforced polymer (NFRP) composite plate material by using bio epoxy resin. Instead of orthopaedic alloys (such as titanium, cobalt chrome, stainless steel and zirconium). NFRP composite (bio composite plate material) can be coated with bone graft substitutes such as calcium phosphate and hydroxyl apatite and this plate material can be used for both inside fixation and external fixation of fractured human bone [9].

A Bio-material 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

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living tissues or organs. Biomaterial devices used in orthopaedics are commonly called implants; these are manufactured for a great number of orthopaedic applications.

The main fundamental requirements that orthopaedic devices must fulfil in order to function adequately are summarized in this section.

- Biocompatibility.
- Appropriate Design and Manufacturability of Implants, Mechanical and Biological Stabilities.
- Corrosion Resistance.
- Resistance to Implant Wear and Aseptic Loosening. Properties of Biomaterials [17].

METHODOLOGY

Characterization is carried out using Epoxy resin -LY556 as a matrix material and hardener -HY 951 with 12%, 24% and 36% Natural fibres as the reinforcement material (with fiber weight fraction, randomly continuous long fibre orientation) by using hand layup fabrication technique the specimens are prepared as per ASTM standard G-99 for Wear Tests.

OBJECTIVE

The objective of the present study is:
1. To study the bio mechanical behaviour f the implants.
2. To report wear analysis.
3. To study wear properties of biomaterials.
4. To compare results of wear with different compositions of composite material [15]

EXPERIMENTAL PROCEDURE

A. NATURAL FIBRES PREPARATION

The natural fibers such as Sisal, Jute and Hemp were extracted by the decorticating process. Here continuous fibre is used for fabricate the natural fibre composites. First the natural fibres are cleaned in the distilled water. The cleaned natural fibres are dried in the sun light. The dried natural fibres are again cleaned by chemical cleaning process. In chemical cleaning process the 80% sodium hydroxide (NaOH) is mixed with 20% distilled water. The dried natural fibres dipped in the diluted sodium hydroxide solution which it cleans from muddy particles and we get the smooth fibers. It is again dried in sun light .The dried natural fibres are cut in the length of different size by manually. The cut natural fibres are used in fabricate the natural fibres reinforced epoxy composite material. In this Research we make use of the following three Natural fibers that is Sisal, Jute and Hemp as shown in fig 1.

Fig 1. (a) Sisal Fiber (b) Jute Fiber (c) Hemp Fiber

B. PROPERTIES OF NATURAL FIBERS USED FOR FABRICATION WORK

Table 1: Properties of Natural Fibers Used For Fabrication Work. [14]

PROPERTY	SISAL	JUTE	HEMP
Density [g/cm^3]	1.33	1.46	1.48
Tensile strength [N/mm^2]	600-700	400-800	550-900
Stiffness [kN/mm^2]	38	10-30	70
Elongation at break [%]	2-3	1.8	1.6
Moist absorption [%]	11	12	8
Price of raw fibre [$/kg]	0.6-0.7	0.35	0.6-1.8

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 Natural Fibres-Sisal fibre, Jute and Hemp
3. Requirements for the Fabrication of Composites- Epoxy resin, Hardener, Natural Fibre, Sodium Hydroxide (NaOH), Weighing Machine, Roller, Stirrer and Oven or Furnace to dry the specimen.

D. MOULD PREPARATION AND FABRICATION PROCESS FOR WEAR TEST.

Fig 2. (a): Mould for the preparation of Wear Test ASTM Standards. Fig (b): Measuring and cutting the Fibers as per the Requirement. Fig (c): Required length of fibers for fabrication. Fig (d): Applying Epoxy Resin, Hardener & Fiber layer by layer. Fig (e): Both Pieces of mould attached and applying the C-Clamps. Fig (f): Furnace for Annealing Process. Fig (g): Full length Fabricated Specimen.

E. PREPARATION OF THE SPECIMEN

Mould The wear specimen the mould is prepared by the wood material of 10/12mm Diameter and Length of 500mm.. Later specimens are cut from the prepared casting according to the ASTM Standards.

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. For hybrid combination the corresponding weight of fiber obtained is shared by three natural fibers.

SPECIMEN: Mixing the Epoxy resin LY556 and the hardener HY-951 with a ratio of 10:1. This solution is used as Matrix and the different types of natural fibers are used as a reinforcement that is Sisal, Jute and Hemp; then the hybrid Natural fiber polymer composite material is Prepared. The Hybrid natural fibers are used in varying weight percentages of 12%, 24% and 36%.

EXPERIMENTAL TESTS

F. CUTTING THE WEAR SPECIMEN TEST INTO SAMPLES OF DESIRED DIMENSION

A Wire Hacksaw blade was used to cut each specimen into smaller pieces, according to the **ASTM G-99** round shape (10x30) mm. The No. of the test specimen is three as shown in fig 3.

Fig 3. 12% HNFPCM 24%HNFPCM 36%HNFPCM

G. WEAR TEST BY PIN-ON-DISC MACHINE.

Fig 4: Wear Test Machine.

This test method covers a laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus and is issued under the standard ASTM G 99. For the pin-on-disk wear test conducted in this research, the specimens were a pin with a rounded tip, which is positioned perpendicular to a flat circular disk (the test sample). A ball, rigidly held, is often used as the pin. The test machine causes either the disk specimen or the pin to revolve about the disk centre. The sliding path is a circle on the sample surface. The pin is pressed against the disk at a specified load usually by means of an arm or lever and attached weights.

DATA ACQUISITION: The friction coefficient 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. The software allows 4 different logged test files for on-line analysis / mapping. The software displays the test time, turn count, linear velocity, and user-defined test parameters. This data can be stored and printed along with the friction traces.

PURPOSE: Records friction and wear in sliding contact in dry, lubricated, controlled environment and partial vacuum.

APPLICATION: Fundamental wear studies. Wear mapping and PV diagrams. Friction and wear testing of metals, ceramics, soft and hard coatings, plastics, polymers and composites, lubricants, cutting fluids, heat processed samples.

Standards: ASTM G-99 Instrumented & data Acquisition system for the measurement of RPM, Wear, frictional force, Temperature ,PC acquires data online and displays it in several ways, Graphs of individual tests can be printed, Results of different tests can be superimposed for comparative viewing, Data can be exported to other software, Tests at ambient temperature ,Dead weight loading ,Electrical contact resistance measurement, Displays Load, Friction, temp, rpm / speed on the display panel, Auto on/off (timer).

RESULTS AND DISCUSSION

WEAR TEST RESULTS FOR 12% HNFPCM FOR 20N, 40N, 60N AND 80N LOAD

Fig 7.Graph for Wear, Coefficient of friction, friction force for 12% HNFPCM for 20N.

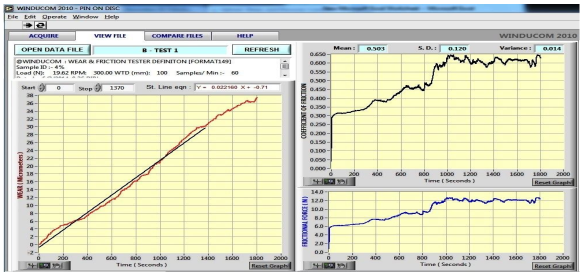

Fig 8 Graph for Wear, Coefficient of friction, friction force for 12% HNFPCM for 40N.

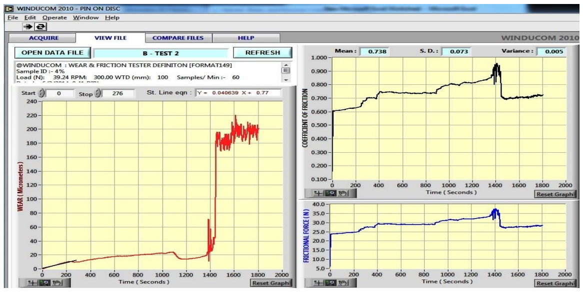

Fig 9 Graph for Wear, Coefficient of friction, friction force for 12% HNFPCM for 60N.

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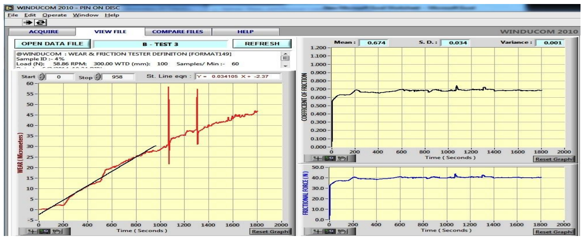
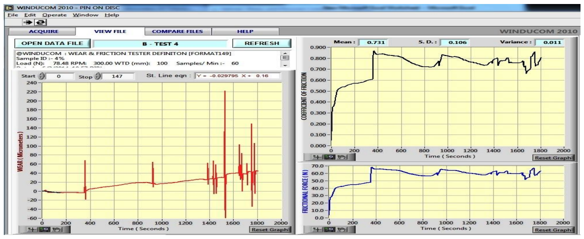


Fig 10 Graph for Wear, Coefficient of friction, friction force for 12% HNFPCM for 80N.



WEAR TEST RESULTS FOR 24% HNFPCM FOR 20N, 40N, 60N AND 80N LOAD

Fig 11 Graph for Wear, Coefficient of friction, friction force for 24% HNFPCM for 20N.

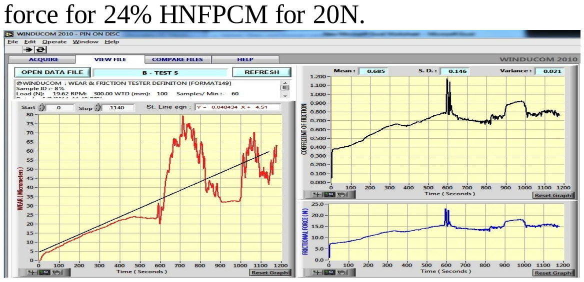


Fig 12 Graph for Wear, Coefficient of friction, friction force for 24% HNFPCM for 40N.

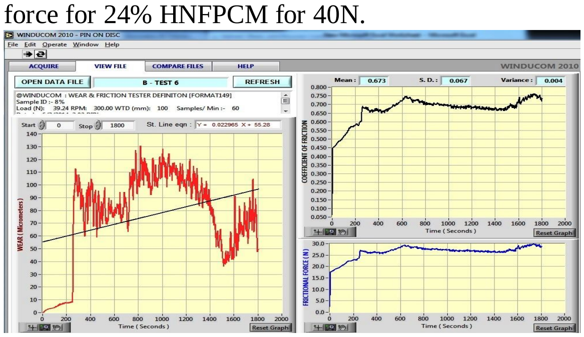


Fig 13 Graph for Wear, Coefficient of friction, friction force for 24% HNFPCM for 60N.

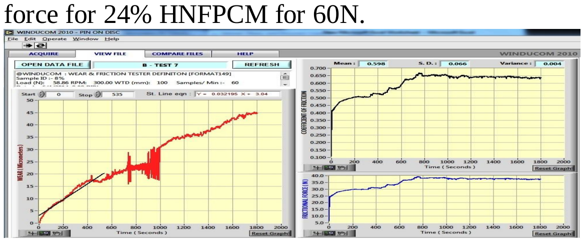
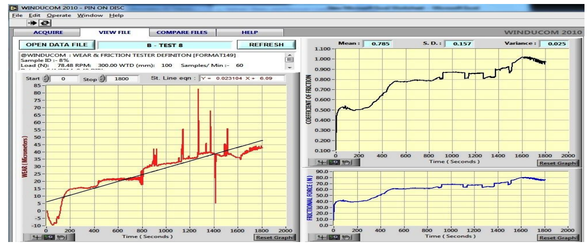


Fig 14 Graph for Wear, Coefficient of friction, friction force for 24% HNFPCM for 80N.



WEAR TEST RESULTS FOR 36% HNFPCM FOR 20N, 40N, 60N AND 80N LOAD

Fig 15 Graph for Wear, Coefficient of friction, friction force for 36% HNFPCM for 20N.

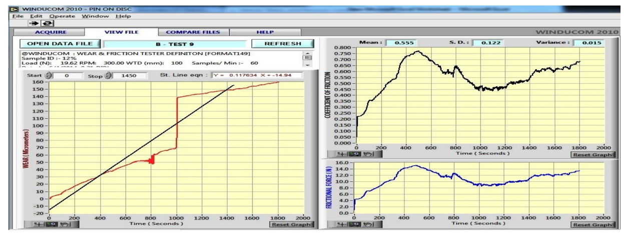


Fig 16 Graph for Wear, Coefficient of friction, friction force for 36% HNFPCM for 40N.

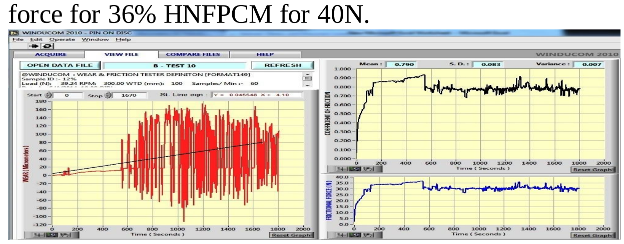


Fig 17 Graph for Wear, Coefficient of friction, friction force for 36% HNFPCM for 60N.

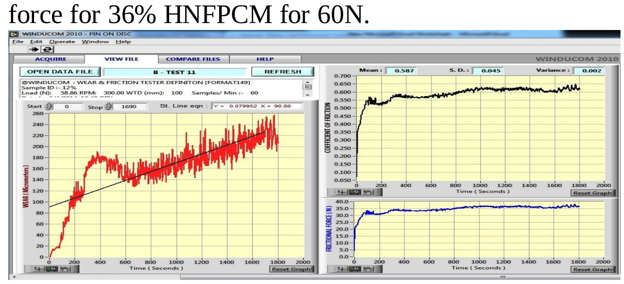


Fig 18 Graph for Wear, Coefficient of friction, friction force for 36% HNFPCM for 80N.

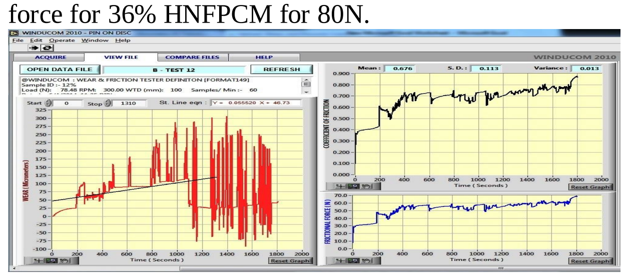


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Table 2: Tabulated results of the Dia-10mm Specimen with Pin on Disc Apparatus (a).

Diameter of Specimen 10mm							
Sl No	**Specimen (%of Natural Fibers)**	**Load (N)**	**Speed (rpm)**	**Wear (µm)**	**Co-efficient of Friction**	**Frictional Force (N)**	**Time (sec)**
1	**12%**	20	300	37	0.65	13	1800
		40	300	220	0.93	37	1800
		60	300	58	0.75	45	1800
		80	300	222	0.86	69	1800
2	**24%**	20	300	79	1.15	23	1800
		40	300	132	0.75	30	1800
		60	300	46	0.65	39	1800
		80	300	83	1.01	81	1800
3	**36%**	20	300	160	0.75	15	1800
		40	300	170	0.93	37	1800
		60	300	258	0.63	38	1800
		80	300	305	0.88	70	1800

Table 3: Tabulated results of the Dia-10mm Specimen with Pin on Disc Apparatus (b).

% of Natural Fiber	**Test No**	**Load (N)**		**Initial Weight (gms)**	**Final Weight (gms)**	**Weight Difference (gms)**
12%	1	20	**Speed RPM=300**	3.50769	3.50768	0.00001
	2	40	**Track Dia (mm)=100**	3.24556	3.24226	0.0033
	3	60		3.50768	3.50508	0.0026
	4	80	**Time (sec)=1800**	3.24226	3.23909	0.00317
24%	1	20		3.28262	3.28043	0.00219
	2	40	**Sliding Velocity (m/s)=1.5**	3.28275	3.28003	0.00272
	3	60		3.23476	3.23275	0.00201
	4	80		3.23275	3.22959	0.00316
36%	1	20	**Sliding Distance (m)=2700**	3.18783	3.18495	0.00288
	2	40		3.18495	3.18191	0.00304
	3	60		3.17119	3.16654	0.00465
	4	80		3.16654	3.1602	0.00634

Fig 19 .Wear test Graph's for 12% HPCM for 20N, 40N, 60N & 80N.

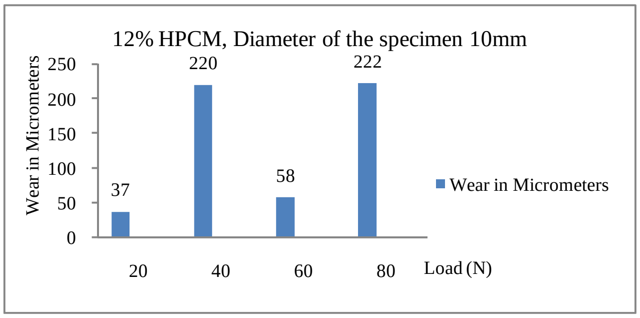


Fig 20. Wear test Graph's for 24% HPCM for 20N, 40N, 60N & 80N.

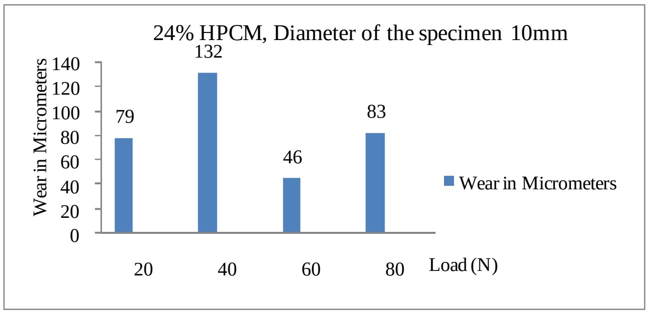


Fig 21. Wear test Graph's for 36% HPCM for 20N, 40N, 60N & 80N.

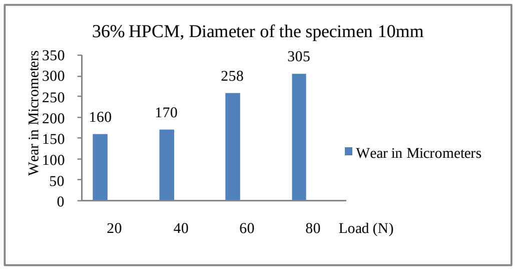


Fig 22. Co-efficient of friction test Graph's for 12% HPCM for 20N, 40N, 60N & 80N.

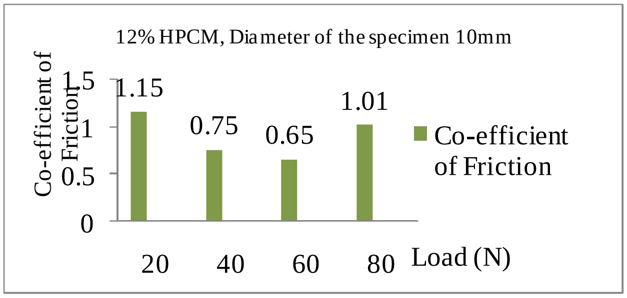


Fig 23 .Co-efficient of friction test Graph's for 24% HPCM for 20N, 40N, 60N & 80N.

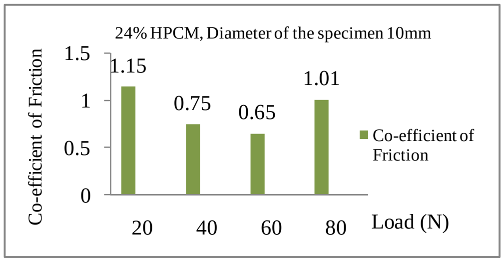


Fig 24. Co-efficient of friction test Graph's for 36% HPCM for 20N, 40N, 60N & 80N.

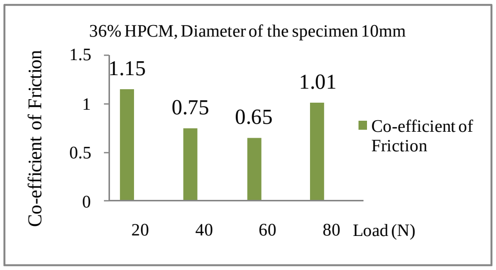


Fig 25. Frictional Force test Graph's for 12% HPCM for 20N, 40N, 60N & 80N.

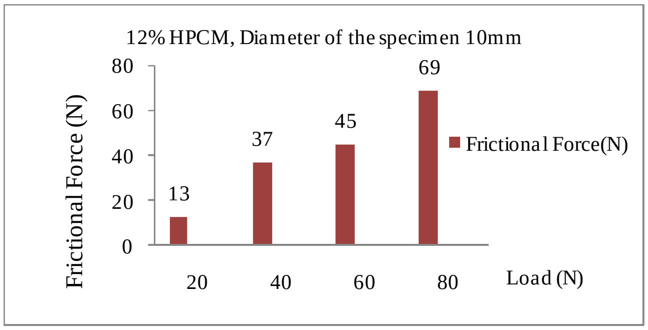


Fig 25. Frictional Force test Graph's for 24% HPCM for 20N, 40N, 60N & 80N.

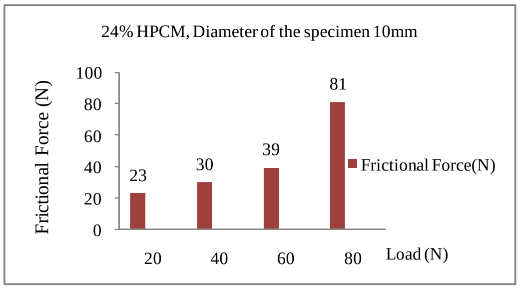


Fig 26.Frictional Force test Graph's for 36% HPCM for 20N, 40N, 60N & 80N.

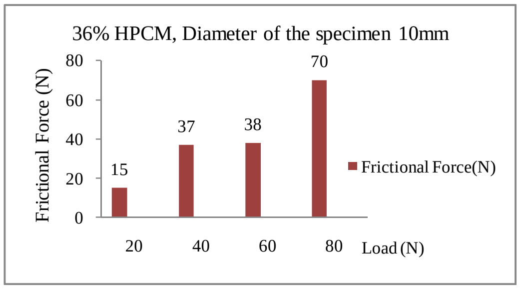


Fig 27. Weight Loss Graph's for 12% HPCM for 20N, 40N, 60N & 80N.

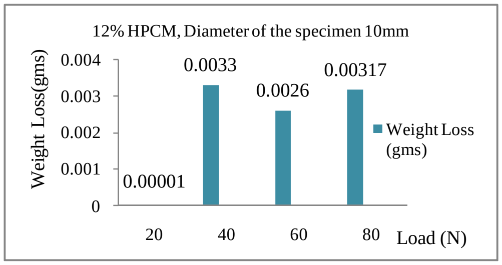


Fig 28. Weight Loss Graph's for 24% HPCM for 20N, 40N, 60N & 80N.

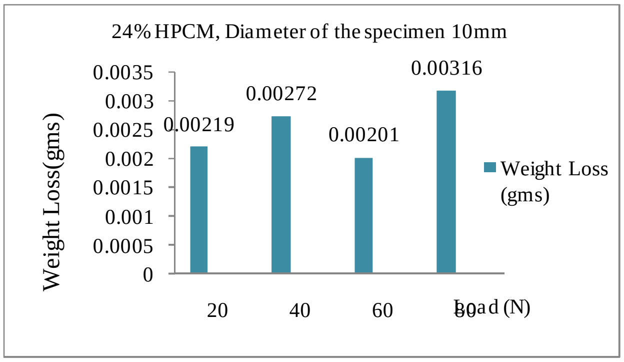
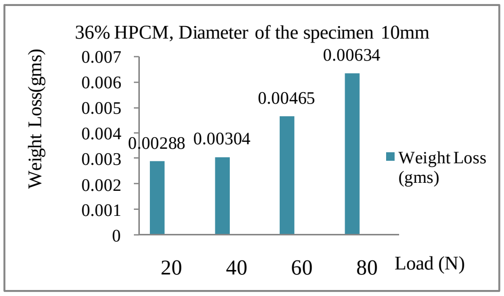


Fig 29.Weight Loss Graph's for 12% HPCM for 20N, 40N, 60N & 80N.



CONCLUSION

1. According to experimental results, 12% Hybrid Natural fibers Polymer Composite Material has wear rate of 37 micrometers for 20N, 220 micrometers for 40N, 58 micrometers for 60N and 222 micrometers for 80N. From these results it is found that as weight increases the wear rate also increases.
2. According to experimental results, 24 % Hybrid Natural fibers Polymer Composite Material has wear rate of 79 micrometers for 20N, 132 micrometers for 40N, 46 micrometers for 60N and 222 micrometers for 80N. From these results it is found that as weight increases the wear rate also increases.
3. According to experimental results, 36 % Hybrid Natural fibers Polymer Composite Material has wear rate of 160 micrometers for 20N, 170 micrometers for 40N, 258 micrometers for 60N and 305 micrometers for 80N. From these results it is found that as weight increases the wear rate also increases.
4. Finally with all the above conclusions we concluded that by increasing the percentage of the Natural fibers for the characterization work it increases the wear rate of the specimen.
5. Both the Weight Loss and Friction Force is more in the 36% Hybrid Natural fibers Polymer Composite Material when compared to the 12% and 24% Hybrid Natural fibers Polymer Composite Material.
6. By increasing the fiber the weight of the specimen decreases. Hence 36% Hybrid Natural fibers Polymer Composite Material is a low weight material compare to 12% and 24% Hybrid Natural fibers Polymer Composite Material, so 36% Hybrid Natural fibers Polymer Composite Material can be used as the alternative material for Human Orthopaedic Implants.

SCANNING ELECTRON MICROSCOPE

INTRODUCTION

The Scanning Electron Microscope (SEM) is a type of Electron microscope that images the sample surface by scanning it with a high-energy beam of electrons in a raster scan pattern. The electrons interact with the atoms that make up the sample producing signals that contain information about the samples surface topography, composition and other properties such as electrical conductivity. SEM can produce very high-resolution images of a sample surface, revealing details about less than 2 to 5 nm in size. Due to the very narrow electron beam, SEM micrographs have a large depth of fielding a characteristic three-dimensional appearance useful for understanding the surface of a structure of a sample. For conventional imaging in the SEM, specimens must be electrically conductive, at least at the surface, and electrically grounded to prevent the accumulation of electrostatic charge at the surface. Metal objects require little special preparation for SEM except for cleaning and mounting on a specimen stub. Nonconductive specimens tend to charge when scanned by the electron beam, and especially in secondary electron imaging mode, this causes scanning faults and other image artefacts. They are therefore usually coated with an ultrathin coating of electrically conducting material, commonly gold, deposited on the sample either by low vacuum sputter coating or by high vacuum evaporation. Conductive materials in current use for specimen coating include gold, gold/palladium alloy, platinum, osmium, iridium, tungsten, chromium and graphite. Coating prevents the accumulation of static electric charge on the specimen during electron irradiation. The image may be captured by photography from a high resolution cathode ray tube, but in modern machines is digitally captured and displayed on a computer monitor and saved to a computer's hard disc.

SEM FOR 12% HNFPCM SPECIMENS

Fig 30 a: 12% HNFPCM 10X

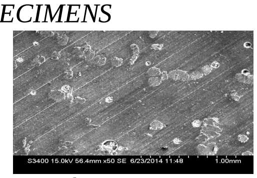


Fig 30 b: 12% HNFPCM 50X

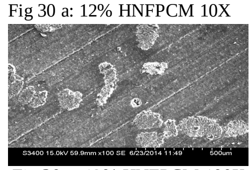


Fig 30 c: 12% HNFPCM 100X

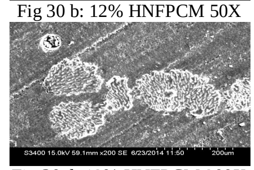


Fig 30 d: 12% HNFPCM 200X

Fig 30: SEM FOR 12% HNFPCM SPECIMENS.

SEM FOR 24 % HNFPCM SPECIMENS

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Fig 31 a: 24% HNFPCM 10X

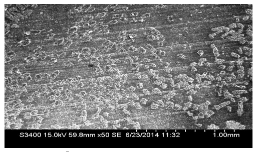

Fig 31 b: 24% HNFPCM 50X

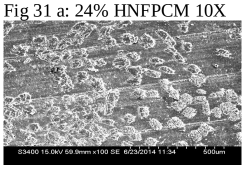

Fig 31 c: 24% HNFPCM 100X

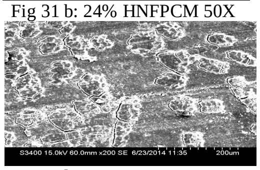

Fig 31 d: 24% HNFPCM 200X

Fig 31: SEM FOR 24% HNFPCM SPECIMENS.

SEM FOR 36% HNFPCM SPECIMENS

Fig 32 a: 36% HNFPCM 10X

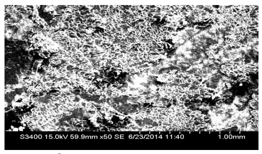

Fig 32 b: 36% HNFPCM 50X

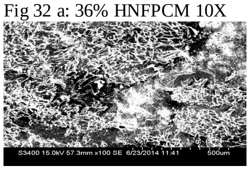

Fig 33 c: 36% HNFPCM 100X

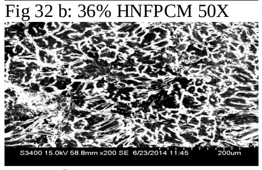

Fig 33 d: 36% HNFPCM 200X

Fig 33: SEM FOR 36 % HNFPCM SPECIMENS.

From above all the Figures 8.1, 8.2 and 8.3 shows the SEM micrographs for the 12%, 24% and 36% HNFPCM specimens respectively. SEM analysis indicates that there is good bonding between the three Natural fibers and matrix material in 36% HNFPCM specimens when it is compared with the 12% and 24% HNFPCM specimens. Therefore the strength of the 36% HNFPCM specimens much higher than the 12% and 24% HNFPCM specimens. Hence 36% Hybrid Natural fibers Polymer Composite Material can be used as the alternative material for Human Orthopaedic Implants.

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