Investigation on Wear Behavior of Natural Fiber Reinforced Polymer Composite Materials

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***Abstract*—In the area of medical field, requirement of alternative materials to manufacture orthopaedic implants having more scope. In this Project work the polymer based natural fibre reinforced composite materials with different weight fraction of fibres are developed and characterized. By considering the Rule of mixture, different weight fraction of Epoxy Resin LY556 as a Matrix material, LY95l as Hardener with Kenaf and Hemp as a natural fibre reinforced materials Hybrid composite material is developed with addition of 5% filler material Al_2O_3 by Hand Lay-up Technique. In this Project work the Wear and Surface Roughness are evaluated. Experimentations are conducted as per biomaterials ASTM standards to ensure the requirements of the implant material. As a result of this Project work, polymer based natural fibre reinforced composite with 24% Hybrid fiber (Kenaf & Hemp) filled with 5% Al_2O_3 composite material fabricated by vacuum bag Molding technique is showing very good mechanical properties among the other specimens. Thus, in this Project work, suggests the above mentioned 24% Hybrid fiber (Kenaf & Hemp) filled with 5% Al_2O_3 composite material as an alternative implant material for trabecular bone of femur bone and other orthopaedic implants.**

Keywords— Natural Fibers, Al_2O_3, Wear Test, Design of Experiments.

I. INTRODUCTION

In growing demand to meet the industrial needs for satisfying applications to bridge the various operations, the technology in unearthing the newer and their combinations of materials will have a prominent and vital role to assure for successful functioning. Currently Industries are focusing upon choosing the consistent and suitable materials for their specific services considering technically benefit able aspects in terms of both effectiveness and suitable application. Composites are generally known process for materials combination and their successful blending to extract the required application in various fields like automobile, aerospace, defence, medical, Etc., [1]. Composite oriented materials have entered into the expanded fields yielding attractive results in connection with satisfying serviceable products by various processes. In research fields composite materials are in great demand for innovative material combination for successful scope in the respective areas of investigations [2]. Now-a-days NFRPC is widely adopted in various fields because of its ample advantages. The primary reason for choosing these materials is because of its eco-friendly nature, recyclability and biodegradability [3]. NFRPC are chosen to use in the various manufacturing industries like automobile, medical, household appliances etc. natural fiber is referred to the fibers which are extracted from natural resources like plant [4]. Natural fibers exhibit stronger properties when compared with the artificial fibers. Low density, low weight, eco-friendly nature is some of the dynamic properties of natural fiber [5].

II. LITERATURE SURVEY

D Chandramohan They suggested to use the benefits provided by the renewable resources & their application in the stream of orthopaedic because NFRPC (Natural fiber reinforced polymer composite) plates will have faster fracture healing capacity and they provide suitable environment for the growth of the bone which results in increasing bone density [6]. Ribot et.al they came to know that the kenaf base fiber has got more strength than the natural fibers like jute, sisal etc. The kenaf fiber has got tensile strength of rage 400-550Mpa. So, the kenaf fiber will fall into the group of good reinforcement material, hence in polymer composite material it can be used as reinforcement material and it has got all the required properties [7]. Giuseppe Cristaldi et.al during their research on composite material they concentrated on the natural fibers and their uses, and they chose it has reinforcement material in composite. Most of the researchers will employee this as reinforcement because of their environmental and cost-effective property. Even it has got his own limitation and which need to be overcome for proper utilization of this [8]. Hajnalkahargitai et.al on his work and as well as by considering the mechanical test it is concluded that 40-50% of hemp fiber is optimum and dry composite samples has got fewer bending properties than the wet sample [9]. Girisha.C et.al while carrying their research work, the investigation is carried out on the composite which are fabricated with sisal, coconut spat as reinforcing material for testing the tensile properties. The alkali treatment is carried out on the natural fibers which are extracted by manual as well as retting process. Composite with a reinforcement of natural fiber of individual type shows less tensile strength when compared to reinforcement of hybridization type [10]. H G Hanumantharaju et.al from his research work he concluded that the alumina can be used as substitute material for bone in the field of orthopaedic based on the following consequence's i.e., the density and as well as the mechanical property of the Ti-6Al-4V is less and better than SS316L respectively. If we considered the test like wear test alumina exhibit less weight loss than the SS316L. In case of weight SS316L is more weight when compare to the alumina. It also exhibits low material density [11]. Mohammed Haneef et.al they have concluded that if the percentage of reinforcement increases in the hybrid polymer composite, then there will be increase in the strength like hardness, tensile and bending. The density of hybrid polymer composite also increases. If the TiO_2 and Al_2O_3 used along with the polymer matrix composite will have plenty of utilization in the human body [12]. Ramesh K et.al for the improvement of mechanical property they have used the Al_2O_3, SiO_2 and TiO_2 for modifying the matrix. Hand lay-up method is used for the manufacturing of composite material. The other micro modifiers will exhibit less ILSS, flexural strength and modulus when compared with the SiO_2 modified epoxy composite [13]. Rajesh et .al with the various proportion of SiC and Al_2O_3 with GFRP by using the silicon carbide and aluminum oxide they have manufactured the composite with epoxy and polyester resin. To identify the properties of composites which are fabricated the various tests are conducted like shear bi axial, tensile, impact etc. finally they arrived to a conclusion that the polyester resin composite will show less strength when compare to the epoxy resin composite [14]. Pavan kumar.et.al they carried a research work to study the GFRP mechanical properties with the white cement as filler material by varying its weigh percentage like 0,5,10wt% by hand layup fabrication method. The specimens were prepared according to the standards (ASTM) and later they are subjected to the various tests. Upon conducting the test, they arrived to the conclusion that the filler material (white cement) also influences the mechanical properties of composite such as flexure and tensile strength [15].

III. METHODOLOGY

Characterization is carried out using Epoxy resin as a matrix material & hardener with (12, 18, 24%) Natural fibers as the reinforcement the specimens are prepared along with Al_2O_3 as filler material [16], the samples are done as per ASTM using hand lay-up technique and finally concluding the results.

IV. MATERIALS USED AND ITS PROPERTIES.

A. *Kenaf*

The main use of this fiber is during the recycling of papers, we can recycle the papers only one or two times after that fiber become too short so they cannot be recycled further. But by mixing recycling papers with fibers coming from kenaf will increases the number of recycling frequency.

B. *Hemp*

Hemp Crete wall has capability to regulate the temperature and humidity inside the structure and it also resists fire mold and vermin and eliminates the needs for the vapour barrier and gypsum drywall. Another big advantage of hemp Crete is that its environmentally friendly. It's a pretty flexible material to work with and it takes the shape of the form work into which it is poured so that you can create curved walls [16].

C. *Aluminium oxide*

The chemical formula of aluminium oxide is Al_2O_3. Alumina is most commonly used name. it has other name like aloxite, oralundum, which depends upon the application in which it is used. Aluminium oxide is associated with strongest bonding between the atoms.it is associated with high strength (compressive). The most important property which plays prominent role in this is its Hardness about 15 to 19 GPa.

D. *Epoxy Resin*

There are 3 main types of resin used to prepare composites i.e., polyester, vinyl ester and epoxy. Each type of this offers unique benefits and drawbacks that must be considered when selecting resin. Most epoxy resins can be post cured with heats to improve their strength service, temperature and dimensional stability, because heat causes post curing parts should be cured or post cured at a temperature that matches or exceeds their expected maximum temperature prior to being put in service. If an epoxy part or mold is subjected to a service temperature higher than it was cured it can distort or wrap [16].

V. EXPERIMENTAL TESTING

A. *Wear Test*

Wear Test Wear test have been conducted under different operating conditions like applied load, 20N, 40N and 60N and sliding speeds 1-m/s, 2-m/s and 3-m/s and 12%, 18%, 24% Natural Fibers Reinforcement. This test method covers a laboratory procedure for determining the wear of materials during sliding using a pin-on-disk apparatus model TR20LE supplied by DUCOM, material characterization systems is showed in figure 4.1 and is issued under the standard ASTM G-99. Average surface roughness (Ra) in micrometers or microns (μm) were recorded by using Surface roughness tester SJ201 in order to analyze the influence of the friction and wear behavior. A roughness tester is used to quickly and accurately determine the surface texture or surface roughness of a material.

Fig 5.1. Wear Testing Machine.

For the pin-on-disk wear test conducted in this research, the specimens were a pin, which is positioned perpendicular to a flat circular rotating disk. The sliding path is a circle on the surface. The pin is pressed against the disk at a specified load usually by means of an arm or lever and attached weights. The friction coefficient signal is displayed in real time on a monitor. Data can be viewed as it is logged for the entire specified test duration, which can be recalled later for detailed analysis. ASTM G-99 Instrumented & data Acquisition system for the measurement. Results of different tests can be superimposed for comparative viewing, Data can be exported to other software, Dead weight loading, Electrical contact resistance measurement, Displays Load, Friction, speed on the display panel, Auto on/off (timer).

B. Surface Roughness Tester

Fig 5.2. Surface Roughness Tester.

C. Design of Experiments

The key confidence of Taguchi's methodology was the use of a parameter design that specifies the parameter settings that generate the best quality characteristics with minimal variance. Taguchi's methodology was ideally suited to engineering problems. This technique acquires data in a controlled manner through a limited number of experiments, indicating the exact nature of the procedure. Based on the number of variables, interactions and their degree, an orthogonal array was chosen. The Taguchi approach is based on the signal-to-noise (S/N) ratio as the consistency characteristic of choice. Experiments were performed to investigate the effect of test parameters on workpieces made of Natural Fiber Reinforced Polymer Composites on volumetric wear, frictional force, coefficient of friction and surface roughness. Code and control parameter values are shown in the Table 1.1. This indicates that the experimental plan had three stages. Using Minitab 18, the effect on wear of control parameters such as applied load (L), sliding speed (S) and percent fiber content (F) was measured using a S/N response analysis. The analysis is carried out using lower-the-better criterion and the same is expressed as

$$\eta = -10 log_{10} \sum \frac{y^2}{n}$$

Table 5.1 . Process parameters with their values at three levels.

Factors	Control Parameters	Units	Level 1	Level 2	Level 3
A	Load (L)	N	20	40	60
B	Sliding Speed (S)	m/s	1	2	3
C	Fiber (F)	%	12	18	24

Here, is 'y' the experimental data and is 'n' the number of experiments. The experimental design being orthogonal, it is possible to separate out the effect of each control factor at different levels. The experimental findings are translated into a signal-to-noise (S/N) ratio by the Taguchi process. As a matter of fact, the smaller the better-quality characteristics, the Volumetric rate of wear, the frictional force, the friction coefficient and the surface roughness were examined and analyzed in relation to natural fiber reinforced polymer composites.

The ratio of S/N for each stage of the process parameters is calculated on the basis of an analysis of S/N. And therefore, it was determined that a statistical analysis of variance should be performed in order to observe the differences between these parameters. The optimal test conditions for these control variables could be easily determined from the response graphs. The graphs demonstrate the change in the S/N ratio as the setting of the control factors has changed from one point to another. The maximum S/N values in the response graphs were the best rate of wear, frictional force, friction coefficient and surface roughness. Wear Test Specimens are prepared according to ASTM Standard G-99, as in this research wear testing is conducted for specimens made by hand layup and Vacuum bag Molding method of fabrication for preparation of natural fiber polymer composites materials. As a matter of this, the testing samples are prepared in flat shape shown in figure 3 and the dimensions 30x10x03 mm.

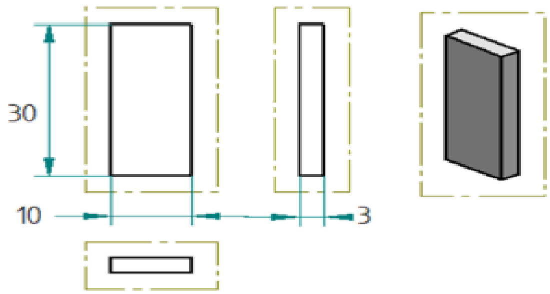

Fig 5.3. Wear Testing Specimen Dimensions.

VI. RESULTS AND DISCUSSION

6.1 Wear Test S/N ratio Results for Kenaf - Al_2O_3 Polymer Composites by Hand Layup Technique.

The table (6.1) represents Standard Taguchi Experimental Strategy with L_9 Notation and its evaluated S/N ratios results are presented in table (6.2) for Volumetric Wear Rate, Frictional power, Coefficient of friction and surface roughness for Kenaf - Al_2O_3 reinforced polymer composites by hand layup technique. Setting process parameters with the maximum S/N ratio often provides the optimal output with the least variance.

Table 6.1: Taguchi L_9 Orthogonal Strategy for Kenaf - AL_2O_3 polymer composites.

L_9 Test	Sliding Speed S (m/s)	Load L (N)	Fiber F (%)	Volumetric Wear Rate V_w (mm^3/m)	Frictional Force F (N)	Co-efficient of friction COF	Surface Roughness R_a (µm)
1	1	20	12	0.0006	8.54	0.43	4.15
2	2	20	18	0.0014	8.94	0.45	3.82
3	3	20	24	0.0012	8.63	0.43	3.38
4	1	40	18	0.0012	18.07	0.45	4.65
5	2	40	24	0.0007	19.66	0.49	2.79
6	3	40	12	0.0016	26.93	0.67	2.92
7	1	60	24	0.0009	28.21	0.47	2.32
8	2	60	12	0.0019	37.92	0.63	3.76
9	3	60	18	0.0022	41.29	0.69	2.59

Table 6.2: S/N Ratios of Wear Test for Kenaf - AL_2O_3 polymer composites.

L_9 Test	SN ratio for Volumetric Wear Rate V_w (db)	SN ratio for Frictional Force F (db)	SN ratio for Co-efficient of friction COF (db)	SN ratio for Surface Roughness R_a (db)
1	65.17463173	-18.62915741	7.391442499	-12.36793575
2	56.77739319	-19.02675038	6.993849537	-11.64884326
3	58.16807548	-18.72021591	7.300383999	-10.57833401
4	58.25668476	-25.13916305	6.902036775	-13.35528327
5	63.06676806	-25.87167027	6.169529557	-8.901700454
6	56.00017627	-28.60472707	3.436472758	-9.317566773
7	60.61907999	-29.00806172	6.554963285	-7.322230468
8	54.21386253	-31.57736657	3.985658434	-11.49605323
9	52.97556925	-32.31689766	3.24612735	-8.254809331

As shown in the table (6.3), the control factor with the greatest effect is defined by the value of 'Δ' (delta). For a given control factor, Delta equals the difference between maximum and minimum S/N ratios. The greater the delta's value, the stronger the control factor. Control variables and their relations have been sorted for delta values.

Table 6.3: Response table for Kenaf - AL_2O_3 polymer composites.

Table 6.3a: Volumetric Wear Rate V_w

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	60.04	61.35	58.46
2	59.11	58.02	56.00
3	55.94	55.71	60.62
Delta	4.10	5.64	4.61
Rank	3	1	2

Table6.3b: Frictional Force F

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	-18.79	-24.26	-26.27
2	-26.54	-25.49	-25.49
3	-30.97	-26.55	-24.53
Delta	12.18	2.29	1.74
Rank	1	2	3

Table 6.3c: Co-efficient of friction CoF

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	7.229	6.949	4.938
2	5.503	5.716	5.714
3	4.596	4.661	6.675
Delta	2.633	2.288	1.737
Rank	1	2	3

Table 6.3d: Surface Roughness Ra

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	-11.532	-11.015	-11.061
2	-10.525	-10.682	-11.086
3	-9.024	-9.384	-8.934
Delta	2.507	1.632	2.152
Rank	1	3	2

It can be seen that the greatest impact was exerted by the sliding speed, fiber percent and load for the volumetric wear rate table (6.3a). For friction force table (6.3b) load, sliding speed and fiber percent. For coefficient of friction table (6.3c) load, sliding speed and fiber percent. For surface roughness table (6.3d) load, fiber percent and sliding speed.

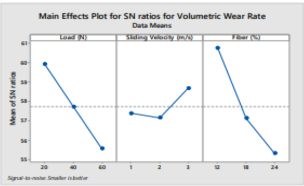

Figure 6.2a: Volumetric Wear Rate.

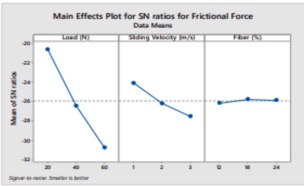

Figure 6.2b: Frictional Force.

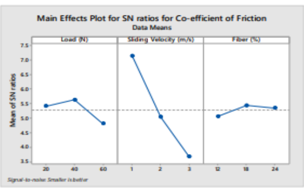

Figure 6.2c: Coefficient of Friction.

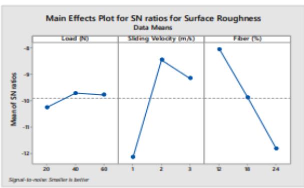

Figure 6.2d: Surface Roughness.

Figure 6.2: Image of plots of Main Effect for S/N ratios for Hemp - Al2O3 polymer composites.

Figures (6.2) for Hemp - Al_2O_3 reinforced polymer composites by hand layup technique indicates the main effect plots S/N ratios and optimum condition for the tested samples are $A_1B_3C_1$ for volumetric wear rate (Figure 6.2a), $A_1B_1C_2$ for friction strength (Figure 6.2b), $A_2B_1C_2$ for friction coefficient (Figure 6.2c) and A2B2C1 for surface roughness (Figure 6.2d). The higher the ratio of S/N, the lower the variance with the desired values of the volumetric wear rate, the frictional force, the friction coefficient and the roughness of the surface.

6.2 Wear Test S/N ratio Results for Hemp - Al_2O_3 Polymer Composites by Hand Layup Technique.

The table (6.4) represents Standard Taguchi Experimental Strategy with L_9 Notation and its evaluated S/N ratios results are presented in table (6.5) for Volumetric Wear Rate, Frictional power, Coefficient of friction and surface roughness for Hemp - Al_2O_3 reinforced polymer composites by hand layup technique. Setting process parameters with the maximum S/N ratio often provides the optimal output with the least variance.

Table 6.4: Taguchi L_9 Orthogonal Strategy for Hemp - AL_2O_3 polymer composites.

L_9 Test	Sliding Speed S (m/s)	Load L (N)	Fiber F (%)	Volumetric Wear Rate V_w (mm^3/m)	Frictional Force F (N)	Co-efficient of friction COF	Surface Roughness R_a (μm)
1	1	20	12	0.0007	8.94	0.45	3.69
2	2	20	18	0.0012	10.29	0.51	2.39
3	3	20	24	0.0012	13.46	0.67	3.93
4	1	40	18	0.0015	17.47	0.44	4.16
5	2	40	24	0.0017	21.44	0.54	3.50
6	3	40	12	0.0009	24.50	0.61	1.97
7	1	60	24	0.0024	26.26	0.44	4.33
8	2	60	12	0.0013	38.24	0.64	2.22
9	3	60	18	0.0015	40.92	0.68	3.05

Table 6.5: S/N Ratios of Wear Test for Hemp - AL_2O_3 polymer composites.

L_9 Test	SN ratio for Volumetric Wear Rate V_w (db)	SN ratio for Frictional Force F (db)	SN ratio for Co-efficient of friction COF (db)	SN ratio for Surface Roughness R_a (db)
1	63.03652302	-19.02675038	6.993849537	-11.33267744
2	58.30415352	-20.2483075	5.772292418	-7.555835352
3	58.37889676	-22.5809012	3.439698716	-11.88048071
4	56.71430577	-24.8458581	7.195341727	-12.38882367
5	55.20086902	-26.62449562	5.416704206	-10.88136089
6	61.27458789	-27.78332169	4.257878139	-5.874615138
7	52.40439517	-28.38589444	7.177130573	-12.72306875
8	57.93441258	-31.65035767	3.912667336	-6.914007812
9	56.35608016	-32.2387125	3.324312507	-9.695484379

As shown in the table (6.6), the control factor with the greatest effect is defined by the value of 'Δ' (delta). For a given control factor, Delta equals the difference between maximum and minimum S/N ratios. The greater the delta's value, the stronger the control factor. Control variables and their relations have been sorted for delta values.

Table 6.6: Response table for Hemp - AL_2O_3 polymer composites.

Table 6.6a: Volumetric Wear Rate V_w

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	59.91	57.39	60.75
2	57.73	57.15	57.12
3	55.56	58.67	55.33
Delta	4.34	1.52	5.42
Rank	2	3	1

Table 6.6b: Frictional Force F

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	-20.62	-24.09	-26.15
2	-26.42	-26.17	-25.78
3	-30.76	-27.53	-25.86
Delta	10.14	3.45	0.38
Rank	1	2	3

Table 6.6c: Co-efficient of friction CoF

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	5.402	7.122	5.055
2	5.623	5.034	5.431
3	4.805	3.674	5.345
Delta	0.819	3.448	0.376
Rank	2	1	3

Table 6.6d: Surface Roughness Ra

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	-10.256	-12.148	-8.040
2	-9.715	-8.450	-9.880
3	-9.778	-9.150	-11.828
Delta	0.541	3.698	3.788
Rank	3	2	1

It can be seen that the greatest impact was exerted by the fiber percent, load and sliding speed for the volumetric wear rate table (6.6a). For friction force table (6.6b) load, sliding speed and fiber percent. For coefficient of friction table (6.6c) sliding speed, load and fiber percent. For surface roughness table (6.6d) fiber percent, sliding speed and load.

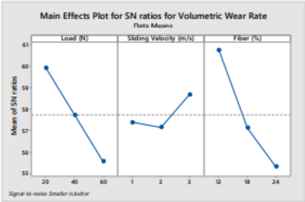

Figure 6.2a: Volumetric Wear Rate.

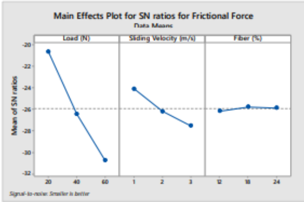

Figure 6.2b: Frictional Force.

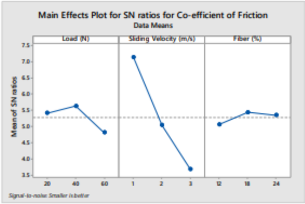

Figure 6.2c: Coefficient of Friction.

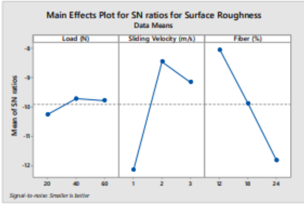

Figure 6.2d: Surface Roughness.

Figure 6.2: Image of plots of Main Effect for S/N ratios for Hemp - Al2O3 polymer composites.

Figures (6.2) for Hemp - Al_2O_3 reinforced polymer composites by hand layup technique indicates the main effect plots S/N ratios and optimum condition for the tested samples are A1B3C1 for volumetric wear rate (Figure 6.2a), $A_1B_1C_2$ for friction strength (Figure 6.2b), $A_2B_1C_2$ for friction coefficient (Figure 6.2c) and $A_2B_2C_1$ for surface roughness (Figure 6.2d). The higher the ratio of S/N, the lower the variance with the desired values of the volumetric wear rate, the frictional force, the friction coefficient and the roughness of the surface.

6.3 Wear Test S/N ratio Results for Hybrid (Kenaf & Hemp) - Al_2O_3 Polymer Composites by Hand Layup Technique.

The table (6.7) represents Standard Taguchi Experimental Strategy with L_9 Notation and its evaluated S/N ratios results are presented in table (6.8) for Volumetric Wear Rate, Frictional power, Coefficient of friction and surface roughness for Hybrid (Kenaf & Hemp) - Al_2O_3 reinforced polymer composites by hand layup technique. Setting process parameters with the maximum S/N ratio often provides the optimal output with the least variance.

Table 6.7: Taguchi L_9 Orthogonal Strategy for Hybrid (Kenaf & Hemp) - AL_2O_3 polymer composites.

L_9 Test	Sliding Speed S (m/s)	Load L (N)	Fiber F (%)	Volumetric Wear Rate V_w (mm^3/m)	Frictional Force F (N)	Co-efficient of friction COF	Surface Roughness R_a (µm)
1	1	20	12	0.0006	7.89	0.39	4.83
2	2	20	18	0.0010	8.01	0.40	4.58
3	3	20	24	0.0004	8.88	0.44	2.65
4	1	40	18	0.0009	18.06	0.45	3.10
5	2	40	24	0.0007	18.90	0.47	2.83
6	3	40	12	0.0012	23.90	0.60	2.28
7	1	60	24	0.0006	27.64	0.46	2.18
8	2	60	12	0.0014	38.07	0.63	1.50
9	3	60	18	0.0014	39.06	0.65	2.36

Table 6.8: S/N Ratios of Wear Test for Hybrid (Kenaf & Hemp) - AL_2O_3 polymer composites.

L_9 Test	SN ratio for Volumetric Wear Rate V_w (db)	SN ratio for Frictional Force F (db)	SN ratio for Co-efficient of friction COF (db)	SN ratio for Surface Roughness R_a (db)
1	64.71347788	-17.94154006	8.079059849	-13.68493495
2	59.75370964	-18.07265032	7.947949592	-13.22362887
3	67.2021134	-18.96825932	7.052340598	-8.453984954
4	60.73571366	-25.13435492	6.906844907	-9.827233877
5	63.70021497	-25.52923608	6.511963743	-9.03572871
6	58.25828893	-27.56795802	4.473241808	-7.145988979
7	64.50187609	-28.83076077	6.732264234	-6.769129872
8	56.84562934	-31.61165754	3.951367471	-3.521825181
9	57.25180784	-31.83464478	3.728380229	-7.458240059

As shown in the table (6.9), the control factor with the greatest effect is defined by the value of 'Δ' (delta). For a given control factor, Delta equals the difference between maximum and minimum S/N ratios. The greater the delta's value, the stronger the control factor. Control variables and their relations have been sorted for delta values.

Table 6.9: S/N Ratios of Wear Test for Hybrid (Kenaf & Hemp) - AL_2O_3 polymer composites.

Table 6.9a: Volumetric Wear Rate V_w

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	63.89	63.32	59.94
2	60.90	60.10	59.25
3	59.53	60.90	65.13
Delta	4.36	3.22	5.89
Rank	2	3	1

Table 6.9b: Frictional Force F

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	-18.33	-23.97	-25.71
2	-26.08	-25.07	-25.01
3	-30.76	-26.12	-24.44
Delta	12.43	2.15	1.26
Rank	1	2	3

Table 6.9c: Co-efficient of friction CoF

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	7.693	7.239	5.501
2	5.964	6.137	6.194
3	4.804	5.085	6.766
Delta	2.889	2.155	1.264
Rank	1	2	3

Table 6.9d: Surface Roughness Ra

Level	Load (L)	Sliding Speed (S)	Fiber (F)
1	-11.788	-10.094	-8.118
2	-8.670	-8.594	-10.170
3	-5.916	-7.686	-8.086
Delta	5.871	2.408	2.083
Rank	1	2	3

It can be seen that the greatest impact was exerted by the fiber percent, load and sliding speed for the volumetric wear rate table (6.9a). For friction force table (6.9b) load, sliding speed and fiber percent. For coefficient of friction table (6.9c) load, sliding speed and fiber percent. For surface roughness table (6.9d) load, sliding speed and fiber percent.

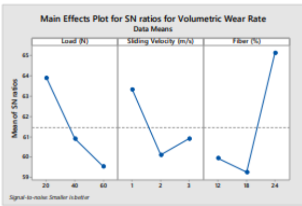

Figure 6.3a: Volumetric Wear Rate.

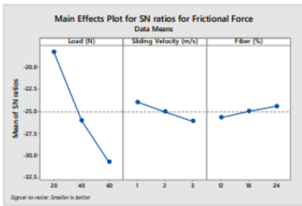

Figure 6.3b: Frictional Force.

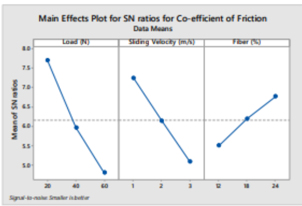

Figure 6.3c: Coefficient of Friction.

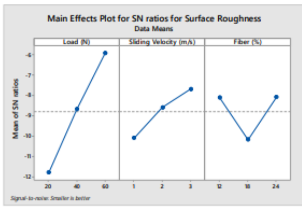

Figure 6.3d: Surface Roughness.

Figure 6.3: Image of plots of Main Effect for S/N ratios for Hybrid (Kenaf & Hemp) - Al_2O_3 polymer composites.

Figures (6.3) for Hybrid (Kenaf & Hemp) - Al_2O_3 reinforced polymer composites by hand layup technique indicates the main effect plots S/N ratios and optimum condition for the tested samples are A1B1C3 for volumetric wear rate (Figure 6.3a), $A_1B_1C_3$ for friction strength (Figure 6.3b), $A_1B_1C_3$ for friction coefficient (Figure 6.3c) and $A_3B_3C_3$ for surface roughness (Figure 6.3d). The higher the ratio of S/N, the lower the variance with the desired values of the volumetric wear rate, the frictional force, the friction coefficient and the roughness of the surface.

VII. CONCLUSIONS

Natural Fiber Reinforced Composite Materials contribution as bone implants. The natural fibers used for research work is Hemp, Kenaf and Hybrid (Hemp and Kenaf) with Al_2O_3 as filler materials. Bio-Composites were prepared by using Epoxy resin (LY556) as a matrix material and hardener (HY951) with 12%, 18% and 24% by using Kenaf, Hemp and Hybrid (Hemp and Kenaf) by using Hand Layup Technique.

It is observed that Hemp fiber reinforced composites set of specimens have more volumetric wear rate, less for kenaf reinforced composites and least for hybrid composites. For Hemp set of composites, the volumetric wear rate is more due to less mechanical properties when it is compared with Kenaf and Hybrid, whereas in kenaf reinforced fiber, the volumetric wear rate is reduced but the corresponding values are little higher than hybrid reinforced composites.

It is observed that for sliding speed with 1-m/s and 2-m/s under lower applied load, the volumetric wear rate is almost minimum for all set of specimens. The same is not true under high loads. Under high loads the amount of material removal from wearing surface is more whereas the same is low for lower applied load. It is observed that frictional force for hybrid is less when compared to the kenaf and hemp fibers.

REFERENCES

[1] Sonar T, Patil S, Deshmukh V, Acharya R 2015 Natural fiber reinforced polymer composite material-A review IOSR Journal of Mechanical and Civil Engineering 4 pp 142-147

[2] Virupaksha Gouda H, S Channabasavaraj, A Thimmana Goud, S P Jagadish 2017 Natural Fibers Reinforced Polymer Composite Materials – A Review International Journal of Scientific Research and Review 7(5) pp 119-129

[3] Raviraj Havaldar, S C Pilli, B B Putti 2013 Effects of Magnesium on Mechanical Properties of Human Bone IOSR Journal of Pharmacy and Biological Sciences 7(3) pp 08-14

[4] A Thimmana Gouda, Jagadish S P, K R Dinesh, Virupaksha Gouda H, N Prashanth 2014 Characterization and Investigation of Mechanical Properties of Hybrid Natural Fiber Polymer Composite Materials Used as Orthopaedic Implants for Femur Bone Prosthesis IOSR Journal of Mechanical and Civil Engineering 11(4) pp 40-50

[5] Raviraj Havaldar, S C Pilli, B B Putti 2012 Effects of Ageing on Bone Mineral Composition and Bone Strength IOSR Journal of Dental and Medical Sciences 1(3) pp 12-16

[6] D Chandramohan and K Marimuthu 2011 Bio Composite Materials Based on Bio Polymers and Natural Fibers Contribution as Bone Implants International Journal of Advanced Medical Sciences and Applied Research 1(1) pp 009-012

[7] Ribot, N M H., Ahmad, Z., Mustaffa, N.K. 2011 Mechanical Properties of Kenaf Fiber Composite Using Co- Cured In-Line Fiber Joint International Journal of Engineering Science and Technology 3(4) pp 3526-3534

[8] Gianluca Cicala, Giuseppe Cristaldi, Giuseppe Recca and Alberta Latteri 2010 Composites Based on Natural Fibre Fabrics Book on Woven Fabric Engineering Chapter 17 pp 317- 342

[9] Hajnalka Hargitai, Ilona Ra. CZ and Rajesh D Anandjiwala 2008 Development of Hemp Fiber Reinforced Polypropylene Composites Journal of Thermoplastic Composite Materials 21(2) pp 165-174

[10] Girisha C., Sanjeevamurthy and Gunti Rangasrinivas 2012 Mechanical Performance of Natural Fiber-Reinforced Epoxy Hybrid Composites International Journal of Engineering Research and Applications 2(5) pp 615-619

[11] H G Hanumantharaju, H K Shivananda, Manjunath G Hadimani, K Suresh Kumar, S P Jagadish 2012 Wear Study on SS316L, Ti-6Al-4V, PEEK, Polyurethane and Alumina used as Bio-Material International Journal of Emerging Technology and Advanced Engineering 2(9) pp 296-300

[12] Mohammed Haneef, J Fazlur Rahman, Mohammed Yunus, Syed Zameer, Shanawaz Patil and Tajuddin Yezdani 2013 Hybrid Polymer Matrix Composites for Biomedical Applications International Journal of Modern Engineering Research 3(2) pp 970-973

[13] Ramesh K. Nayak, Alina Dash and B C Ray 2014 Effect of epoxy modifiers (Al_2O_3/SiO2/TiO2) on mechanical performance of epoxy/glass fiber hybrid composites Procedia Materials Science 6 pp 1359-1364

[14] S Rajesh, B Vijaya Ramnath, C Elanchezhian, N Aravind, V Vijai Rahul, S. Sathish 2014 Analysis of Mechanical Behaviour of Glass Fibre/ Al_2O_3- SiC Reinforced Polymer composites Procedia Engineering 97 pp 598-606

[15] N Pavan Kumar, D Harsha Vardhan, B Anjaneyulu 2017 Fabrication and Experimental Study of Mechanical Properties of GFRP with White Cement as Filler Material International Research Journal of Engineering and Technology 4(2) pp 1781-1783

[16] A Thimmana Gouda, Jagadish S P, K R Dinesh, Virupaksha Gouda H, N Prashanth 2014 Wear Study on Hybrid Natural Fiber Polymer Composite Materials Used as Orthopaedic Implants International Journal of Recent Development in Engineering and Technology 3(1) pp 25-33