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WEAR BEHAVIOR ON HYBRID COMPOSITE MATERIAL USING PRINCIPAL COMPONENT ANALYSIS

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ABSTRACT

Present work progress a methodology to fabricate a composite material with isotropic material such as jute and chopped e-glass materials to analyze its wear and coefficient of friction using Pin-on-Disc testing method and comparing the results with Principal Component Analysis.It is observed that an improvement in the wear resistance and frictional behavior of the epoxy with the addition of Jute, Chopped E-Glass and Jute with Chopped e-Glass with 0 grams Aluminum gives low wear rate and it is suitable for high wear resistance

Keywords: Hybrid composite, wear test, coefficient of friction, Principal Component Analysis.

1. INTRODUCTION

Composite material is a combination of two or more materials; the materials may be natural or synthetic in this work, hybrid composite material which is formed by the combination of the natural and the synthetic material. Jute is used as a natural fiber and Chopped e-glass as a synthetic fiber. By using hand lay-up technique is used to prepare the composite material and wear rate can be determined by using dry sliding wear testing machine.

2. LITRATURE REVIEW

M. Sudheera. et al. (2014). [1] used the Epoxy/glass composite containing two different micro-fillers was developed by vacuum bagging technique. The effect of ceramic whisker (7.5 wt%) and solid lubricant filler (2.5 wt%) on mechanical and dry sliding wear behavior of epoxy/glass composites was studied. The mechanical property characterization included evaluations of tensile, flexural and impact properties as per ASTM standards. The dry sliding wear tests were conducted on pin-on-disc arrangement with steel disc as counter face. Siddesh Kumar N G et al. (2014). [2].in their paper evaluate the microstructure, density, micro-hardness, tensile and dry sliding wear test. The result reveal that, the reinforcement particles are randomly & fine dispersed in matrix alloy as seen in microstructure. The density and micro-hardness of A12219 alloy is relatively low as compared to hybrid composite. A. G. Wang. et al.(2013). [3] worked on the wear resistance of the composites was found to range from almost two to six times that of the unreinforced matrix alloy. A transition in wear behavior was found for the various sizes of abrasive particle. With small particles, the wear resistance of the composite increased with increasing fibre volume fraction and the worn surfaces were relatively smooth.Dr A Thimmana Gouda, Jagadish S P, Dr K R Dinesh, Virupaksha Gouda H, Dr N Prashanth.(2014). [4] Presents a 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 behavior of long human bones, such as Femur Bone.Gun Y. Leea et al. [5] in their paper, A simple physically-based model for the abrasive wear of composite materials is presented based on the mechanics and mechanisms associated with sliding wear in soft (ductile)- matrix composites containing hard (brittle) reinforcement particles. The model is based on the assumption that any portion of their reinforcement, that is removed as wear cannot contribute to the wear resistance of the matrix material. Hasan Muhandes, Gábor Kalácska, Nawar Kadi and Mikael Skrifvars[6] in their paper gives five types of composite materials which are suggested to replace these steel parts. The materials choosen are ESD PA6 G, HD1000, PA6E, PA6G and PA66GF30 as test materials and two kinds of testing methods were done to test these materials. First one is a pin-on-plate test with sliding abrasive clothes, the second one is a sand slurry test which uses standard abrasive particles.Indu Sekhar R. et al. [7] in their paper suggest that hybrid composites concept allows the possibility of use of these materials for high end applications where in the materials are with stand to high temperature, higher normal load, pressure and sliding condition. T R Hemanth Kumar, R.P.Swamy&T.K Chandra Sekhar [8] paper study and evaluate the influence of wear test parameters such as sliding speed and normal load on dry sliding wear performance of Al-Cu-Mg/Titanium dioxide particle reinforced composites.Ramadan J. Mustafa [9] in their paper reports the results of abrasive wear tests on specimens of continuous Silicon Carbide (SiC) and high strength Carbon (H.S.C) fibres reinforced Al(1100) and Al(6061) matrix materials, with 50- 60% fibre volume fraction, and made by matrix fibre coating and hot-consolidation fabrication process.**2.1 .Objectives of the present work:** The objective is to develop a new hybrid fiber reinforced composite by incorporating jute/ chopped e-glass fibers. The present work is expected to satisfy the need of light weight and high wear resistance engineering materials. Fabrication of jute/chopped e-glass Hybrid fiber reinforced epoxy based composite by using hand lay-up technique.

3. METHODOLOGY

Methodology presents the materials and methods used for the fabrication of composites under study. It gives the fabrication and testing of mechanical properties of the composite materials. The steps involved are: 1. Specimen Fabrication by using Hand Lay-Up method.2. Wear Test **3.1 Raw Materials:** Raw materials which are used in this experimental work are: Jute fiber mat,chopped e-glass mat,Epoxy resin,Hardener and Accelerator as shown in Fig.1to 3

Fig.1 Jute FibreMat

Fig.2 Chopped e-Glass Mat

Fig.3 Epoxy Resin & Hardner

3.2 Fabrication of Composite: The composite is prepared by using hand lay-up technique as shown in the below Table.1

Table.1: Type of Composite & Composition	
Type of Composites	Composition
JJJJJ	JJJJJ(23%)+Epoxy (77%)
CECECECECECE	CECECECECECE (40%) + Epoxy (60%)
JCEJCEJCE	JCEJCEJCE(26%)+E-poxy (74%)
JJCEJJCE	JJCEJJCE(26%)+Epo-xy(74%)
JJJCECECE	JJJCECECE (26%) + Epoxy (74%)
JJJJJ+0.75gAluminium	JJJJJJ(18.2%)+Epoxy(80%)+Aluminum (1.8%)
CECECECECECE+0.75gr Aluminium	CECECECECECE (35%) + Epoxy (63%) + Aluminum (2%)
JCEJCEJCE +0.75gr Aluminium	JCEJCEJCE(33.1%)+Epoxy(65.4)+Aluminum (1.5%)
JJCEJJCE+ 0.75gr Aluminium	JJCEJJCE(33.1%)+Ep-oxy(65.4%)+Aluminu-m (1.5%)

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JJJCECECE +0.75gr Aluminium	JJJCECECE(33.1%)+ Epoxy(65.4%)+Alumi-num(1.5%)
JJJJJ+1gr Aluminium	JJJJJJ(19.07%)+Epo-xy(78.5%)+Aluminum (2.43%)
CECECECECECE+1gr Aluminium	CECECECECECE(34.6%)+Epoxy(63.46%)+ Aluminum (1.94%)
JCEJCEJCE +1gr Alumi-nium	JCEJCEJCE(27.6%)+ Epoxy(70.21%)+Alu-minum (2.19%)
JJCEJJCE + 1gr Alumini-um	JJCEJJCE(27.6%)+E-poxy(70.21%)+Alumi-num (1.94%)
JJJCECECE+1gr Aluminum	JJJCECECE (27.6%) + Epoxy(70.21%)+Alu-minium (1.94%)
JJJJJ+2gr Aluminium	JJJJJJ(18.6%)+Epoxy (76.7%)+Aluminium(4.7%)
CECECECECECE+2gr Aluminium	CECECECECECE (34%) + Epoxy (62%) + Aluminium(4%)
JCEJCEJCE+2gr Aluminium	JCEJCEJCE(28%)+E-poxy(68%)+Aluminiu-m(4%)
JJCEJJCE+ 2grAlumini-um	JJCEJJCE(28%)+Epo-xy(68%)+Aluminium (4%)
JJJCECECE +2grAlumin-ium	JJJCECECE(28%)+ Epoxy(68%)+Alumini-um(4%)

3.3Hand Lay-up Technique: The appropriate numbers of fiber plies were taken: three for each. Then the fibers were weighed and accordingly the resin and hardeners were weighed. Epoxy and hardener were mixed by using glass rod in a bowl. Avoid formation of bubbles during the process, because the air bubbles were trapped in matrix may result failure in the material. The subsequent fabrication process consisted of putting a releasing film on the mould surface. A polymer coating was applied on the sheets. Then fiber ply of one kind was put and proper rolling was done. Then resin was again applied, next to it fiber ply of another kind was put and rolled. Rolling was done using cylindrical mild steel rod. This procedure was repeated until four alternating fibers have been laid. On the top of the last ply a polymer coating is done which serves to ensure a good surface finish. Finally a releasing sheet was keep on the top and a light rolling was carried out. Then it was left for 24 hours to allow sufficient time for curing and subsequent hardening as shown in Fig.4

Fig.4 Hand Lay-up techniques of Hybrid composites

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3.4 Preparation of test specimens: A jig saw machine was used to cut each laminate into smaller pieces for wear test. The mechanical testing methods that were carried out were based on American Standard Testing Methods (ASTM) **3.5 Dry-Sliding Wear Testing**: The dry-sliding wear tests are performed on steel counter disc tester as per ASTM G 65 test standards. The schematic diagram of the wear test rig and its setup is shown in Fig.5 to 7.The setup for test is capable of creating a dry-sliding wear environment for analyzing the wear properties of the prepared composites. The apparatus consists of sample holder, nozzle, particle collecting bag, steel disk, and an arrangement for the application of load.

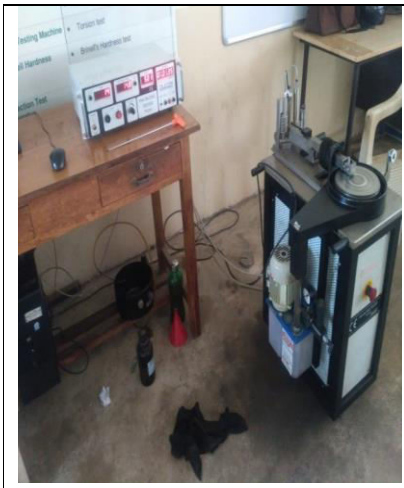		
Fig.5 Pin on Disc Machine	**Fig.6 Dead Weights**	**Fig,7 Pin on Disc**

Samples to be tested are placed in sample holder .The test sample is pressed against wheel at a specified load by means of lever arm .The wheel is allowed to rotate by adjusting the speed .For each test run the samples were cleaned in acetone, dried and weighted before and after the test using a precision electronic balance to an accuracy of ± 0.1 mg. The specific wear rate and friction coefficient values were determined by considering factors like sliding velocity, sliding distance, normal load and fiber loading. The specific wear rate of the sample is calculated using Equation 3.1

$$Ws=\Delta M/\rho \ldots\ldots\ldots\ldots\ldots 3.1$$

Where, ΔM is the mass loss of the sample during the test, ρ is the density of the sample used

3.6 Principal Component Analysis: Principal Component Analysis (PCA) is a dimensional-reduction tool that can be used to reduce a largest set of variables to a small set that still contains most of the information in the large set. Principal Component Analysis (PCA) is a mathematical procedure that transforms a number of correlated variables into a number of un correlated variables called Principal Components. It follows the following steps:

STEP 1: In this step ,collecting data of hybrid composite structures by doing dry sliding wear test.

STEP 2: For PCA to work properly you have to subtract the mean from each of the data dimensions. The mean subtracted is the average across each dimension. From the subtracted mean data the variances will occur.

$$\text{Standard variance - } \sqrt{\sum_{i=1}^{n} \frac{x_i-\bar{x}}{n-1}}$$

$$\mathrm{Cov}[x_1, x_2] - \sum_{i=1}^{n} \frac{(x_i-\bar{x})\,(y_i-\bar{y})}{n-1}$$

STEP 3: Since the dataset we took is 2-dimensional, this will result in a 2x2 Covariance matrix.

$$Matrix(Covariance) = \begin{bmatrix} Var[X_1] & Cov[X_1, X_2] \\ Cov[X_2, X_1] & Var[X_2] \end{bmatrix}$$

Please note that $Var[X_1] = Cov[X_1,X_1]$ and $Var[X_2] = Cov[X_2,X_2]$.

STEP 4: Calculate the eigen values and eigenvectors

Next step is to calculate the eigen values and eigenvectors for the covariance matrix. The same is possible because it is a square matrix. λ is an eigenvalue for a matrix A if it is a solution of the characteristic equation:

$$det(\lambda I - A) = 0$$

Where, I is the identity matrix of the same dimension as A which is a required condition for the matrix subtraction as well in this case and '*det'* is the determinant of the matrix. For each eigenvalue λ, a corresponding eigen-vector v, can be found by solving:

$$(\lambda I - A)v = 0$$

STEP 5: Choosing components and forming a feature vector:

The eigenvalues from largest to smallest so that it gives us the components in order or significance. Here comes the dimensionality reduction part. If a dataset with n variables, then the corresponding n eigenvalues and eigenvectors are required. It turns out that the eigenvector corresponding to the highest eigenvalue is the principal component of the dataset and it is our call as to how many eigenvalues are choosen to proceed our analysis.To reduce the dimensions, choose the first p eigenvalues and ignore the rest. If 2 dimensions in the running example, can either choose the one corresponding to the greater eigen value or simply take both.

$$Feature\ Vector = (eig_1, eig_2)$$

STEP 6: Forming Principal Components:

This is the final step where the principal components using are the transpose of the feature vector and left-multiply it with the transpose of scaled version of original dataset.

$$NewData = FeatureVector^T \ x \ ScaledData^T$$

New Data is the Matrix consisting of the principal components, *Feature Vector* is the matrix we formed using the eigenvectors we chose to keep, and *Scaled Data* is the scaled version of original dataset

4. RESULTS AND DISCUSSION

On successful conducting of experiments, wear and co-efficient of friction are obtained and are tabulated as shown in Table.3

Table.2 Mechanical Properties of a stacking sequence of hybrid composite at 20N load at 500 r.p.m

S. No	Composite Material	Load (N)	Speed (r.p.m)	Sliding Distance (mm)	Wear (μm)	Analytical (PCA) value Wear (μm)
1	JJJJJJJ	20	500	100	10	-1952.41
2	CECECECE CECE	20	500	100	14	-1276.25
3	JCEJCEJCE	20	500	100	30	1428.38
4	JJCEJJCE	20	500	100	32	1766.46
5	JJJCECECE	20	500	100	31	1597.42
6	JJJJJJJ + 0.75gr Aluminium	20	500	100	15	-1107.21
7	CECECECE CECE +0.75gr Aluminium	20	500	100	15	.262.01
8	JCEJCEJCE+ 0.75gr Aluminum	20	500	100	20	245.1

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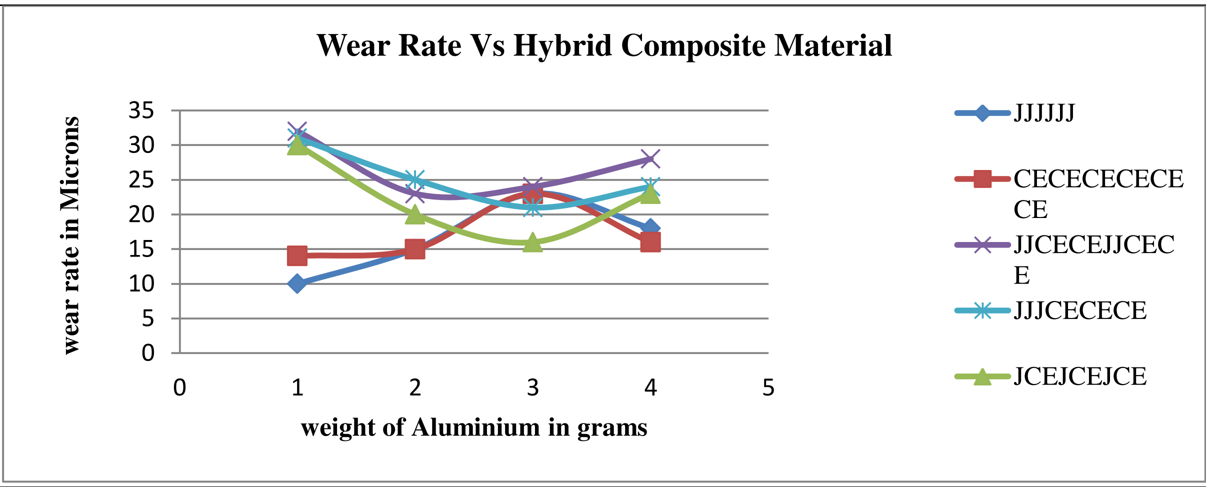
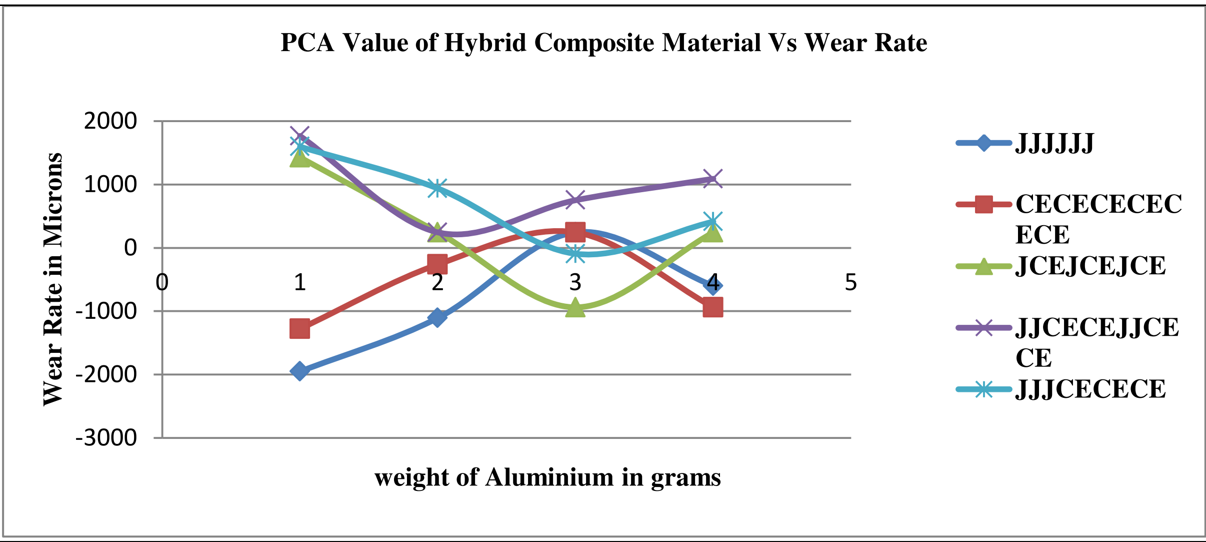
9	JJCEJJCE+ 0.75gr Aluminium	20	500	100	23	245.1
10	JJJCECECE + 0.75gr Aluminium	20	500	100	25	938.17
11	JJJJJJJ + 1gr Aluminium	20	500	100	23	245.1
12	CECECECE CECE + 1gr Aluminium	20	500	100	23	245.1
13	JCEJCEJCE + 1gr Aluminium	20	500	100	16	-938.17
14	JJCEJJCE + 1gr Aluminium	20	500	100	24	752.22
15	JJJCECECE + 1gr Aluminium	20	500	100	21	-92.97
16	JJJJJJJ + 2gr Aluminium	20	500	100	18	-600.09
17	CECECECE CECE + 2gr Aluminium	20	500	100	16	-938.17
18	JCEJCEJCE + 2gr Aluminium	20	500	100	23	245.1
19	JJCEJJCE + 2gr Aluminium	20	500	100	28	1090.3
20	JJJCECECE + 2gr Aluminium	20	500	100	24	414.14

From the above Graph 1and 2 by comparing the results of both experimental and analytical data of hybrid composite material in terms of wear ,on comparison s the graphs are similar to each other as it confirms the validation of experimental and analytical (PCA)method. JJCECEJJCECE at 0gr Aluminum Hybrid composite gives the best result to wear resistance property



Graph.1Experimental Values of Wear Rate Vs Hybrid Composite Material



Graph.2 Analytical(PCA) Values of Wear Rate Vs Hybrid Composite Material

5. CONCLUSION AND FUTURE SCOPE OF WORK

5.1 Conclusions

The study on the mechanical properties of hybrid polymer composites leads to the following conclusions: Fabrication of hybrid polymer composites has been done successfully. Dry-sliding wear study depicted an improvement in the wear resistance and frictional behavior of the epoxy with the addition of Jute, chopped e-Glass and jute+ chopped e-Glass Fibre. Jute at 0 grams Aluminum gives best results for wear resistance and it is suitable for high wear resistance applications

5.2 Scope for Future work

The work can be extended further by considering other methods of composite fabrication and the effect of manufacturing techniques on the performance of composites can similarly be analyzed.

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