International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 05 | May-2016 www.irjet.net p-ISSN: 2395-0072

Mechanical and Sliding Wear Behaviour of E-GLASS Fiber Reinforced with EPOXY Composites

Sikandar Yadav[1], MD. Zyaoul Haque[2], Sunil Kumar[3], Sandeep[4]

[1,2]PG student, Dept. of Mechanical Engineering, MITM, Jevra, Hisar, Haryana, India.
[3,4]Assistant Professor, Dept. of Mechanical Engineering, MITM, Jevra, Hisar, Haryana, India.

Abstract - *Due to increasing demand and widespread application of Fibre reinforced polymer (FRPs) composites, they have been used in a variety of application like aerospace, automotive, sports, ships and constructional work. Because of their several advantages such as relatively low cost of production light weight, easy to fabricate and superior strength to weight ratio. In the present work E-glass fibre is used as reinforcing agent with and without alumina filler. The objective of the present research work is to study the mechanical and abrasive wear behaviour of E-glass fibre reinforced epoxy based composites. The effect of fibre loading and filler content on mechanical properties like tensile strength, flexural strength of composites are studied. A robust design technique called Taguchi method is also used to determine the optimal condition for specific wear rate of the composites by considering different parameters.*

Key Words: ***Coating,*** **E-glass fibre, Epoxy, filler, Taguchi method etc.**

1. INTRODUCTION

A combination of two or more materials with different properties, or a system composed of two or more physically distinct phases separated by a distinct interface whose combination produces aggregate properties that are superior in many ways, to its individual constituents. A new material with combination of two or more material can provide enhanced properties that produce a synergetic effect [1].

In composite materials there are two constituents one is matrix and other is reinforcement. The constituents which is continuous and present in greater quantity is called matrix. The main functions of the matrix is to holds or bind the fibre together, distribute the load evenly between the fibres, protect the fibre from mechanical and environmental damage and also carry inter-laminar shear. While the other constituent is reinforcement; its primary objective is to enhance the mechanical properties e.g. stiffness, strength etc.

1.1 Matrix Materials

The main elements of polymer matrix composite are resin (matrix), reinforcement (e.g. fibre, particulate, whiskers), and the interface between them. The present work deals with the fibre reinforced polymer. FRP's offers significant advantages, like combination of light weight and high strength to weight ratio and it is way easy to fabricate which is better than many metallic components [1].
The matrix of FRPs is further classified into-

I. Thermosetting resin
II. Thermoplastic resin

Thermoset resin (e.g. polyester, vinyl esters and epoxy) undergo chemical reaction that cross link the polymer chain and thus connect the entire matrix into three dimensional network due to this they possesses high dimensional stability, resistance to chemical solvent, and high temperature resistance. On the other hand unlike thermoset, curing process of thermoplastic resin (e.g. polyamide, polypropylene, and polyether-ether-ketone) is reversible. Their strength and stiffness depends on the molecular weight. They are generally inferior to thermoset in case of high temperature, strength, and chemical stability but are more resistant to cracking and impact damage [2].

1.2 Reinforcement Materials

As far we concerned about the reinforcement, there are wide variety of it, like natural fibre (e.g. hemp, kenaf, sisal, coir, jute etc.), synthetic fibre (e.g. glass fibres, ceramic etc.) and organic fibre (e.g. aramid). Natural fibres are cheap, easily available, and biodegradable but these advantages are not sufficient to overcome their major drawbacks like moisture absorption, It can be easily attacked by chemicals and has low strength compared to synthetic fibres.

There are numerous types of synthetic fibres such as nylon, acrylic, polyester, glass fibres etc. Now a day most commonly used synthetic fibre is glass fibres. There are also varieties of glass fibres e.g. A-glass, C-glass, D-glass, E-CR glass, E- glass and S-glass, among them E-glass and S-glass are most widely and commonly used, in many industry they represent over 90% of reinforcements used. Glass fibres which are available commercially are mainly manufacture in the form of woven roving (cloth), chopped strands, long continuous fibres, Woven roving's consist of continuous roving, which is a fabric are woven in two mutually perpendicular directions. In chopped strand, continuous fibres are cut to the short length and fibres are arranged in the form of bundle [3]. In E-glass fibre the term "E" stands for electric, which is made from alumino- borosilicate glass containing oxides of alkali less than 1% by weight [4]. The typical composition of E-glass fibre is shown in the Table 1 given below.

Table – 1: Composition and properties of E-glass fibres

Compositions	**In E-glass (%)**
SiO_2	52.4
$Al_2O_3 + Fe_2O_3$	14.4
CaO	17.2
MgO	4.6
$Na_2O + K_2O$	0.8
B_2O_3	10.6
Properties	
Density (gm/cm^3)	2.60
Thermal Conductivity (W/mK)	13
Coefficient of Thermal Expansion ($10^{-6}K^{-1}$)	4.9
Tensile Stress (GPa)	3.45
Elastic Modulus (GPa)	76

In the present work randomly oriented short E-glass fibre is used as reinforcing agent because of its good strength, light weight, chemical resistance and more importantly its low cost. Aluminium oxide (Al_2O_3) also called as alumina is used as a filler material. The addition of filler to the composites enhances the mechanical as well as physical properties [6]. The properties of Al_2O_3 like chemical inertness, high hardness, good strength and less expensive made it fit for the use where friction and wear conditions are predominant e.g. for low cost automotive brake linings [7]. Pure aluminium is chosen as coating material because of its wear and corrosion resistance property due to its passivation effect (it is the property of material to form thin coating film of its oxide and prevents its surface from foreign factors e.g. air and moisture) [8]. And also filler material is compound of aluminium.

2. COMPOSITE FABRICATION

2.1 For Mechanical Testing

In the present work, short glass fibre is taken as reinforcing agent. The epoxy resin (LY-556), hardener (HY-917) and Alumina (Al_2O_3) is used as a filler material, having particle size in the range of 80-100 pm. The short E-glass fibre mixed with epoxy resin and hardener in the ratio of 10:1 by weight with and without use of alumina filler. Then combined mixture is carefully mechanically stirred and poured into different moulds using hand lay-up technique. A mould releasing sheet is used for the easy removal of composites from the mould. The cast is allowed to cure under a load of 20 kg at room temperature 27^{0}C for 24 h. By varying weight percentage of E-glass fibre different composite samples are made (EG-1 to EG-4) with no use of filler material. Other composite samples with varying fibre loading and 5% of alumina (EGA-1 to EGA-3) are also prepared. After curing, samples were cut to the desired dimensions for different mechanical test. The composition and description of composite used in this study are listed in Table 2

Table -2: Designation of Composite

Composites	Compositions
EG-1	Epoxy + E-glass fibre (0 wt %)
EG-2	Epoxy + E-glass fibre (10 wt %)
EG-3	Epoxy + E-glass fibre (15 wt %)
EG-4	Epoxy + E-glass fibre (20 wt %)
EGA-1	Epoxy + E-glass fibre (10 wt %) + Alumina (5 wt %)
EGA-2	Epoxy + E-glass fibre (15 wt %) + Alumina (5 wt %)
EGA-3	Epoxy + E-glass fibre (20 wt %) + Alumina (5 wt %)

2.2 For Wear Test Measurement:

In case of wear test, the samples are prepared using syringe needle of 2.5 ml volume, of circular cross-section having diameter of 10 mm and 50 mm length. The fibre and filler percentage of the composites, curing temperature and duration remains same as before.

3 TESTING

3.1 Mechanical Testing

The tensile test is conducted on all the samples as per standards. Specimens are positioned in the grips of universal testing machine and a uniaxial load is applied through both the ends until it gets failure. During the test, the crosshead speed is taken as 2 mm/min, specimens of rectangular cross-sections having length and width of 100 mm and 15 mm respectively are used. Figure 1 shows the experimental setup for the tensile test.

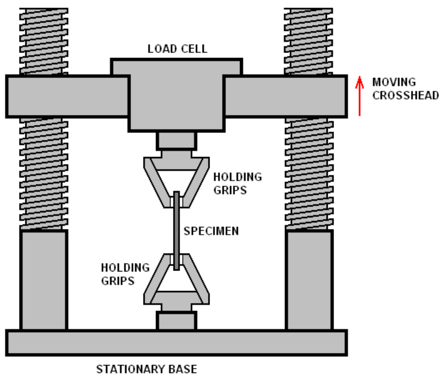

Fig -1: Block diagram for tensile test set up.

To determine the flexural strength of composites a three point bending test is performed. Before testing width and thickness of specimens measured at different point and mean value is taken. Samples were placed horizontally upon two points and midpoint is perpendicular to loading nose. The crosshead speed for test is maintained at 2mm/min. Flexural strength in terms of Mpa is determined using the equation

$$F = 3PL/2wt^2$$

Where,

P = Load applied on center of specimen(N)
L = Span length of specimen (m)
w = Width of specimen (m)
t = Thickness of specimen (m)

3.2 Sliding Wear Test

Wear behaviour of composites is studied using a pin-on-disc apparatus under dry sliding condition. Figure 2 shows the pictorial view of pin- on-disc setup, respectively. The sliding wear test is performed according to ASTM G99 test standards (standard test method for wear testing with a pin-on-disk apparatus).

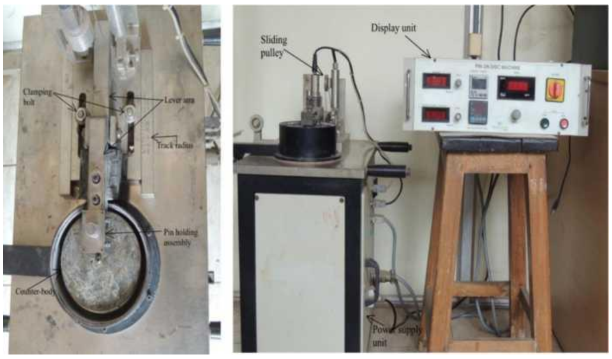

Fig – 2: Pin on disc set up

The specimen is held stationary in pin assembly and counter disc is rotated while the normal load is applied through a lever arm mechanism. Counter disc is made of case hardened steel. Series of wear test are conducted at different sliding velocities and at normal load. Weight loss of composites is measured using precision electronic balance with accuracy of — 0.1 mg. The specific wear rate of the material is given by the below mentioned equation

$$Ws = \frac{\Delta m}{\rho_c t V_s F_N}$$

Where,

Δm = Difference in mass of the samples before and after the test
P_c = Density of Composite (gm/mm3)
t = Duration of test (sec)
V_s = Sliding Velocity (m/s)
F_N = Applied normal load (N)

3.3 Taguchi Design of Experiments

Taguchi method is the technique based on performing experiments to test the sensitivity of a test of response variables to a set of control factors (or independent variables) by designing experiments in *"orthogonal array"* with an objective to attain the finest set of control. An array indicates the number of rows and columns and also number of level in each column. The important tools for robust design is Taguchi method, design of experiment (DOE), and regression analysis. For instance $L_4(2^3)$ has four rows and three "2 level" columns. The no. of rows of orthogonal array represents required number of experiments. The no. of rows must be at least equal to degree of freedom associated with control variables. In present study, four parameters is, sliding velocity, sliding distance, normal load, and fibre loading are set at three levels while filler content. Mixed level type L_{36} (2^11 3^12) orthogonal array design is used. Table 3 shows the experimental details of control factors and their level.

Table -3: Experimental details of control factors and their level

Control factors	Levels			Units
	I	II	III	
Filler Content	0	5	-	%
Coating Thickness	0	0.25	-	µm
Sliding Velocity	0.523	0.7854	1.1	m/s
Sliding Distance	314.16	471.3	659.73	M
Normal Load	5	10	15	N
Fibre Loading	10	15	20	%

There are three types of S/N ratios available according to the type of response. For minimum specific wear rate, S/N ratio falls under the category of smaller is better. Mathematically it can be expressed as

$$\frac{S}{N} = -10log\frac{1}{n}(\sum y^2)$$

Where, n = number of observations
And y = observed data

3. RESULTS

3.1 Mechanical Properties of Composites

3.1.1 Without filler at different fibre loading

The mechanical properties of the short E-glass fibre reinforced epoxy composites at different fibre loading without filler are presented in Table 4. It is observed from the Table 4 that at 20wt% of fibre loading the composites exhibits better mechanical properties as compared to other composites.

Table -4: Mechanical properties of composites without filler at different fibre loading

Composites	Flexural Strength (MPa)	Tensile Strength (MPa)
EG-1	16.41	4.62
EG-2	54.5	11.23
EG-3	62.2	14.3
EG-4	48.3	14.46

The flexural strength of unfilled composites increases with increase in fibre loading up to 15 wt% and then decreases on further increasing the fibre loading. The decrease in flexural strength at 20 wt% fibre loading may be due to insufficient wetting between fibre and matrix because of which stress doesn't transfer properly to the fibres.

The tensile strength value of the composites is shown in Table 4. An increase in tensile strength is observed with the increase in the fibre loading in case of glass epoxy composites without filler. This improvement at higher fibre loading may be attributed to presence of more fibres which act as the load carrying members in the composites [7, 9].

3.1.2 with filler at different fibre loading

The mechanical properties of the short E-glass fibre reinforced epoxy composites at different fibre loading with filler are presented in Table 5. It is observed from Table 5 that composites with 10wt% of fibre loading with 5 wt% of alumina content i.e. EGA-1 display better flexural strength as compared to others composites. On the other hand EGA-3 and EGA-2 composites exhibit higher tensile strength values.

Table -5: Mechanical properties of composites with filler at different fibre loading

Composites	Flexural Strength (MPa)	Tensile Strength (MPa)
EGA-1	75.4	26.19
EGA-2	35.65	33.55
EGA-3	69.2	22.83

The flexural strength of filler content composites reduces when fibre loading increases from 10 wt% to 15 wt% this may be due to poor dispersion of particulate and possibility of existence of voids [9, 31]. It is clearly observed from the Table 5 that Al_2O_3 filled composite with 15wt% of fibre has more void percentage as compared to Al_2O_3 filled composite with 10wt% of fibre loading. However, the strength increases for Al_2O_3 filled composite with 20wt% of fibre loading as it has low void content.

The tensile strength of the alumina filled composites increases with increase in fibre loading up to 15 wt% after that it decreases for composite with 20 wt% of fibre loading. The improved tensile strength of alumina filled composites up to 15 wt% fibre loading may be due to better dispersion of filler, better wettability and good adhesion between the matrix and filler. The reduction in tensile strength with filler addition may be due to the weak chemical bond strength between filler particles and the matrix body which is unable to transfer the tensile load [9].

3.2 Sliding wear behaviour

3.2.1 Effect of fibre loading on wear of unfilled composites

The variation of wear rate with respect to fibre loading at different testing conditions is shown in Chart 1. Specific wear rate of the composites decreases with increase in fibre loading, at A1 testing condition. The hardness plays an important role in the wear resistance of the material. As fibres are harder phase in the composite more energy is required for the failure of the fibres. Thus, the wear failure is less in case of composites with higher fibre loading. At A2 testing condition (sliding velocity 250 rpm, sliding distance 471.23m and normal load 10N) minimum specific wear rate is observed in case of composite with 20 wt % fibre loading. Among all the testing conditions (i.e. A1, A2 and A3) composites with 15 wt % fibre loading exhibit minimum specific wear rate [10].

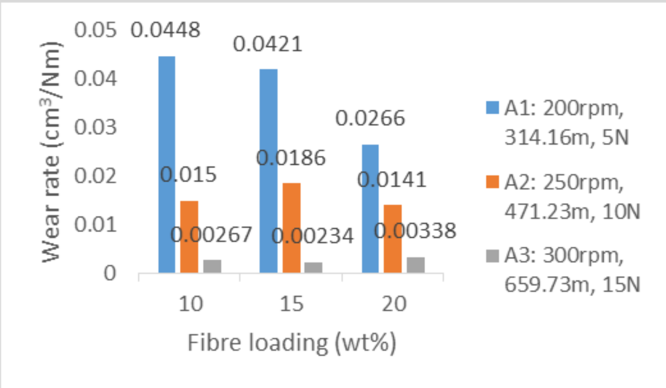

Chart -1: Wear rate of unfilled composite at different fibre loading and test condition

3.2.2 Effect of fibre loading on wear of filled composites

The specific wear rate of Al_2O_3 filled composites are shown in Chart 2. The filler content is same for all samples. Wear resistance of polymer composites depends on the bonding between filler and matrix, distribution of filler material, fibre loading and also the presence of voids in composite samples.

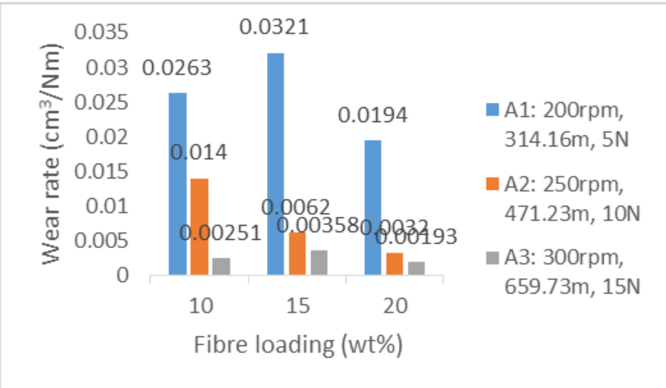

Chart -2: Wear rate of filled composite at different fibre loading and test conditions

At sliding velocity 200 rpm, sliding distance 314.16 m and normal load 5 N, wear rate increases from 0.0263 to 0.0321 cm/Nm with the increase in fibre loading up to 15 wt% beyond which specific wear rate decrease. However, at sliding velocity 250 rpm, sliding distance 471.23 m and normal load 10 N, wear rate gradually decreases with increase in fibre loading [11]. This may due to less voids and uniform distribution of filler and fibre throughout the matrix. But at sliding velocity 300 rpm, sliding distance 659.73 m and normal load 15 N, specific wear rate of specimens is lesser than the those specimens subjected to A2 and A3 test conditions, as observed from Chart 2.This may be due to the less contact time during the wear test.

3. CONCLUSIONS

The experimental work done on the effect of fibre loading, filler content on mechanical and also the effect of coating on sliding wear behaviour of E-glass reinforced epoxy composite leads to obtained the following conclusions from the present study as follows:

1. Fabrication of E- glass fibre reinforced epoxy composites with and without filler composites is done using simple hand lay-up technique.
2. The addition of glass fibre in the composites improves the mechanical property of polymer resin. The tensile strength of the composite increases with the increase in fibre loading. Flexural strength of the fibre reinforced composites increased up to an optimum level of fibre loading.
3. Flexural and tensile properties of the glass epoxy composites are enhanced with addition of Al_2O_3 filler in the glass-epoxy composites.
4. The addition of filler in to the glass-epoxy composites results in improved sliding wear resistance of the glass-epoxy composites.
5. The factor combination of filler content of 5 %, coating thickness of 0.25 %, sliding speed of 0.6280 m/s, sliding distance of 659.73 m, normal load of 10 N and fibre loading of 20 wt% gives minimum specific wear rate.

REFERENCES

[1]. A.K. Dhingra, "Metal replacement by composite", JOM 1986, Vol. 38 (03), page 17.

[2]. Kamaleshwar Upadhya, "Composite materials for aerospace applications, developments in ceramic and metal matrix composites", PA: TMS publications, 1992, page 3 to 24.

[3]. Greg Fisher, "Composite: Engineering the ultimate material", Am. Ceram. Soc, Bull. Vol. 63 (2), page 360 to 364.

[4]. T. G. Nieh, K. R. Forbes, T.C. Chou and J. Wadsworth, "Microstructure and deformation properties of an Al_2O_3 – Ni_3Al composite from room temperature to 1400^0C", High performance composite for the 1990's Eds. S. K. Das, C. P. Ballard and F. Marikar, TMS-New Jersey,1990, page 85 to 96.

[5]. T. W. Clyne, An Introductory Overview of MMC System, Types and Developments, in Comprehensive Composite Materials, Vol-3; Metal Matrix Composites, T. W. Clyne, Elsevier, 2000, page 1 to 26.

[6]. M. A. EL Baradie, "Manufacturing aspects of metal matrix composites", Journal of Materials Processing Technology, Vol. 24, 1990, page 261 to 272.

[7]. S. D. Ridder, S. Kou and R. Mehrabian, "Effect of Fluid Flow on Macrosegation in Axi-Symmetric Ingots," Metall. Trans., Vol. 12B, Sept.1981, page 435 to 447.

[8]. R.H. Bricknell, "The Structure and Properties of a Nickel-Base Super alloy Produced by Osprey Atomization-Deposition", Metall. Trans., Vol. 17A, 1986, page 583 to 591.

[9]. S. Kohara, Mater. Manufacuring Process, Vol. 5, 1990, page 51.

[10]. Mohanty J.R., Das S. N., and Das C. H., Effect of Fibre Content on Abrasive Wear Behaviour of Date Palm Leaf Reinforced Polyvinyl Pyrrolidone Composite, ISRN Tribology, 2014 (2014), pp. 1-10.

[11]. Unal H., Findik F., and Mimaroglu A., Mechanical Behaviour of Nylon Composites Containing Talc and Kaolin, Journal of Applied Polymer Science, 88 (2003), pp. 1694-1697.

[12]. A.R. Champion, W.H. Krueger, H.S. Hartman and A.K. Dhingra, Proc. Int. Conf. on Composite Materials, AIME, Warrendale, PA 1978, page 883.

[13]. S.F. Moustafa, S.A. El-Badry, A.M. Sanad and B. Kieback, "Friction and wear of copper–graphite composites made with Cu-coated and uncoated graphite powders", Wear 253 (2002), page 699 to 710.

[14]. Jin-Kun Xiao, Lei Zhang, Ke-Chao Zhou, Xin-Ping Wang, "Microscratch behaviour of copper–graphite composites", Tribology International 57 (2013), page 38 to 45.

[15]. Jaroslav Kovacik, Stefan Emmerb, Jozef Bielek, L'ubomır Kelesi, "Effect of composition on friction coefficient of Cu–graphite composites", Wear 265 (2008) 417 to 421.

[16]. Wenlin Ma, Jinjun Lu, "Effect of surface texture on transfer layer formation and tribological behaviour of copper–graphite composite", Wear 270 (2011) 218–229.

[17]. K. Rajkumar, S. Aravindan, "Microwave sintering of copper–graphite composites", Journal of Materials Processing Technology 209 (2009), page 5601 to 5605.