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Thermo-mechanical Correlations to Erosion Performance of Chopped E-Glass Fibre Reinforced Epoxy Resin Composites with Filler SiC

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Abstract—*Thermo-mechanical properties and erosion performance of chopped E- glass fibre reinforced epoxy resin based isotropic polymer composites with five different fibre weight fractions have been investigated. The storage, loss and damping characteristics were analysed to assess the energy absorption/viscous recoverable energy dissipation and reinforcement efficiency of the composites as a function of fibre content in the temperature range of 0–120°C. The composite with 0wt.% of chopped E-glass fibres has been observed to show superior thermo-mechanical response with highest energy dissipation/damping ability accompanied with a constant storage modulus without any substantial decay till 82°C. The erosion rates (Er) of these composites are evaluated at different impingement angles (30–90°), fibre loadings (0–20 wt.%), impact velocities (60 m/s), stand-off distances (55 mm) and erodent sizes (150–200 μm) following the erosion test schedule in an air jet type test rig. The unfilled glass Epoxy composite has a strength of 90.92 MPa in tension and that this value increase to 113.73 MPa and 99.75 MPa with addition of 10 wt% and 20 wt% of SiC respectively. A theoretical model has been proposed for estimation of erosion damage caused by solid particle impact on glass fibre reinforced epoxy composites.*

Keywords*: mechanical properties, Dynamic mechanical analyzer, SiC, Chopped E-glass fibre.*

1. INTRODUCTION

Fibre reinforcement polymer composites used in aircraft, helicopters, space-craft, satellites, ships, submarines, automobiles and transportation industry, chemical engineering industry ,defence industry, sporting goods and civil infrastructure. Composites are important materials because of their light weight, high strength ,durability, stiffness, excellent fatigue resistance and outstanding corrosion resistance compared to most common metallic alloy such as steel and iron. Advantages of composites include the ability to fabricate, improves mechanical properties, low thermal expansion coefficients and high dimensional stability. The unique combinations of properties available in these fibres provide the outstanding useful and structural characteristics such as high strength and stiffness to the fibre reinforced composites. In addition to the higher mechanical strength achieve due to the addition of fillers in polymeric composites; there is direct cost reduction due to the less consumption of resin material [1].The testing results indicated that the composites exhibited appreciably improved tribological performance and mechanical properties as rather low filler content [2]. Aluminium matrix composites reinforced with SiC are preferred due to their high thermal conductivity, wear resistance, low thermal expansion and other improved mechanical properties [3]. Silicon Carbide is one of the best filler material, has low density, high strength, high hardness, high thermal conductivity and excellent thermal shock resistance[3]. Silicon Carbide (SiC) filler particles were added to fibre-reinforced epoxy to increase the mechanical properties of composites and it has been observed that mechanical properties at optimum fibre loading condition can be determined with the addition of fibre/ filler reinforcement on matrix composites[4]. Storage modulus values for SiC- filled glass fibre reinforced epoxy composite decreases with the increase in SiC content, and storage modulus values decrease with the increase in the percentage of SiC content, whereas elastic range of the material increase with the increase in SiC content [4]. The addition of fillers along with reinforcements give rise to improved properties such as higher load bearing capacity, reduced coefficients of friction, improved wear resistance and thermal properties and higher mechanical strength[5].The effect of addition of silicon carbide filler in different weight percentage on physical properties, mechanical properties, and thermal properties of chopped glass fibre reinforced epoxy composites has been investigated that the physical and mechanical properties of SiC- filled glass fibre-reinforced epoxy composites were better than unfilled glass

fibre- reinforced epoxy composites[6]. The strength and the modulus in tensile and flexural mode for glass- fibre reinforced epoxy composite increase with increasing with filler loading[7].The literature mentioned above gives a brief overview about the effects of addition of filler/fibre to mechanical and thermal properties of SiC- filled glass fibre-reinforced epoxy composites. it has been observed that various mechanical properties at best fibre loading conditions can be determined with the addition of filler/fibre reinforcement on matrix composites.

2. MATERIALS AND METHODS

Materials required

Chopped E-glass fibre manufactured by Ciba Geigy and locally supplied by Northern Polymers Ltd,New Delhi, India, is used as fibre reinforcemement. Commercially available SiC powder of particle size 30 to 90 µm obtain from silcarb recrystalized Pvt, Ltd, Banglore, India, is used as a particulate filler. The matrix material consists of epoxy resin LY556 and room temperature curing hardener HY951 supplied by crystal chemicals, Delhi, India. The composites were fabricated by combination epoxy resin, glass fiber, and SiC filler in a sure weight percentage reinforcement. Five different compositions of composites were prepared by varying the SiC filler reinforcement with fixed weight percentage (wt.%) of chopped glass fiber reinforcement. SiC filler in five different weight percentages (0wt%, 5 wt%, 10 wt%, 15 wt%, and 20 wt.%) are added with fixed 40 wt.% of chopped glass fiber and remaining epoxy so as to examine the effect of SiC reinforcement on physical, mechanical, and thermal properties of chopped glass fiber reinforced epoxy composites. The composites were ready by mixing certain weight percentage of fiber/filler and epoxy resin in separate containers and then poured in a mold of desired dimensions. Labelling was done with the help of rollers, and suitable weights were applied on top of the mold. Similarly, five different compositions of fiber, filler, and epoxy resin are poured in separate molds by varying five percentages of SiC filler content with that of the epoxy resin keeping the chopped glass fiber weight percentage as constant. The composites are then left for solidification at room temperature for 24 hour. After the solidification process, the composites are then disconnected from the mold and marking is done as per the test standards. Specimens were equipped as per American Society for Testing Materials (ASTM) test standards for tensile and flexural tests.

Tests for mechanical properties

The mechanical properties were determined to know the behaviour of the material under different loading environment. To understand how materials deform or break as a function of applied load, time, temperature, and other conditions, tensile strength, flexural strength, of the composite specimens were determined. Tests for mechanical properties, i.e., tensile test, interlaminar shear strength, and flexural strength, are done on a universal testing machine Instron 1195. The tensile test is performed to measure the ductility of the material. Equal and opposite loads are applied at both ends of the rectangular specimen on the UTM Instron 1195 (ASTM 1976). Dimensions of the test specimen are 210 mm long, 17.5 mm wide, and with variable thickness 3mm (depending on the composition of the composite material). Flexural strength is the ability of the material to resist bending under the application of load. A three-point bend test was performed on the same UTM Instron 1195 with a span length of 50 mm in between the supports and a crosshead speed of 10 mm/min to measure the amount of failure when subjected to loading. Rectangular test specimen with dimensions 100 mm length, 17.5 mm width, and 3 mm thickness has been used for the experiment.

3. RESULTS AND DISCUSSION

The physical and mechanical properties illustrate the behaviour of the material to various practical applications. The properties such as hardness explain the physical state of the system. The mechanical property of the material is a measure of the behavior of the material under various loading conditions. Tests were done to notice the effect of addition of SiC filler on the physical and mechanical properties and the most favourable fiber/filler loading of glass fiber-reinforced epoxy composites at which specific wear rate in lowest amount.

Effect of tensile strength on SiC- filled chopped E- glass fibre reinforced epoxy composites

The ultimate tensile strength is an engineering value can be calculated by dividing the maximum load on a material by the initial cross section of the test sample. Fig. 1 shows the graph of tensile strength versus the SiC-filled chopped glass fiber-reinforced epoxy composite.

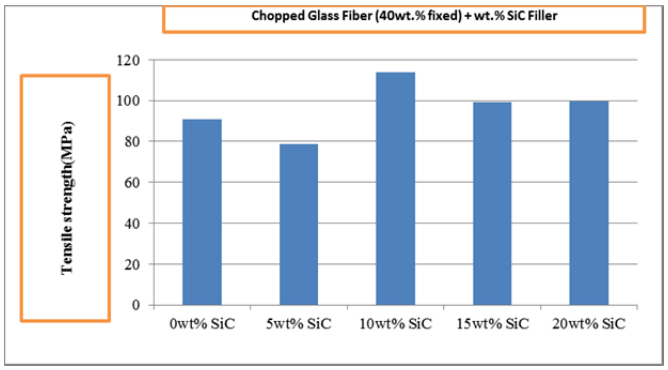

Fig. 1: Effect of tensile strength on SiC filled chopped glass fibre- reinforced epoxy composites.

Tensile strength increases from 0 to 10 wt.% SiC content, whereas further increase in SiC content results in the decrease

in the value of tensile strength. This is because filler particles act as a wall in transferring stress from one point to another, and an increase in SiC content beyond 10 wt.% results in the increase of transfer of stresses from one point to another. Also as the fibre/filler content increases, the bonding surface area increases and hence bonding strength decreases. and maximum tensile strength at 10wt% at 5800N (113.73 MPa).

The maximum extension in the test specimen at the maximum load is 3.3638mm of 10wt% epoxy with SiC filler. Due to insufficient amount of bonding between three different constituents, the loads may not successfully be transferred from one end to another and hence there is reduction in tensile strength of the composite. Tensile strength of carbon fiber-reinforced polyetheramide improves extensively with the addition in the percentage of fiber/filler reinforcement.The extent of development of tensile strength however is not proportional to the amount of carbon fiber reinforcement [8-9].

Effect of flexural strength on SiC-filled chopped glass fiber-reinforced epoxy composites

Fig. 2 shows the flexural strength of SiC-filled glass fiber reinforced epoxy composites.

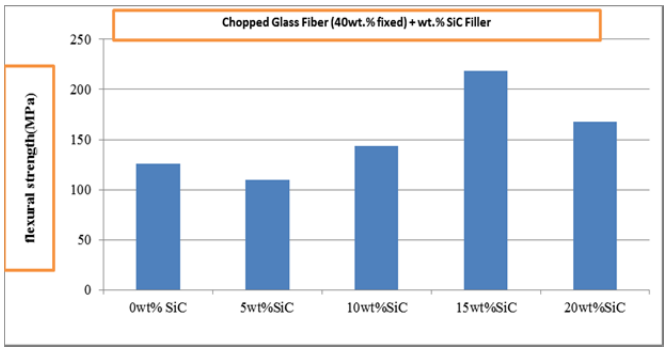

Fig. 2: Effect of flexural strength on SiC-filled chopped glass fiber-reinforced epoxy composites.

flexural strength increases from 90.92MPa to 113.73 MPa with the increase in SiC filler content from 0 to 10 wt.%; an increase filler the flexural strength at 15wt.% SiC is maximum. As the results in the decrease in flexural strength after 15wt%SiC. When the specimen is positioned on two support points and load is applied from the top of the specimen, then the specimen is subjected to bending and the top layer is subjected to compressive loading, whereas the bottom layer is subjected to tensile loading. When the bonding between the fiber/filler and the matrix is increased, a flexural strength increases and strong bonding transfers loads from one end to another resultant in the increase in flexural strength of the specimen, whereas when the percentage of fiber/filler exceeds the required percentage, then the surface area increases glass fibre reinforced- epoxy composites.

Thermo-mechanical properties of composite (dynamic mechanical analysis)

Variation of loss modulus and storage modulus with tanδ for SiC filled chopped glass fiber-reinforced epoxy composites.

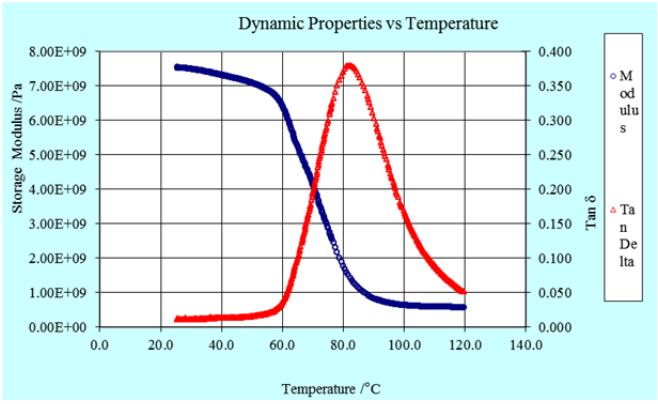

Fig. 3: Variation of loss modulus with 40wt% glass fibre (fixed) + 0wt% SiC

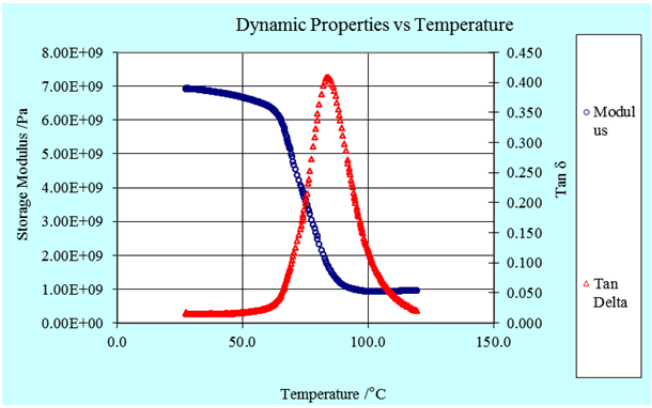

Fig. 4 Variation of loss modulus 40wt% glass fibre (fixed) + 5wt% SiC

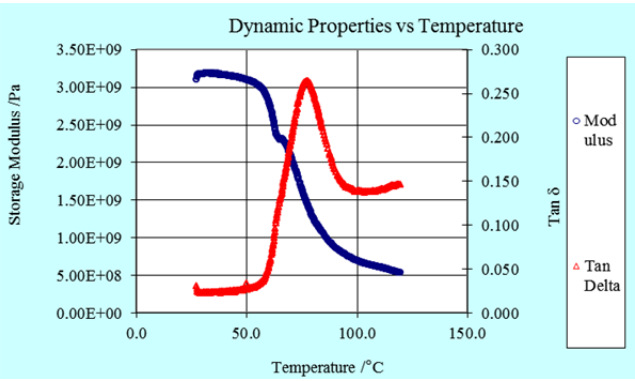

Fig. 5: Variation of loss modulus 40wt% glass fibre (fixed) + 10wt% SiC

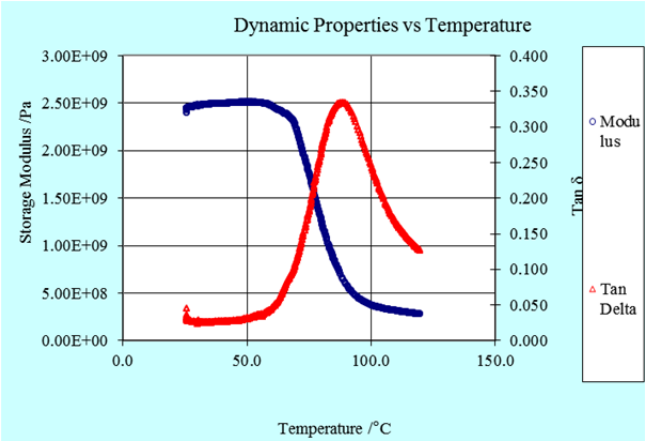

Fig. 6: Variation of loss modulus 40wt% glass fibre (fixed) + 15wt% SiC

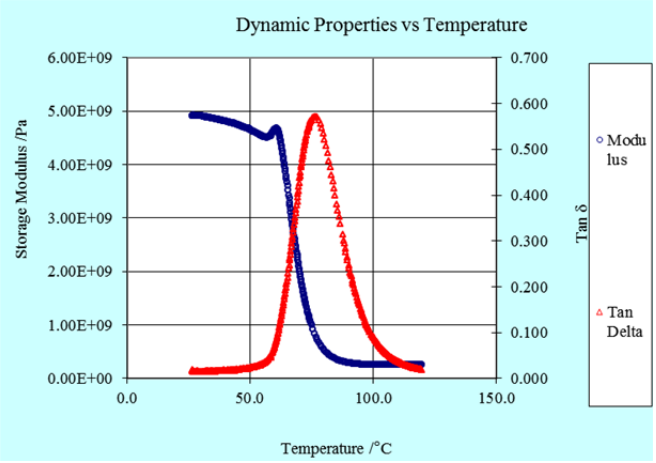

Fig. 7: Variation of loss modulus 40wt% glass fibre (fixed) + 15wt% SiC

A general cause of tribological failure of composite parts is the inability to support a given load due to the loss in modulus at frictionally induced elevated temperatures. Dynamic mechanical analysis (DMA) has emerged as one of the most powerful tools presented for the study of the behaviour of materials. Basically, Dynamic mechanical analysis measures the viscoelastic properties of materials. Dynamic mechanical analysis plot provides values of those temperature regions where material properties are very constant with temperature and where rapid changes will occur that would provide the material useless[10]. One important application of dynamic mechanical analysis is measurement of the glass evolution temperature of polymers. Amorphous polymers have dissimilar glass transition temperatures, above which the material will have tough properties instead of glassy behavior and the stiffness of the material will drop significantly with an increase in viscosity. At the glass transition, the storage modulus decreases significantly and the loss modulus reaches a maximum [11]. Dynamic mechanical analysis of chopped glass fiber with SiC filler-reinforced epoxy composite have been carried out in this study to explore the variation of storage modulus (E′), loss modulus (E″) and damping factor (tan delta) i.e.:

$$\tan \delta = E'/E'' = \text{storage modulus/ loss modulus} \quad (1)$$

Equation(1) represents that tan δ is the measure of storage modulus to loss modulus, i.e., as the value of loss modulus increases, the value of storage modulus decreases [11]. Similar tendency is noticed in Figures 3 to 7 at different wt%. All tests run as Perkin Elmer Dynamic mechanical analyzer (DMA 8000) test standards using a fixed frequency of oscillation of 1 Hz and a sample heating rate of 3°C/min and displacement 0.050mm. All tests were initiated from room temperature and goes to 140°C temperature. The mode of stress applied is flexure, and the fixture arrangement is a single cantilever beam. Figures 3, 4,5,6 and 7show the most common graphic representation for elastic or storage modulus, the viscous or loss modulus, and tan delta as a function of temperature at different wt%, respectively.Fig. 3 shows a graph of storage modulus versus temperature for SiC-filled chopped glass fiber-reinforced epoxy composite. Storage modulus values for chopped glass fiber SiC filler-reinforced epoxy composites show a linear trend with slight decrease in the value of storage modulus with the change in temperature (room temperature to 60°C). This shows glassy command in region owt% SiC, i.e., from room temperature to 65°C,graph rapidely decrease. Fig 4 shows a sharp decline in the values of storage modulus with the increase in the values of temperature (65°C to 90°C), i.e., the material changes from glassy to rubbery transition regime in the temperature range of 65°C to 90°C; due to a sharp drop in the value of storage modulus, the material has lost its usefulness as a structural material. Due to amorphous structure in the polymer and the presence of unorganized intermolecular structure, the storage modulus value drops suddenly. From Fig. 5 again is a straight line showing negligible decrease in the values of storage modulus with the increase in the value of temperature. Here, the values of storage modulus nearly tend to zero, which shows a rubbery regime indicating degradation of the moduli above 90°C. In the glassy state, i.e., at low temperatures, stiffness is related to the small displacement of molecules, whereas in the rubbery state at high temperature, molecular chains have extensive flexibility; so that in the unreformed state, they can adopt conformations that lead to maximum entropy. The higher values in region 1 and sharp decrease in the values in region 2 are due to the fact that in region 1, the material is in glassy state in which the contribution of elastic modulus is more than the viscous modulus, whereas in region 2, the material is in glass transition stage in which a change from glass transition state into rubber elastic state takes place. Fig. 7 clearly shows the value of loss modulus with the increase in the value of temperature. From the values obtained in the graph, we notice that the values of loss modulus rise to a maximum as the storage modulus values are in their most rapid rate of decent.

The peak of the loss modulus curve denotes the glass transition temperature (Tg). Fig. 7 denotes the glass transition temperature as 90°C and desired loss modulus values (minimum values) obtained for 10 to 20 wt.% SiC content. This may be due to the increase in the percentage of fiber/filler content, i.e., as the percentage of fiber/filler content increases, the height of the E″curve decreases and the peak width spreads across a wider temperature.range leading to a decrease in the rate of loss modulus (desired value obtained). Further, it has also been experimental from Fig. 7 that the composition with lower fiber/filler content peak of glass evolution temperature shifted towards lower temperature with a sharp peak and higher value of loss modulus. Fig. 8 shows the graph of tan delta versus temperature. The tan δ curve intimately resembles the loss modulus curve important to the glass evolution tan δ values well below 0.1. The rapid increase in tan δ values closely resembles the rapid decline in storage modulus values. The peak value of tan δ indicates that the material is non-elastic, whereas the lower value of tan δ indicates that the material is elastic in nature [11].Fig. 1 shows that the material is extremely elastic, and as the value of tan δ shifts to in Fig. 2, the nature of material shifts from elastic to plastic. The peak value of tanδ show that any further increase in temperature beyond this changes the material from elastic to plastic zone. Fig. 3.shows that as the percentage of fiber/filler increases the value of tanδ decreases with increase in temperature., the peak value shifts towards higher temperature resulting in wider elastic range of temperature, whereas as the percentage of fiber/filler decreases, the peak value shifts towards the lower temperature range resulting in slight elastic range.

4. CONCLUSION

Experimental observations are carried out on SiC filled chopped glass fibre- reinforced epoxy matrix composites to notice the effect of mechanical and thermal properties. Based on the experimental observations, the following conclusions can be drawn:

1.Mechanical properties such as tensile strength, flexural strength increase with the increase in SiC filler content ,Tensile strength increases from 0 to 10 wt.% SiC and maximum tensile strength at 10wt%SiC at 5800N (113.73 MPa).

2. the value of tensile and flexural strength increase up to 10wt% SiC filler content.

3. Storage modulus value for SiC- filled glass fibre- reinforced epoxy composite decrease with the increase in SiC content. storage modulus values decrease with increase in the percentage of SiC content, whereas elastic range of the material enlarge with the increase in SiC.

4. As the percentage of SiC content increases, the area under the curve spreads across the wider range and peak value shifts in the direction of the higher temperature region resulting in increase in elastic range of the composite.

5. From the analysis of the results of mechanical properties and thermal properties, it has been concluded that the optimum properties are obtained for 10wt% SiC content in addition to 40wt% chopped glass fibre- reinforced epoxy composite.

6. As the percentage of fiber/filler increases the value of tanδ decreases with increase in temperature.

REFERENCE

[1] B.Suresh, Siddaramaiah, Kishore, S.Seetharamu, P.Sampath Kumar, (2009).Investigations on the influence of graphite filler on dry sliding wear and abrasive wear behaviour of carbon fabric reinforced epoxy composites, Wear, 267:1405-1414.

[2] Simona Matei, Maria Stoicanescu, Aurel Crisan,(2016), Composites with Short Fibres Reinforced Epoxy Resin Matrix, preceida technology 22, 174-181.

[3] S.Rajesh, B.VijayRamnath, C.Elanchezhian, N.Aravind, V.Vijai Rahul, (2014), Analysis of Mechanical Behavior of Glass Fibre/ Al_2O_3 –SiC Reinforced Polymer Composites. precedia Engineering 97, 598-606.

[4] Gaurav Agarwal, Amar Patnaik,and Rajesh Kumar Sharma, (2013), Thermal- Mechanical Properties of Silicon Carbide-Filled Chopped Glass Fibre- Reinforced Epoxy Composites. International Journal of Advanced Structural Engineering.

[5] B Suresha, G Chandramohan, P R Sadananda Rao, P Sampathkumaran, S Seetharamu & Vartha Venkateswarlu, (2006), Friction and Slide Wear Characteristics of Glass- Epoxy Filled With SiCp Composites. Indian Journal of Engineering & Materials Sciences; Vol.13, pp. 535-541.

[6] Md Nadeem M, K Chandrashekara, Yathisha N, Rudramurthy, (2014), Study of The Effects of Carbon And Glass Fibre Reinforcement and other Fillers on Elevated Temperature Resistant Properties of Er Matrix Composites; International Journal of Research in Engineering and Technology, Vol. 03, ISSN. 2319-1163.

[7] Basappa Hulugappa, Mysuru V. Achutha, Bheemappa Suresha, (2016), Effect of Fillers on Mechanical Properties and Fracture Toughness of Glass -Fabric Reinforced Epoxy Composites;Journal of Minerals Characterization and Engineering, 4,1-14.

[8] Sua F, Zhang Z, Wang K, Jiang W, Liu W (2005), "Tribological and mechanical properties of the composites made of carbon fabrics modified with various methods". Compos Part A 36:1601–1607.

[9] Devendra K, Rangaswamy T, (2012), "Determination of mechanical properties of Al2O3, Mg (OH)2 and SiC filled E-glass/epoxy composites". Int J Eng Res Appl 2(5):2028–2033

[10] Ward IM, Sweeney J (2004), An introduction to the mechanical properties of solid polymers. Wiley, New York.

[11] Agarwal G, Patnaik A, Sharma RK (2013), Parametric optimization of three-body abrasive wear behavior of long and short carbon fibre reinforced epoxy composites. Tribology Material, surface and interfaces 7(3):150–160.