International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 13 (2015) pp 33826-33830

Mechanical Properties Of Carbon-Epoxy With Ceramic Particles On Composite

[1] K. Karthik

Assistant professor, karthikk@veltechuniv.edu.in,

[2] T.Raja

Assistant professor, rajat@veltechuniv.edu.in

[3] S.Prabu

Assistant professor, prabus@veltechuniv.edu.in

[4] R.Ganesh

Assistant professor, ganeshr-07@rediffmail.com
[1,2,3,4] Departmental of Mechanical Engineering,
VEL TECH UNIVERSITY, Avadi, Chennai – 600062, Tamil Nadu, India

Abstract
In this research, the investigation was aimed to develop plain journal bearing with better wear resistance. The Carbon-epoxy composite with addition of different fillers in different weight fractions were fabricated. The fillers such as silicon carbide and aluminum oxide were used as secondary reinforcement and fabricated using vacuum bag molding technique. The mechanical properties were evaluated using Universal testing machine and Brinell hardness testing machine as per ASTM standards. Better mechanical properties and wear properties were obtained with increase in weight percentage of secondary reinforcement content. Further it was found that carbon-epoxy with 10 % SiC and 5 % Al_2O_3 exhibited better wear resistance and better strength which can be used for bearing application.

Keywords: - Polymer composite, Hardness, Compressive strength,

1. INTRODUCTION
The fiber reinforced polymer composites are the most rapidly growing class of materials, due to their good combination of high specific strength and modulus. They are widely used in variety of engineering and automobile applications.In recent years, there have been rapid growth in the development and application of fiber reinforced thermosetting polymer composites such as epoxy, polyester and vinyl ester. This is due to the realization of their good strength, low density and high performance to cost ratio with rapid clean processing. In recent times, there has been a remarkable growth in the large-scale production of fiber and/or filler reinforced epoxy matrix composites. Because of their high strength-to- weight and stiffness-to-weight ratios, they are extensively used for a wide variety of structural applications as in aerospace, automotive and chemical industries. On account of their good combination of properties, fiber reinforced polymer composites (FRPCs) are used for producing a number of mechanical components such as gears, cams, wheels, brakes, clutches, bearings and seals [1]. Most of these are subjected to tribiological loading conditions. Various researchers have studied the tribiological behavior of FRPCs. Studies have been conducted with various shapes, sizes, types and compositions of fibers in a number of matrices. Many investigations have been done on wear properties on polymer composites. B. Suresha et al (2010) studied the tribiological properties of vinyl ester based composites with two different fibers such as carbon and glass fibers. They conclude that friction and wear characteristics of bidirectional fabric reinforced vinyl ester composites depends on the fabric materials. Carbon-vinyl ester composites showed lower friction under different loads /sliding velocities and hence may be suitable for bearing applications. The wear resistance is improved with addition of carbon fiber in vinyl ester than glass fiber.In recent years, many researches have been devoted to explore the potential advantage of thermoset matrix for composites applications [2]. G. Chandramohan et al (2008) studied the wear behavior of vinyl ester based composite with the addition of different fillers such as SiC, graphite and glass fiber. Wear volume increases with increase in abrading distance/loads for all samples. They conclude that SiC filled glass-vinyl ester composites showed better wear resistance and wear rate is higher in unfilled glass fiber reinforced vinyl ester composites and graphite fillers are not very beneficial to the wear performance [3]. R. Prehn et al (2005) studied wear performances of polymer composites with different fillers. Epoxy resin with addition of fillers such as silicon carbide exhibits good wear properties which can be used for bearing applications [4]. Y.Z.Wan et al (2006) wear performances increased with addition of more percentage of

fiber content in polymer composites. Carbon fiber has good tribiological and mechanical properties which increases the wear properties of the composites with specific wear rate and coefficient of friction gradually increases with increase in fiber volume content in composites [5]. B. Suresha et al (2009) investigated the dry sliding wear of carbon-epoxy with the addition of graphite fillers from 5 to 10%. They conclude that wear properties is improved with increase in graphite powder content in carbon-epoxy composites and further they conclude that 10% graphite carbon-epoxy exhibits high wear resistance compared to 5% and unfilled composites [6]. K.Gopala Krishna et al (2009) studied the friction and wear characteristics of polymer based composites with addition of steel powder and alumina powder. They conclude that addition of steel powder exhibits high wear rate compared to ceramic particles. Alumina is suitable for increasing wear performances. Polymer exhibits low friction coefficient compared to metals to their low interfacial adhesion energy. By reinforcing fillers such as metals, ceramics and fillers increase the strength and stiffness of the matrix [7]. H. Unal et al (2004) studied wear performances on PTFE composites with different fillers such as glass, carbon and bronze with different volume fractions. They conclude that addition of glass fiber, bronze and carbon fillers to PTFE were found effective in reducing the wear rate of the PTFE composites. Wear rates are little sensitive to test speed and large sensitivity to the applied loads particularly at high values [8]. Siddhartha et al (2012) studied the mechanical and tribiological properties of epoxy based composites with two different fiber forms bidirectional and chopped glass fiber. They conclude that bidirectional glass fiber exhibits good mechanical and tribiological properties compared to chopped fibers, because of bonding between the fibers and matrix [9]. Hui Zhang et al (2007) studied the influence of fiber length on tribiological properties and carbon fiber reinforced epoxy composites. They conclude that long carbon fibers exhibits better wear resistance than these with short carbon fibers in epoxy composites [10]. Osman Asi (2010) investigated the bearing strength of glass-epoxy composites with addition of $Al_2O_3$with different volume fractions. The increase of Al_2O_3particle loading in the matrix improved bearing strength of the composites. Further it is concluded that increase in Al_2O_3 more than 10% decreases the strength but remains above that of the unfilled glass reinforced epoxy composites [11]. B. Suresha et al (2006) investigated glass-epoxy with SiC as fillers. They conclude that silicon carbide filled glass-epoxy composites shows higher resistance to slide wear compared to plain glass-epoxy composites [12]. BekirSadik et al studied tribiological properties of polymer based journal bearing with different polymers such as PE, PA, POM, PTFE and Bakelite bearing. They conclude that higher wear resistance has been obtained in PA and POM bearings [13]. L. Wang et al (2000) compared conventional steel, silicon nitride material shown significant benefits in terms of rolling contact fatigue life and the lower density of the material greatly reduces the dynamic loading which can be used in high speed applications such as machine tool spindles and gas turbine engines. As a result of their sustained development and testing. It is expected that silicon nitride baking will be usedin all types of applications [14]. Guang Shi et al (2003) investigated friction and wear of low nanometer silicon nitride filled epoxy composites. They conclude that incorporation of nano-Si_3N_4 particle into epoxy can significantly reduce frictional coefficient and wear rate of the latter under dry sliding wear conditions [15]. Siddhartha et al (2011) conclude that the addition of Titania in epoxy composites exhibits high wear resistance and better mechanical properties and Zhenyu et al (2008) carbon fiber reinforced polyphenlylene with TiO_2 as fillers.Sandhyatani Biswas et al (2009) investigated the wear performances on red mud filled glass-epoxy composites. They conclude that hardness is improved with increase in red mud content and mechanical properties such as tensile; shear impact strength is decreased with increase in red mud particle content in glass-epoxy composites [16.17,18,]. Fibers reinforced polymer composites are used for producing number of mechanical components such as gears, cams, wheels, brakes, clutches, bush bearing and seals. Considerable efforts are being made to extend the range of applications.In aircraft and space vehicles high reliability and relatively long life are required of all assemblies and elements, including bearings. With the advent of the space era very demanding bearing operating conditions such as high vacuum, extreme temperatures, large temperature differentials, long life (both wear and fatigue life, usually 10–15 years without maintenance) and low frictional power are quite common. Use of inorganic fillers dispersed in polymeric composites is increasing. Fillers not only reduce the cost of the composites, but also meet performance requirements, which could not have been achieved by using reinforcement and resin ingredients alone. Pushkar Venkatesh Kulkarni et al (2012) fabricated and testing PTFE based composite bearing material for turbine pump with addition of different fillers in PTFE composites. They conclude that bronze filled with PTFE composite bearing exhibits good wear resistance [19].

2. EXPERIMENTAL DETAILS

2.1 MATERIALS

The materials such as carbon, epoxy resin and ceramic particles were used. Epoxy resin (LY 556) with room temperature curing hardener (HY 951 grade) with diluent DY 021 mix was employed as the matrix material. The carbon particles of 15 µm and the ceramic materials such as Silicon carbide and Alumina with average size of 40 µm (supplied by Snam Abrasives, Hosur) were used as reinforcement in the carbon-epoxy composite. The details of compositions are shown in Table 1

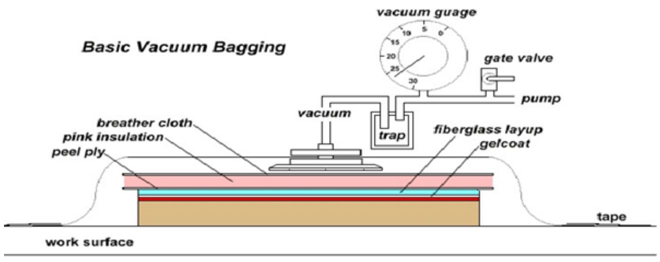
Table 1 Details of prepared composite

Samples	Epoxy (wt %)	Carbon (wt %)	SiC (wt %)	Al_2O_3 (wt %)
1	40	60	-	-
2	40	55	5	-
3	40	50	5	5
4	40	45	10	5

2.2 FABRICATION PROCESS

The fabrication process was done using vacuum bag molding.

The vacuum bag molding is the modification of the wet hand layup technique. The circular mold was prepared as per required dimensions (15 mm diameter and 180 mm length). The carbon-epoxy material and ceramic particles with different volume fractions was mixed and stirred manually. The mixed materials are poured into the prepared mold. The mold was placed inside the bag made of flexible film and all edges are sealed. The bag was then evacuated, so that pressure eliminates voids in the laminate, forcing excess air and resin from the mold. The laminate was then placed in the oven with 100°C temperature and kept for 1 hour for curing completely. The cutting operation was done for cutting the laminate into dimensions required for the test such as wear test, compressive test and hardness test.



2.3 HARDNESS TEST

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex. Hardness is an important characteristic which affects the wear behavior of the bearing material. Hardness depends on ductility, elastic stiffness and visco elasticity. The specimen is prepared as per ASTM D 785 – 08 standards and size of the specimen is 12 mm x12 mm. An appropriate scale is chosen to be used. The indenter moves down into position on the part surface. A minor load is applied and a zero reference position is established. The major load is applied for a specified time period (dwell time) beyond zero. The major load is released leaving the minor load applied. The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with a radius equal to half the diameter of the ball. The average of the two diagonals is used in the following formula to calculate the Brinell hardness. The intender used was 2.5 mm ball intender with a load of 187.5 N.

2.4 COMPRESSIVE TEST

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size. It can be measured by plotting applied force against deformation in a testing machine.The testing will be conducted using Universal testing machine. Some materials fracture at their compressive strength limit. Measurements of compressive strength are affected by the test method and conditions of measurement. The compressive strength is important characteristics of a bearing. The compressive strength is usually obtained experimentally by means of a compressive test. The apparatus used for this experiment is the same as that used in a tensile test. The specimen is prepared as per ASTM D 695 standards. The size of the specimen is 12.7 mm x 25.4 mm..

3. RESULTS AND DISCUSSIONS

In the present work, the friction and dry sliding wear behavior of carbon-epoxy composite without addition and with addition of ceramic particles were studied. The ceramic particles are added from 5% to 10%. The composite samples were studied in terms of the coefficient of friction and specific wear rate. The compressive strength and hardness are also studied for the samples.

3.1 HARDNESS

The hardness test was carried out in a Brinell hardness testing machine with ASTM standards to measure the hardness of the fabricated composites. The hardness values of composite for different compositions a\were shown in Fig 1. It is noted that the hardness value of the carbon-epoxy composite without ceramic particle is very less and addition of ceramic particle increases the hardness of the composites. This is because ceramic particles have good mechanical properties and which increases the hardness. The maximum hardness (51 BHN) is exhibited for carbon-epoxy composite with 10 % SiC and 5 % Al_2O_3.

Fig 1 Brinell hardness Testing Machine

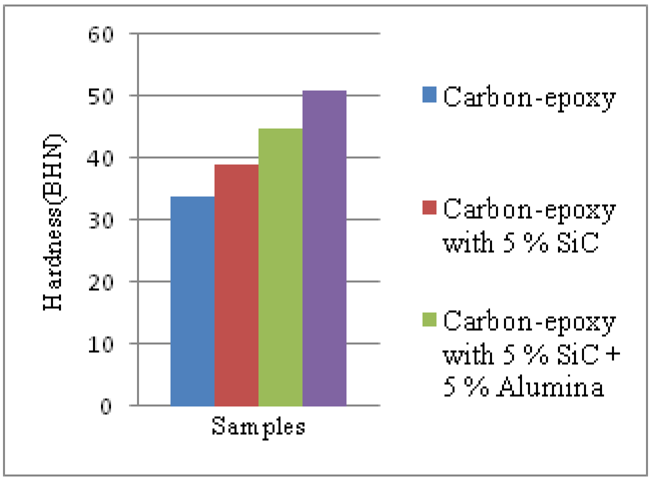


Fig 1 Hardness values for various fabricated composites

3.2 COMPRESSIVE SRENGTH

The compressive strength for the fabricated carbon-epoxy composite with addition of ceramic particle samples is shown in Fig 2. It is noted that compressive strength is low for carbon-epoxy composite without ceramic particle as 78.69 N/mm^2.

Fig 2 Universal Testing Machine

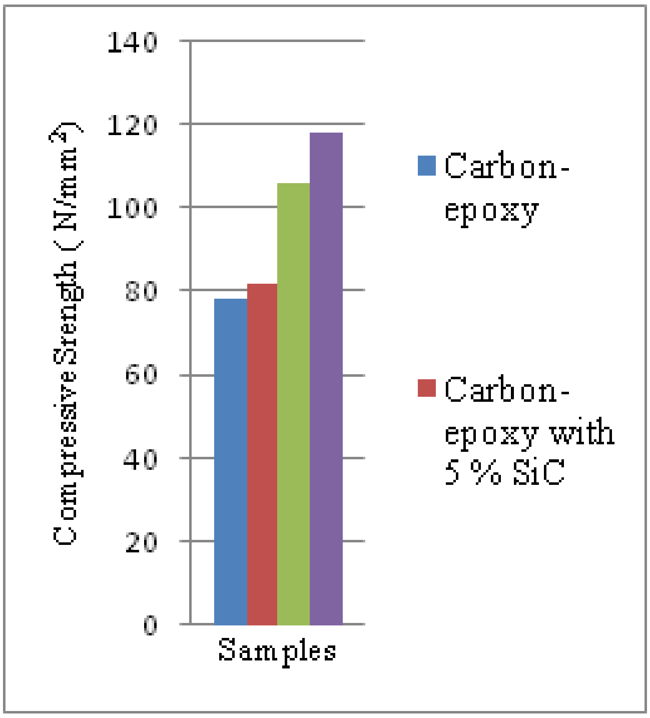


Fig 2 Compressive Strength for various fabricated composites

The strength increases with increase in weight percentage of ceramic particle content in carbon-epoxy composite. This is because ceramic particle has good mechanical properties. The highest compressive strength 118.48 N/mm^2 was exhibited for carbon-epoxy composite with 10 % SiC and 5 % Al_2O_3.

CONCLUSIONS

Based on the experimental observations, it was found that the compressive strength and hardness were improved with increase in weight percentage of filler content. The specific wear rate was also decreased with increase in weight percentage of ceramic particle in Carbon–Epoxy composite. The results show that wear properties were improved with increase in weight percentage of ceramic particles. The composite with 10 % SiC and 5 % Al_2O_3 different loads and hence may be suitable for bearing application. The plain journal bearing was fabricated with better wear resistance, for centrifugal pump and tested.

REFERENCES

[1] ASM Hand book, Materials Park, Ohio, USA, ASM International, 18 (1992).

[2] Suresha, B. Chandramohan, G.“Three body abrasive wear behavior of particulate filled glass vinyl ester composites” Jr. of material processing and technology, 200 (2008), 306-311.

[3] Suresha, B. Chandramohan, G. “The role of fillers on friction and slide wear characteristics in glass-epoxy

composite systems" Jr. of minerals and material characterization Engg, 5(2006), 87-101.

[4] Prehn, R. Haupert, "Sliding wear performance of polymer composites under abrasive and water lubricated conditions for pump applications" Wear, 259 (2005), 693-696.

[5] Wan, Y.Z. Chen, G.C. Raman, S. "Friction and wear behavior of three dimensional braided carbon fiber / epoxy composites under dry sliding conditions" Wear, 260 (2006), 933-941.

[6] Suresha, B. Ramesh, B.N. Subbaya, K/M."Influence of graphite filler on two body abrasive wear behavior of carbon fabric reinforced epoxy composites" Materials and design, 31(2010), 1833-1841.

[7] Gopala Krishna, K. Divakar, K. Venkatesh, K. "Tribiological studies of polymer based ceramic metal composites processed at ambient temperature" Wear, 266 (2009), 873-883.

[8] Unal,H. Mimoroglu, A. "Sliding friction and wear behavior of PTFE and its composites under dry conditions" Materials and design, 25 (2004), 239-245.

[9] Siddhartha, kuldeepgupta "Mechanical and abrasive wear characterization of bidirectional and chopped E-glass fiber reinforced composite materials" Materials and design, 35(2012), 467-479.

[10] Hui zhang, Zhongzhang, "Effect of fiber length on the wear resistance of short carbon fiber reinforced epoxy composites" Composite Sci. and Tech, 67 (2007) 222-230.

[11] Osman Asi, "An experimental study on the bearing strength behavior of Al_2O_3 particle filled glass fiber reinforced epoxy composite pinned joints" Composite Structures, 92 (2010), 354-363.

[12] Suresha, B. Kunigalshivakumar, Seetharamu, S. Sampathkumaran, P "Friction and dry sliding wear behavior of carbon and glass fabric reinforced vinylester composites", Tribology international, 43(2010), 602-609.

[13] Bekirsadikunlu, Sinankoksal, "Tribiological properties of polymer based journal bearings" Materials and design, 30 (2009), 2618-2622.

[14] Wang, L. Sindle, L.W. "Rolling contact silicon nitride bearing technology, a review of recent research" Wear, 246 (2000), 159-173.

[15] Guang Shi, Ming Qui zhang,"Friction and wear of low nanometer Si_3N_4filled epoxy composites" Wear, 254(2003), 784-796.

[16] Siddharatha, Amar patnaik, "Mechanical and dry sliding wear characterization of epoxy-TiO_2 particulate filled functionally graded composite materials using Taguchi design of experiment" Materials and design, 32 (2011), 615-627.

[17] Sandhayarani Biswas, Aloksatapathy,"Tribo performance analysis of red mud filled glass-epoxy composites using Taguchi experimental design" Materials and design, 30 (2009), 2841-2853.

[18] Zhenyu Jiang, Ladaantonavogyurova, "Study on friction and wear behavior of polyphenylene sulfide composites reinforced by short carbon fibers and micro TiO_2 particles" Composite Sci. and Tech., 68 (2008), 734-742.

[19] Pushkar Venkatesh kulkarni, Chaphnane, N.K. "Development and testing of PTFE based composite bearing material for turbine pump" IJEAT, 1 (2012), 2249-2258.

[20] Suresha, B. Siddaramaiah, Kishore, "Investigation on the influence of graphite filler on dry sliding wear and abrasive wear behavior of carbon fabric reinforced epoxy composites" Wear, 267(2009), 1405-1414.

[21] Basavarajappa, S. Ellangovan, S. "Dry sliding wear characteristics of glass-epoxy composite filled with Silicon carbide and graphite particles" Wear, 296 (2012), 491-496.

[22] Subbaya, K.M. Suresha, B. Rajendra, N. "Grey based Taguchi approach for wear assessment of SiC filled carbon-epoxy composites" Materials and design, 41 (2012), 124-130.