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Study of Wear Characteristics of Bone Particulate Reinforced Epoxy Composites

Harish.S[a1], Sanjeevamurthy[b], N S Venkatesh Guptha[c]

[a] Research Scholar, [b] Professor and [c] Professor

[a,b] Department of Mechanical Engineering, Sri Siddhartha Institute of Technology

[c] Department of Mechanical Engineering , Siddaganga Institute of Technology

Tumkur -572103, Karnataka, India.

ABSTRACT

Particulate reinforced epoxy composite is widely used in industrial application. The demand for development of low cost, less weight leads to production of new composite material. The aim of this paper is study the wear behavior of Epoxy with different wt% of bone particulate reinforced composite. The results show that specific wear rate decreases with increase in filler content. The wear volume loss and specific wear rate may be optimum for 6-7wt% of the filler material. SEM (Scanning electron microscopy) technique was used to validate the experiment results.

Key words: Bone particulate, Wear test, Scanning electron microscopy.

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1. INTRODUCTION:

The need for the use of newer materials to combat wear situations has resulted in the emergence of polymer based composite materials. Fiber/particulate reinforced polymeric composites are the most rapidly growing class of materials, due to their good combination of high specific strength and specific modulus. They are widely used for a variety of engineering applications. The importance of tribological properties convinced many researches to study the friction and wear behavior and to improve the wear resistance of polymeric composites. For fiber reinforced polymer matrix composites the process of material removal in dry sliding condition is dominated by four wear mechanisms, viz, matrix wear, and fiber sliding wear, fiber fracture and interfacial deboning [1].

Biological ingredients have several advantages such as high specific stiffness, strength, biodegrabiligy etc. They are available naturally and have low cost per unit volume basis [2]. The biological fillers can be used in the manufacture of particulate based polymer composites because they posses attractive physical and mechanical properties. Polymer composites have a special property of self lubrication and this made the composites suitable in tribological applications such as cams, seals, brakes, bearings [3]

Isiaka [4] investigated the influence of cow bone particle size distribution on the mechanical properties of polyester matrix composites in order to consider the suitability of the materials as biomaterials. It was found that fine cow bone particles lead to improved strength while coarse particles lead to improved toughness. The results also showed that these materials are structurally compatible and are being developed from animal fiber based particle. It is expected to also aid the compatibility with the surface conditions as biomaterials. From the literatures, it is clear that natural fibers can be used with improve mechanical properties. In this research, the relationship between the microstructure and mechanical properties of cow bone particle reinforced with epoxy is investigated in order to evaluate their uses as an engineering material and a biomaterial respectively.

2. EXPERIMENTAL DETAILS

2.1 Materials:

Epoxy is used as matrix material of resin LY 556 and hardener HY-951 (room temperature cure system) were procured from M/S Mustafa and sons, Bangalore, India. The resin is a clear liquid, its viscosity at 25° C is 10000 - 14500 MPa and density is 1.15-1.20 g/cc. The hardener is a liquid and its viscosity is 50-80 MPa and specific gravity is 1.59. The cow bone was procured from Indian bone mill, Nagamangala, Karnataka, India which one is washed repeatedly with acetone and dried at 60° C to remove moisture as well as dist and other greasy material. Then the bones were grounded using ball mill to the powder form. Then the powder bone is sieved to obtain the particulate size of less than 100µm.

2.2 Fabrication of Composite:

The composite fabrication consists of three steps: (a) mixing of the epoxy resin using a mechanical stirrer, (b) mixing of the curing agent with the filled epoxy resin, and (c) fabrication of composites. In the first step, a known quantity of filler was mixed with hot epoxy resin using a high speed stirrer to ensure the proper dispersion of filler in the epoxy resin. In the second step, the hardener was mixed into the filler filled epoxy resin using a mechanical stirrer. The ratio of epoxy resin to hardener was 10:1 on a weight basis. After transferring the mixture to the moulds, the composites were cured at room temperature under a pressure of 0.1 MPa (1 bar) for 24 hours and it was post cured up to three hours at 100^0C. The laminates of dimensions 300 mm X 300 mm X 2.8 ± 0.2 mm was fabricated and the specimens for the required dimensions of 5mm X 5 mm were cut using diamond tipped cutter for the required test.

3 MATERIAL TESTING

A dry sliding pin-on-disc (POD) setup was used for the sliding wear tests. The tests were conducted according to ASTM G99 standard. The fabricated specimen (5 mm X 5 mm X 2.6 mm) was glued to the pin of 10 mm diameter and 25 mm height, which came in contact with a hardened En32 steel disc of hardness 55 HRC. The steel disc was polished with water proof SiC emery paper (600 grade) in order to obtain a surface roughness of 0.651m. The test pin was mounted on the lever arm. the applied normal loads were 10 and 20 N, and the sliding velocity was 1.5 m/s. Sliding distance varied from 2,000 8,000 m in steps of 2,000 m. The surface of the specimen was cleaned was cleaned with a soft tissue paper soaked in acetone and with compressed air before and after the test. The specimen weight is recorded using an electronic balance. The difference between initial and final weight of the specimen were measured as the sliding wear loss. The frictional force is measured by attaching a force transducer on pin-on-disc machine and it touches the loaded lever arm. The weight loss was converted into volume loss by using measured density of the specimen. A minimum of three trials was conducted to ensure repeatability of test data.

The worn surface of the composite specimen was examined using a scanning electron microscopy. The wear was measured by the loss in weight, which was then converted into wear volume using density data. The specific wear rate (K_s) was calculated from equation (1)

$$K_s = \frac{\Delta V}{LXD} \ \ \mathrm{mm^3/N-m}$$

4. RESULTS AND DISCUSSION:

4.1 Mechanical properties:

The mechanical properties of epoxy composites reinforced with bone particles are illustrated in table 1, lancaster [7] and Ratner et al [8] have done correlation of wear volume loss with selected mechanical properties such as ultimate tensile strength, elongation and hardness have been reported for single -pass studies of polymers.

Table 1 : Mechanical properties epoxy and reinforced epoxy composites

	Pure epoxy	Epoxy+3wt% bone particles	Epoxy+6wt% bone particles	Epoxy+9wt% bone particles
Tensile strength(Mpa)	380	388	391	394
Elongation(mm)	3.2	3.26	3.29	3.32
Hardness	81	82	83	85

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Retner et al [7] proposed a model which states that the rate of material removal is inversely proportional to the product of stress and strain at rupture. The phenomenon is similar to what is reported in reference [7] in spite of the fact that polymeric materials, testing configuration and conditions are different.

4.2 Sliding wear loss and Specific wear rate

Graphical plots of wear volume as a function of sliding for 0, 3, 6 and 9 wt% bone particulate filled composite at two different loads with constant velocity of 1.884 m/s for varying sliding distances (2000 m - 8000 m) are shown in fig 1 and fig 2. The reinforced composite exhibits lower wear loss compared to pure epoxy. Wear volume loss showed an upward trend in the gradient, as the sliding distance increased, and the same is noted for all the composites tested at all the loads. This result may be due to an increase in temperature which occurred during the wear process. The wear resistance increases as the reinforcement percentage is increased and the enhancement of wear resistance is marginal between 6 to 9wt% reinforcement.

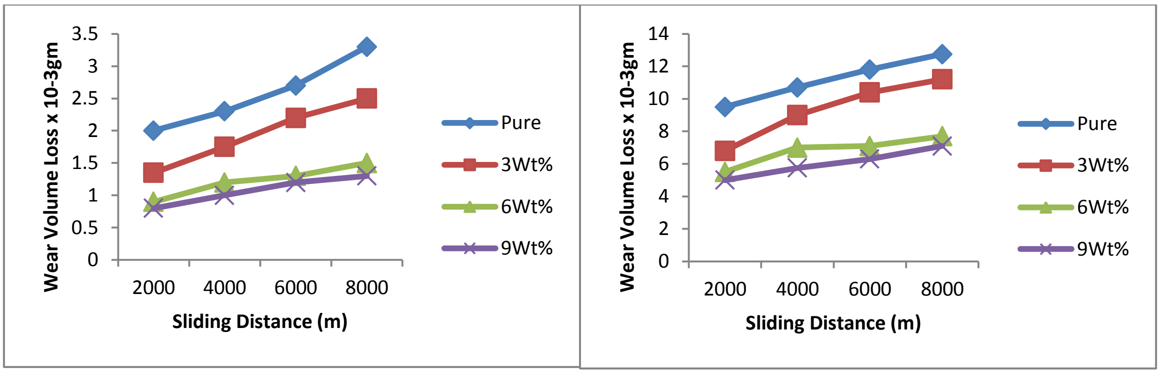

Fig. 1: Wear Volume Loss as a function of sliding distance at (a) 10N and (b) 30N

The specific wear rate decreases linearly with increase in sliding distance. The 9wt% reinforced composite shows the smallest specific wear rate. It may be noted that the resistance offered to wear is larger in 9wt% reinforced compared to unfilled composite, the lesser wear in such composite is on the expected lines. This can be attributed to improve interfacial bonding between the matrix and the reinforcement.

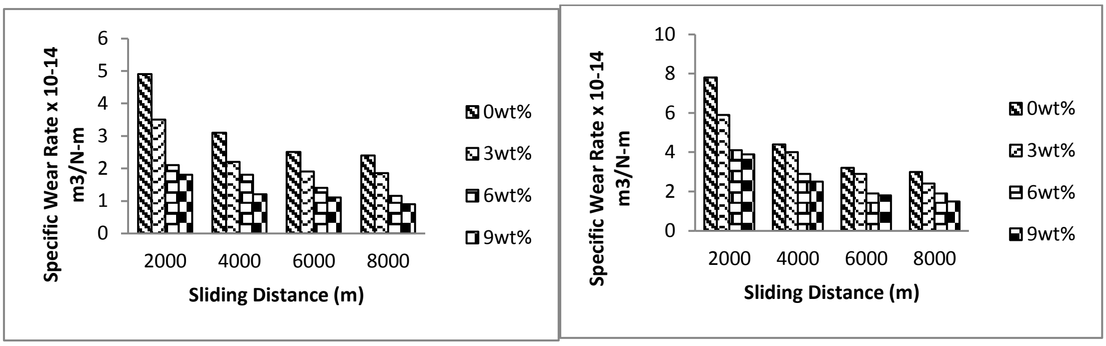

Fig. 2: Specific Wear rate as a function of sliding distance at (a) 10N and (b)

In case of lower sliding distance, polymer matrix rubs with the metallic counterparts. The wear debris consists of shear deformed polymer matrix containing broken pulverized matrix particles and wear powder of the metallic counter surface. The particles can either act as debris or form a transfer layer. In such cases, their component can cushion the counter surface asperities of the composite and reduce the effective toughness, but the pulverized matrix particles and wear powder of the metallic counter surface can act as a third body abrasive, leading to enhanced roughening of the counter surface. Thus, specific wear rate of the composite depends on the various particles in the wear debris. During wear process, no transfer film was formed on the counter surface leading to higher specific wear rate for lower sliding distance.

4.3 Co-efficient of friction

The reinforced particles usually play a major role in the interface quality of the composite material, the capability to transfer stresses and elastic deformation of the matrix materials [5]. If the filler matrix interaction is poor, the reinforcement are unable to carry any part of the applied load, In that case, good wear resistance cannot be expected. If the bonding between the polymer matrix and reinforcement is instead strong enough; the yield strength of the filled composite can be higher than that of the unfilled composite. Similar way, the difference in reducing the friction coefficient and improving the wear resistance of unfilled Epoxy composite and reinforced filled composites are mainly from the adhesion strength of the filler-matrix.

Major load is supported by the fillers, resulting in increased wear resistance of the composite. Bone particles improve the adhesion of the transfer film to the counter surface and thereby reduce the wear process.

5. WORN SURFACE MORPHOLOGY

The SEM feature of worn surface of 0wt%, 3 wt%, 6wt%,and 9wt% composite at a load of 30N and 8000m sliding distance at constant velocity of 1.884 m/s shown in figure 3 and 4. Several mechanisms have been proposed to explain how the composite material is removed from the surface during the sliding wear process. Which involves matrix fracture, peeling of matrix, fibre-matrix de-bonding, shear deformation of the reinforcement, with the help of SEM micrograph, it is possible to identify qualitively the dominant wear mechanisms under sliding. In case of higher load and higher sliding distance, most of the matrix material was taken out and loosening of the fibers results in the exposure of the fibrous region to sliding contact. The area under the sliding contact often transmitted the tribo-film, the fiber ends undergo severe thinning along their length.

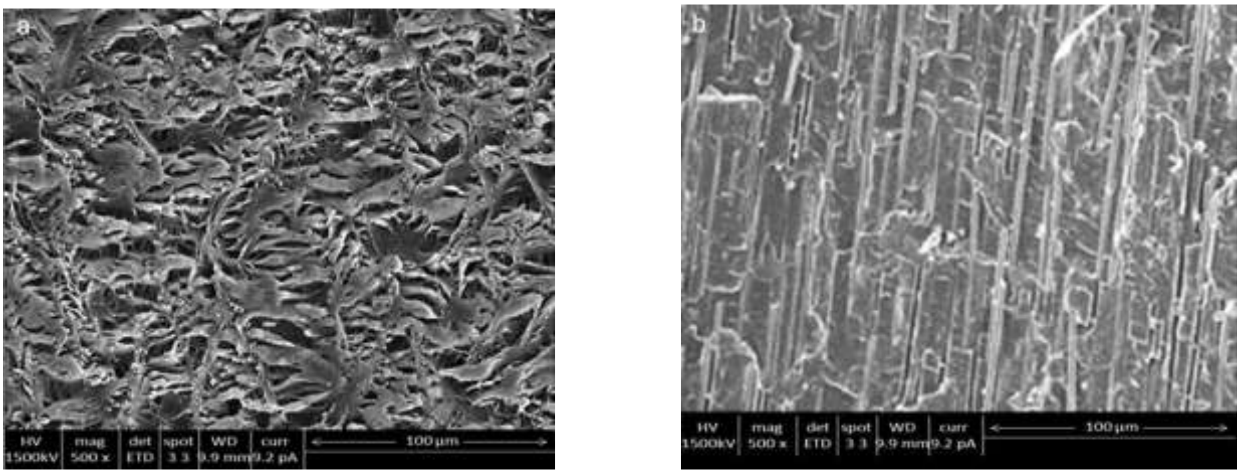

Fig 3: SEM images (a) 3wt% and (b) 6wt% Composite at 30N, 8000m Sliding distance

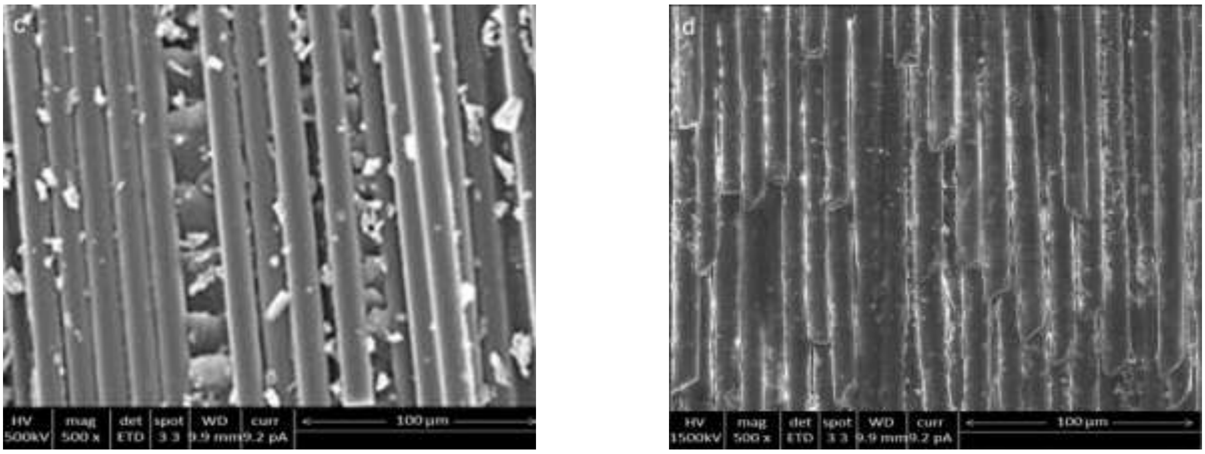

Fig 4: SEM images (c) 6wt% and (d) 9wt% Composite at 30N, 8000m Sliding distance

6. CONCLUSION

From sliding wear studies of pure, 3, 6,and 9wt% composites, the following conclusions could be drawn:

1. Sliding wear loss increases with the increase in abrading distance/applied load for all the composites. however, the 3,6 and 9wt% composites showed better sliding wear resistance

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2. SEM studies of worn out surfaces support the damage to the matrix, exposure of fibres, crushed and fragmented fibres and de-bonding of matrix and filler in composite system.

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