# Friction and Wear Behaviour of Silica Carbide-Alumina Nano Composites

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**Abstract**

Polymer Nanocomposites has many advantages over microcomposites from the viewpoint of tribological properties, it is not always valid to assume that nanofillers invariably improve the friction and wear properties. In this study an attempt has been made to develop polymer matrix Nanocomposites using silica as micro filler material along with Nano-particles of alumina in order to operate under high co-efficient of friction and to achieve low wear rate. Samples with different volume fractions are prepared (i.e. 0, 10, 20, 30, and 40% by weight). Wear properties of the composite are evaluated with different load conditions with a constant sliding velocity. And an attempt was made by adding 5% alumina Nano particles to the traditional fillers and compared with traditional fillers and the objective is achieved by Nano fillers.

***Keywords**: Nanocomposites, Traditional fillers, Pin-on-disc machine, Abrasive wear*

## 1. Introduction

Polymeric materials are become more and more important in various industries as attractive substitutes to metals. Polymer composites are well known for offering engineers high strength-to-weight ratios and flexibility in material design [1, 2]. Recently polymeric nano composites attracted the interest of many researchers and industries all over the world, and many works has been published on the thermo-mechanical properties of nano modified thermoplastic or thermosetting matrices [3, 4]. Composites are often created to increase the wear resistance of a particular polymer matrix. In recent years, there have been a number of successful composites made by blending nanofillers in polymeric matrices [5–12] and also many studies have been conducted on the friction and wear of polymers [13–15]. Nanocomposites are materials that are created by introducing nanoparticulates into a microscopic sample material. This is part of the growing field of nanotechnology. The nanomaterials tend to drastically add to the electrical and thermal conductivity as well as to the mechanical strength properties of the original material. In general, the nano substances used are carbon nanotubes, nanoparticles and they are dispersed into the other composite materials during processing. The percentage by weight of the nanomaterials introduced is able to remain very low (on the order of -5% to 5%) due to the incredibly high surface area to volume ratio of the particles. Much research is going in to developing more efficient combinations of materials and to impart multifunctionalities to the Nanocomposites. Some researchers explained about the enhancements of the wear resistance of epoxy using various fillers [16]. In this work an attempt has been made to develop polymer matrix composite using SiC as filler material along with Nano-particles of alumina to prepare the nano composites.

## 2. Experimental Details

*2.1 Material*

- Traditional fillers (silica carbide)
- Nano materials ($Al_2O_3$)
- Matrix material

*2.1.1 Traditional fillers (SiC)*

Silica Carbide is the only chemical compound of carbon and silicon. It was originally produced by a high temperature electro-chemical reaction of sand and carbon. Silicon carbide is an excellent abrasive material.

*2.1.2 Nano materials ($Al_2O_3$)*

Nano-aluminum alloys are sub-classified into nanocrystalline aluminum, nanophase aluminum, or amorphous aluminum, with the common theme that the source of property improvement is to produce highly refined (in some cases noncrystalline) microstructures on the nanometer scale. The primary driving force for development of nano-aluminum is the potential for large increases in strength. Some alloys that have been developed in Japan are called "GIGAS" because they have tensile strength in the one gigapascal (145 ksi) range. Strengthening results from the very fine size of the grains coupled with dispersion strengthening in nanocrystalline alloys and the hindrance of dislocation motion in amorphous alloys. A recent article indicates that these types of alloys are now seeing use in applications such as rapidly repeating machinery parts requiring high specific strength and high specific modulus, as well as main construction parts in robots in Japan. In addition to increases in strength, there are also now reports of improved fatigue properties and high strain rate super plastic forming ability that could bode well for other applications. Improved strength retention at elevated temperatures has also been measured.

*2.1.3 Matrix Material*

Epoxy LY 556 is the resin which is used as the matrix material. Its common name is bisphenol-A-diglycidyl-ether and it chemically belongs to the ‘epoxide’ family. The epoxy resin and the hardener are supplied by Ciba Geigy India Ltd

*2.2 Methods*

*2.2.1 Preparation of Nano particles of Alumina ($Al_2O_3$)*

Nano particles can synthesize by Auto combustion synthesis and Precipitation process

Auto combustion [17]process involves heating and stirring up of the solution until the solution changes to gel form and once the solution changed to gel then stop stirring and heating is continued till it forms foamy mass and still heated up to remove all the water molecules present in the solution.

Precipitation [18, 19] of an element due to its high concentration can take place in soil solutions. This reaction takes place when the solution becomes supersaturated with respect to that element. A supersaturated solution is a solution containing more solute (in this case the dissolved element) than allowed at equilibrium. This type of solution is unstable and any further addition of solute will cause the precipitation of an insoluble solid.

Pot milling is carried out by rolling of the balls on material as well as frequent impact of balls. The sample kept in the pot along with balls of suitable material and pot rotates on P.U. coated support rolls. The pot rotational speed can be set from 20 to 200 rpm. Pot rotates about its axis, while balls inside the pot spin about their own axis in the same direction, the material gets trapped between the inner wall of bowl & balls and gets rolled over by weight of balls and thus gets pulverized.

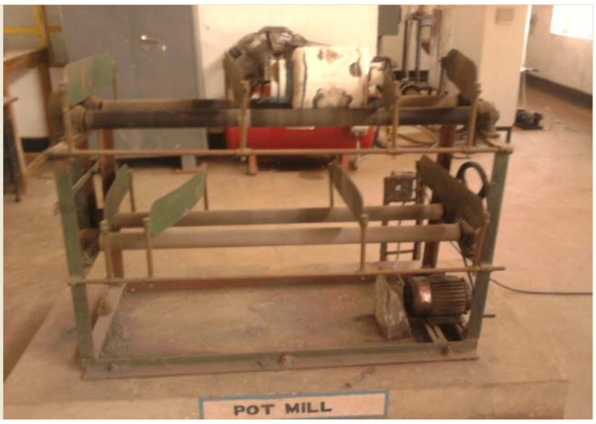

Fig.1 Pot milling

### *2.2.2 Preparation for the test specimens*

The different amount of silica carbide particles has been added to the resin to prepared composite samples with 10%, 20%, 30% and 40% weight fractions of particulates to manufacture pin type composite sample a steel mould has been used in this work which is shown in Figure 2. The mixture of silica carbide particles and resin has been poured into the cylindrical cavity present in the mould and then the two halves of the mould fixed properly. During fixing some of the resin mix has been squeezed out. Therefore care has been taken for this in the experiment to make composite pins of length 35 mm and diameter of 10 mm. The samples were kept in the moulds for curing at the room temperature ($28^0$C) for 36hr. No particulate filler is used in these composites. The other composite 30 SiC +5% $Al_2O_3$ with $Al_2O_3$ nano fillers are fabricated by the same technique. The mix is stirred manually to disperse the particulate fillers in the matrix.

For the purpose of comparison the matrix material was also cast under similar condition. After curing the samples were taken out from the mould, finished ground to required shape, sizes for wear testing.

### *2.2.3 Dry sliding wear test*

Abrasive wear studies were carried out under multi-pass condition on a pin-on-disc type wear machine. Abrasive paper of 400 grades (grit-23 µm) was pasted on a rotating disc (EN 32 Steel disc) of 120mm diameter using double-sided adhesive tape. The specimens under tests were fixed to the sample holder. The holder along with the specimen (Pin) was positioned at a particular track diameter. This track diameter is to be changed after each test (i.e.) a fresh track is to be selected for each specimen under different applied loads for five intervals of 5min. where each time interval corresponded to a sliding distance of 622 m. The effects of various load (5, 7.5, 10 and 15 N) and sliding velocities (0.418m/s) in a track radius 40mm were studied. The samples were cleaned by using Acetone to remove any debris adhered to sample before and after each run. The weight loss was recorded by weighing the pin to an accuracy of $1\times10^{-3}$ gm using an electronic balance after each run. The specific wear rate ($k_0$) was calculated using equation (1)

$$k_0 = \frac{w}{\rho \times L \times F} \quad (1)$$

where $k_0$ is the specific wear rate in $m^3$/Nm, w is the weight loss in grams, ρ is the density of sample, L is the sliding distance in meter, and F is the applied load in Newton.

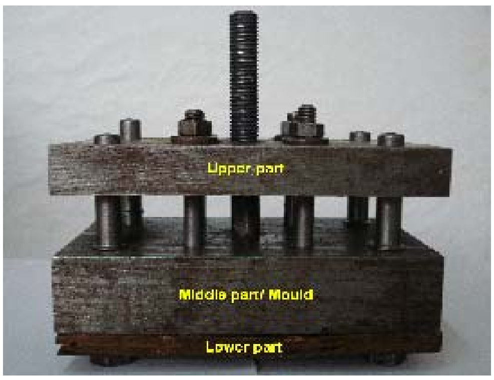


Figure-2 (a)

Figure-2 (b)

Fig.2 Steel Mould and prepared pin type composite samples
(a)Mould used for preparing samples (b) Two halves of the mould

### 3.0 Results and Discussion

*3.1 Density*

The composites under this investigation consists of three components namely matrix, fiber, and particulate filler. The density ($\rho_{ca}$) of the composite, however, can be determined experimentally by simple water immersion technique. The densities of the composites are presented in the table 1. Figure.3. shows the variation of density of SiC and Nano material filled epoxy composites with fiber content. Table 1

Table 1 Densities of the composites

| S.l. no | Composites | Density(gm/cc) |
|---|---|---|
| 1 | 0% | 1.080 |
| 2 | 10% | 1.305 |
| 3 | 20% | 1.403 |
| 4 | 30% | 1.565 |
| 5 | 40% | 1.586 |
| 6 | 30SiC+5$Al_2O_3$ | 1.570 |

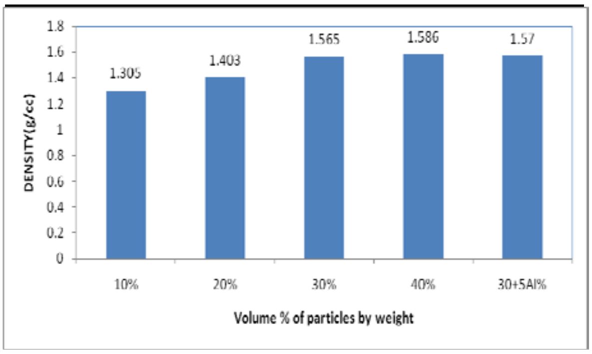


Fig.3 Variation of density with fiber content

*3.2 Abrasive Wear*

Figure.4. Shows the influence of load on the abrasive wear of the traditional filler weight fraction (ie) SiC, and traditional filler with addition of 5% $Al_2O_3$ nano particles respectively at sliding velocity of 0.418m/s. The wear rate increases with the normal load (5, 7.5, 10, 15N). Wear rate was relatively low at lower load (5N) load because of less penetration and less numbers of abrasive particles were in action with rubbing surface. The abrasion wear was greatly increased at higher load due to most of the abrasive particles were penetrated into the surface and created more grooves resulting in more material removal by a severe plastic deformation. It is seen from the plot that with addition of SiC ceramic particles the wear rate of the composite decreases. It is also seen from the plots that the wear rate first decrease up to 30% volume fraction of SiC and then started increasing from 40% of weight fraction of SiC.

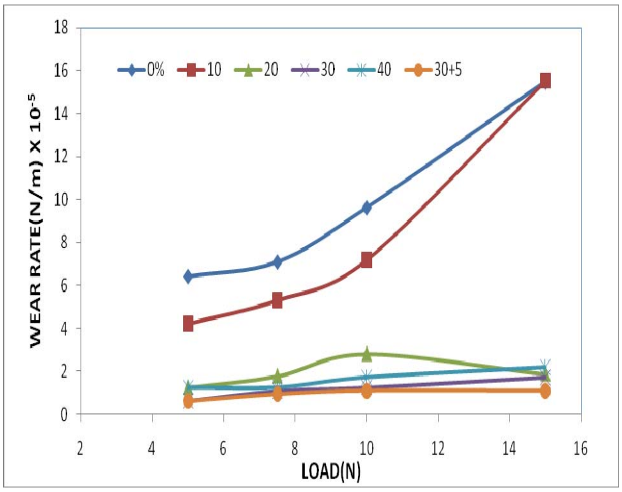


Fig.4 Variation of density with fiber content

Figure.5. shows the variation of co-efficient of friction with normal load. It is clear from the figure that the co-efficient of friction increases initially to a higher value due to the fresh abrasive paper and as the process continues it almost remains same for the entire test period. It is also seen that the co-efficient of friction decreases when the weight fraction of reinforcement is more.

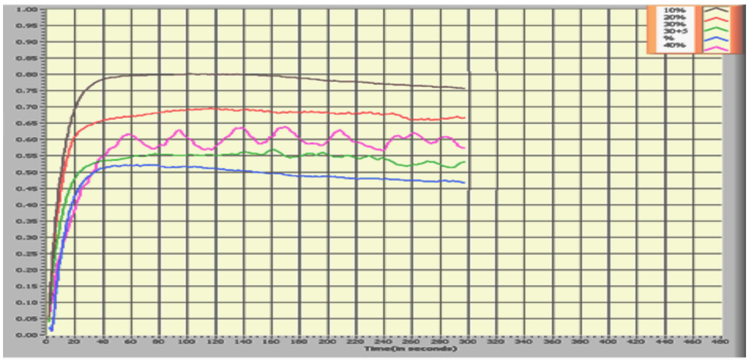

Fig.5 Variation of co-efficient of friction with time

## 4.0 Conclusions

- The traditional fillers SiC can successfully be utilized to produce composite by suitably bonding with resin for value added product.
- Amorphous silica carbide provides the higher hardness values.
- The incorporation of silica carbide particulates into epoxy can significantly reduce abrasive wear loss. The optimum wear resistance property was obtained at the particle content of 30% weight fraction.
- The addition of nano particles that incorporated along with traditional particulate filled samples further reduced were and coefficient of friction

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