Investigation on the Influence of Nano Filler on Tribological Behaviour of Glass-Nylon fiber reinforced epoxy based Hybrid Composites

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Abstract. From the last few decades in engineering applications the polymer matrix composites (PMC’s) were used over conventional engineering materials due to their improved properties and enhanced performance. The researchers are encouraged to perform comprehensive research work on such materials. The tribological behaviour of a glass-nylon fiber reinforced epoxy based hybrid composite material filled with alumina nanoparticles in three different compositions of 0.5%, 1.0 % and 2.0% have been investigated thoroughly using different load and speed conditions. Effect of Alumina nano particles on tribological properties like wear rate, wear loss and coefficient of friction on the Glass-Nylon fiber epoxy based hybrid composite has been studied. The experimental results have showed that hybrid composite with an increase in the percentage of nano filler enhances the tribological property up to 1.0% of nano filler and then shows a declining nature.

Keywords: Hybrid Polymer matrix composites, Nano Fillers, Alumina, Wear.

1. Introduction

Special materials are in great demand for innovative applications in engineering, leading to new inventions in the field of composites. A new trend in engineering has begun to optimize individual properties in order to understand a particular material. The current importance in research area is more on thermoset composites as it is superior in terms of engineering properties and applications. Due to ease in manufacturing and its properties like higher strength and durability, composite materials are gaining importance [1, 2]. Polymers are transformed to achieve high strength to weight ratio and low density, different types of fillers and fibers are reinforced into it [3, 4]. Moreover manufacturing industries, including aerospace, automobile, ships, infrastructure, and petroleum are focussing more on fabric-reinforced polymeric composites [5-7].

The improvement in the performance of composites is observed due to micro or nano filler inclusion in polymer matrix. The reinforcement of filler is not only to reduce the cost of the material but also to
enhance the mechanical, thermal and tribological properties [8]. Alumina is recognised as an important ceramic material used in the fields of aerospace, automotive, packaging industry etc., as it has high strength, excellent corrosion resistance, low thermal conductivity, and better electrical insulation properties [9]. The “pin on disk machine” has been used to study the wear and frictional properties of epoxy based polymer composites under various load and speed conditions [10-12]. An effort is made to enhance the wear characteristics of a hybrid thermoset composite by reinforcing the nano alumina filler under variable parameters [13, 14].

2. Materials and Preparation of Hybrid Samples

The α-Al2O3 nanopowders were purchased from Platonic Nanotech Private Limited, Jharkhand with an average particle size of 30 - 50nm. The type of epoxy resin used in the present investigation is Araldite LY-556 together with HY 951 hardner. The wear test was conducted on three types of samples with the variation of nano Al2O3 percentage i.e 0.5%, 1.0% and 2.0% and the Glass fiber and Nylon fiber of 15% each as per the results from tensile, flexural and modulus test results. The effect of 0.25 % nano Al2O3 on tensile, flexural and modulus test results found to be comparatively lower; hence only 0.5 % to 2.0 % variation is considered for wear test [15]. To avoid the adhesion of composite to mold, a release coating is applied on the bottom and inner mold surface. The prepared sample is kept to cure at ambient temperature for one day. Later, the post-curing has been done at a temperature of 100 ± 5°C for 2 hours in a hot air circulated furnace.

3. Experimental Procedure

Two-body abrasive wear test was conducted using a Pin on Disk Apparatus as per ASTM G99, Test Method [16, 17]. The sample of 10mm×10mm×4mm was attached to a holding pin at one surface, which was fabricated manually. Before the test the sample surface was cleaned using a soft paper that is soaked in acetone. Abrasive paper of 320 grit size was pasted on rotating disc. The composite specimens were abraded against a metal disc at a load of 20 N, 40 N and 60 N for 10 minutes at speeds of 1200 RPM, 1500 RPM, and 1800 RPM on a track of 100 mm diameter. Wear volume (ΔV) and specific wear rate ( Ks ) were calculated using the following equations Eq.1 and Eq.2 :

\[
\Delta V = \frac{\Delta m}{\rho} \quad (\text{mm}^3)
\]

\[
K_s = \frac{\Delta V}{Ld} \quad (\text{mm}^3/N\cdot m)
\]

Where, Δm is the loss in mass gms, ρ is the density of the test material in g/mm3, ΔV is the volume loss in mm3, L is the load in N, and d is the sliding distance in meters. The sample density was calculated by measuring its mass individually and dividing the volume.

4. Results and Discussion

The tribological study is done using three parameters, COF, Wear loss, and specific wear rate for various nano filler percentage, different speeds and load conditions. The hybrid nano composites with various nano filler percentage (0.5%, 1.0%, and 2.0%) at different sliding speeds (1200, 1500, and 1800 RPM) under dry sliding conditions is used to study the variation in different parameters.

4.1. Co-efficient of Friction

From the graphs (Fig.1), it is observed that COF decreases with percentage increment in filler content for lower loadings, but increases from 1.0 % to 2.0% filler addition. The increase in applied load leads to the temperature rise at the interface. Also, it is observed that at 1800 RPM has low COF than that noticed at other speeds. Thus, under dry sliding conditions, the COF decrease with lower applied load and speed leads to higher temperatures generated at the interface. The temperature increases as the filler content increased above 1.0% due to agglomeration of alumina in the epoxy and may be related to a weaker filler matrix interface and/or non-homogeneous filler distribution. Hence the increase in
the friction coefficient noticed in the results. This heat transfer, loosen the fibers in the matrix and shear easily due to higher axial thrust.

![Figure 1](image-url)

**Figure 1.** COF of hybrid nano composites at 20 N (a), 40 N (b) & 60 N (c) Load.

### 4.2. Specific Wear Rate

The result shows (fig.2) irrespective of the sample type a high rate of decrease in specific wear rate with an increase in applied load initially. Beyond 1.0% nano filler addition there no drastic decrease in the specific wear rate noticed. This behaviour of the hybrid composite may be due to once the initial abrasion of epoxy matrix, the fibers which are exposed, and some of the worn particles clog to the abrasive paper, and further wear loss is been restricted [18]. As the load is increased further, the micro cracking of resins, as well as the micro cutting process of fibers in to tiny sections may also increase proportionally. But the existence of debris on the rubbing surface reduces additional abrasion. Hence the wear rate reduction is witnessed with load increment.
4.3. Wear Loss

It is obvious from the sample results (fig.3) that the hybrid nano composites wear decreases with an increase in nano filler percentage initially irrespective of the sample composition. It is also observed with an increase in speed, the wear loss was higher compared to lower speeds. Beyond 1.0% nano filler addition, not a considerable amount of decrease in wear loss is noticed. This behaviour of the hybrid nano composite is due to after the primary abrasion of the epoxy matrix, the fibers which are open to the surface and some worn particles clog to the abrasive paper, and further wear loss will slow down. The fiber debris is observed at the surface of the samples attributed to the twisting forces acting between the fibers efficiently contribute to higher wear resistance at higher load and speed. This will result in clogging of nano filler as well as worn out fibers. The wear loss change follows almost shows a linear trend at higher load. This behaviour is due to, when the material is in touch with the abrasive surface; the wear loss is high. As load and filler content increased, some of the worn particles clog on the abrasive surface, and further wear loss will slow down [18].

Figure 3. Wear Loss of hybrid composites at 20 N (a), 40 N (b) & 60 N (c) Load
5. Conclusion
The prepared hybrid nano epoxy based composites exhibit better anti-frictional behaviour with the reinforcement of aluminum nano particles. This behaviour is observed up to 1.0% of Nano filler addition. The COF of the nano hybrid epoxy based composites at 1800 RPM shows lower value compared to other tested speeds, indicating better nano filler interaction between the matrix and fibers. This behaviour of Nano composite is further attributed to a decrease in wear loss and specific wear rate, due to particles clog into the abrasive surface.

6. References
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