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Two-Body Abrasive Wear Analysis of Epoxy Composites Reinforced with Short Sisal Fibres

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ABSTRACT

In the last few decades, natural fibre-reinforced polymer composites have received substantial attention in the field of research and innovation. Fibre-reinforced polymer composites are in great use because of the good properties and superior advantages of natural fibre over synthetic fibres in terms of its relatively low weight, low cost, less damage to processing equipment, good relative mechanical properties, improved surface finish, renewable resources, being abundant, bio-degradability and minimal health hazards. The present work aims at developing a class of polymer composites consisting of thermoset polymer i.e. epoxy as a matrix material with natural fibre i.e. sisal fibre as a reinforcing material. A set of composites with varying fibre loading has been fabricated by a simple hand lay-up technique. The effect of fibre content on the sliding wear behaviour of such fabricated samples is investigated and presented in this work. From the experimental results, it is found that with an increase in fibre content, the sliding wear rate decreases. Whereas with an increase in sliding velocity and applied load sliding wear rate increases.

Keywords: Polymer matrix composites, Epoxy, Sisal fibre, Sliding wear behaviour.

1. Introduction

Natural fibres in simple definition are fibres that are not synthetic or manmade. They can be sourced from plants or animals. Among the two natural fibres obtained, plant fibres find more potential applications in polymer composites. Natural fibres obtained from plants are harvested from renewable resources and are readily available at low prices. Their specific properties are comparable to synthetic fibres (e.g., glass fibres) that are traditionally used as reinforcing phases in polymer-based composite materials [1]. The plant, which produces cellulose fibres can be classified into bast fibres (jute, flax, ramie, hemp and kenaf), seed fibres (cotton, coir and kapok), leaf fibre (sisal, pineapple and banana), grass and reed fibres (rice, corn and wheat) and core fibres (hemp, kenaf and jute) as well as all other kinds (wood and roots) [2].

Among the different types of natural fibres, sisal fibres is a promising reinforcement for use in composites on account of its low cost, low density, high specific strength and low modulus, no health risk, easy availability & renewability. In recent years there is increasing interest in finding new applications for sisal fibre composites that are traditionally used for making ropes, mats, carpets, fancy articles, etc. Suppakarn and Jarukumjorn [3] presented the flame retardancy behaviour of sisal fibre-reinforced polypropylene composites with and without using flame retardant material. In their study, they found that the addition of flame retardants into sisal/PP composites reduced the burning rate and increased the thermal stability of the composites. Martin et al. [4] studied the thermal analysis of sisal fibre by thermogravimetric analysis and differential scanning calorimetry under air and nitrogen atmospheres. By both the above analysis, they show that cellulose and hemicellulose degraded at lower temperatures than that of the raw sisal fibre, which can be attributed to the removal of lignin.

Zhou et al. [5] work on the development of polymeric composites reinforced with sisal fibres. The main aim of their work is to propose a composite material which will be stronger so that can be used in place of timber structures. They present the mechanical characterization of composites under study. In more recent work, Fiore et al. [6] proposed another method for improving the surface properties of sisal fibre. They utilized eco-friendly and cost-effective surface treatment methods based on the use of commercial sodium bicarbonate (i.e. baking soda) on the properties of sisal fibre and its epoxy composites. Ramesh et al. [7] fabricated hybrid composites with a combination of synthetic and natural fibre. They used sisal and jute fibre as natural fibre and glass fibre as synthetic fibre in their study. They reinforced the combination of these fibres in polyester resin and fabricated a new class of composites.

Orue et al. [8] studied the effect of different chemical treatments on sisal fibre as well as on the tensile properties of their composites with polylactic acid (PLA) as a matrix material. Among the various treatment agent, alkali-treated fibres showed the highest tensile strength values. More recently, Dwivedi et al. [9] fabricated and studied the behaviour of a hybrid composite with carbon nanotubes and sisal fibre as reinforcement in epoxy resin. They investigated the electrical properties of the fabricated composites. In very recent work, Prasad et al. [10] studied the impact strength of sisal fibre polyester composites. For this study, they used treated and untreated sisal fibre as reinforcement. Against this background, an attempt has been made in this research work to develop short sisal fibre (SSF) based epoxy composites using a simple hand lay-up technique and to study their sliding wear behaviour.

2. Material considered

Thermoset resin Lapox L12 is a liquid, unmodified epoxy resin of medium viscosity that is used as the matrix material in the present investigation. It is used with its corresponding hardener which is a low viscosity room temperature curing liquid. Hardener K6 is commonly employed with Lapox L12. The epoxy used in the present investigation possesses a density of 1.1 g/cc, tensile strength of 48 MPa, compressive strength of 91 MPa and flexural strength of 118 MPa. The sisal fibre used in the present work was extracted from the leaf of the plant Agave-Sisalana which is available in plenty in the Southern part of India. It is a herbaceous monocotyledonous plant from the Agavaceae family that consists of a rosette of sword-shaped leaves about 100–150 cm tall and 13–15 cm wide. A sisal plant has a 7–10 year lifespan and produces about 200–250 leaves. When the plant completed two years of its growth, the fibre can be extracted from the sisal leaf. By this, they reach a length of 80-100 cm. Among the various natural fibres, sisal fibre is chosen in the present work because it is easily and cheaply available. Also, it possesses reasonably good physical and mechanical properties. Sisal fibre possesses a density of 0.75 g/cc and tensile strength of 511 MPa.

3. Sample Preparation

In the present investigation, a short fibre-reinforced polymer composite is fabricated using a simple hand lay-up technique. The fabrication of composite using the hand lay-up method involves the following steps:

1. The room temperature curing epoxy resin (L-12) and corresponding hardener (K-6) are mixed in a ratio of 10:1 by weight as recommended.
2. Sisal fibre in its short form with an approximate size of 3 mm will then be added to the epoxy-hardener combination and mixed thoroughly by hand stirring.
3. Before pouring the epoxy/filler mixture into the mould, a silicon spray is done over the mould so that it will easy to remove the composite after curing. The uniformly mixed dough is then slowly poured into the mould so as to get the specimens as per ASTM standards for the entire characterization test.
4. The cast is then cured for 8 hours before it was removed from the mould. In this process, the exothermic reaction between the matrix and hardener occurs which hardened the composite body in this specified duration.

Composites were fabricated with different weight fractions of filler ranging from 0 to 10 wt. %. The list of fabricated composites in the present work is presented in Table 1.

Table 1 List of fabricated composites

S.No.	**Set**	**Composition**
1	Set A0	Neat Epoxy
2	Set A1	Epoxy + 2 % by weight SSF
3	Set A2	Epoxy + 4 % by weight SSF
4	Set A3	Epoxy + 6 % by weight SSF
5	Set A4	Epoxy + 8 % by weight SSF
6	Set A5	Epoxy + 10 % by weight SSF

4. Experimental details

The wear test is performed on a pin-on disc wear tester, where a pin is loaded against a rotating disc. The presently used machine is generally used to determine the wear and friction properties of the material under investigation. Either the rotating disc or the pin can be used as a specimen; the other will act as a tool. In the present investigation, the specimen is used in the form of a disc. To evaluate the performance of these composites under dry sliding conditions, wear tests are carried out as per ASTM G 99 in a pin-on-disc type friction and wear monitoring test rig, supplied by DUCOM.

5. Results and Discussion

Firstly, the effect of fibre content on wear rate is studied by keeping another parameter unchanged i.e. sliding velocity, normal force and sliding distance. Likewise, the effect of other parameters on the wear rate was studied and presented similarly. Figure 1 shows the effect of fibre content on the wear rate of the fabricated composites. To study the loading effect on sliding wear rate, the sliding wear test was performed on samples with different filler content (0 wt. % - 10 wt. %) while the other parameter was kept constant i.e. sliding velocity to 100 cm/s, load to 5 N and sliding time to 200 seconds. It can be seen from the graph that with an increase in filler content, the specific wear rate decreases appreciably. The specific wear rates were calculated from the value obtained from the experimental outcome and fixed parameter values. The wear rate is 1.685×10^{-5} $mm^3/N\text{-}m$ for neat epoxy which reduces to 0.665

× 10^{-5} mm^3/N-m with 10 wt. % fibre loading. This reduction in wear rate counts to around 60.5 %. This reduction in wear rate is mainly due to the presence of sisal fibre which reduces the wear rate of comparatively soft epoxy material [11]. So from this experimental analysis, it can be concluded that the wear rate reduces with an increase in fibre content.

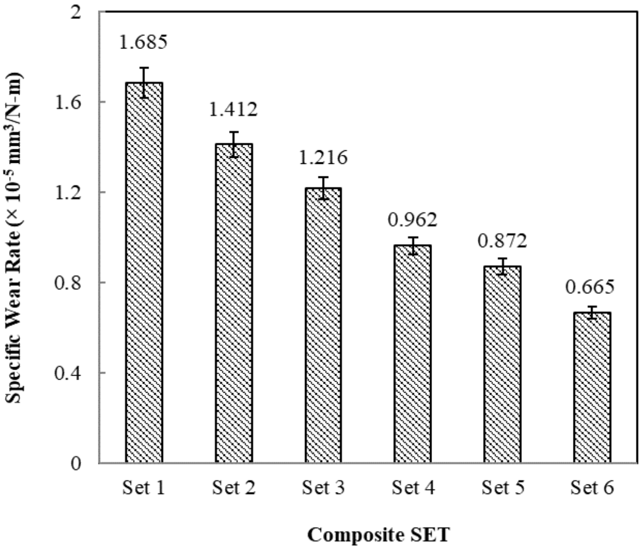

Figure 1 Effect of fibre content on specific sliding wear rate

Similarly, the effect of other parameters is studied by varying one parameter and keeping the other parameter constant. Figure 2 shows the effect of sliding velocity on specific wear rates. Here the experiment was performed by varying the velocity from 100 cm/s to 400 cm/s keeping the other parameter constant i.e. fibre content to 10 wt. %, load to 5 N and sliding time to 200 seconds. From the figure, it is clear that with an increase in sliding velocity, the specific wear rate increases from 0.665 × 10^{-5} mm^3/N-m for sliding velocity 100 cm/s to 1.652 × 10^{-5} mm^3/N-m for sliding velocity 400 m/s when rest of the parameter remains constant. An increase in wear rate is obvious as an increase in speed results in an increase in sliding distance, so the material will undergo sliding wear for more number of turns and result in more specific wear [12].

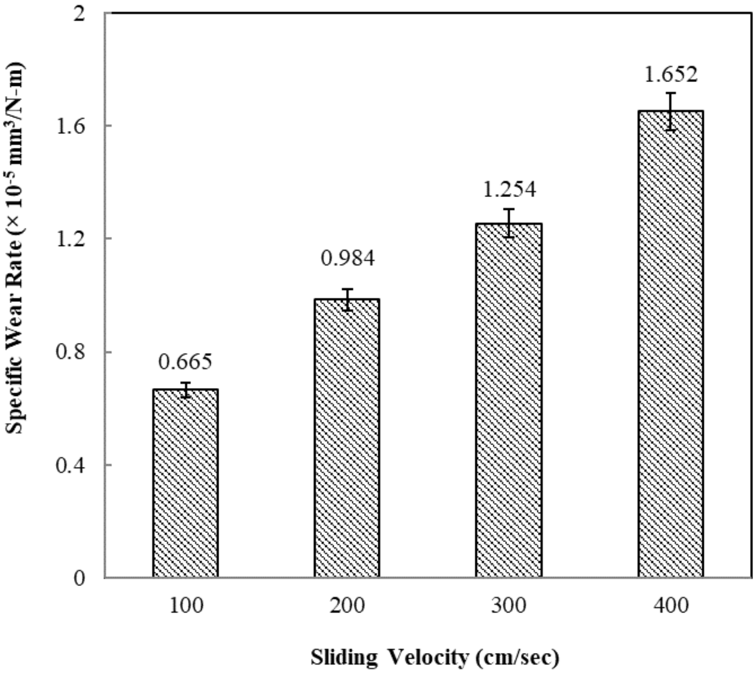

Figure 2 Effect of sliding velocity on the specific sliding wear rate

Next, to study the effect of applied load on specific wear rate, load varies from 5 N to 20 N whereas other parameter remains constant i.e. fibre content to 10 wt. %, sliding velocity 400 cm/sec and sliding time to 200 seconds. Figure 3 shows the effect of applied load on specific wear rates. From the figure, it is clear that with an increase in applied load, the specific wear rate increases.

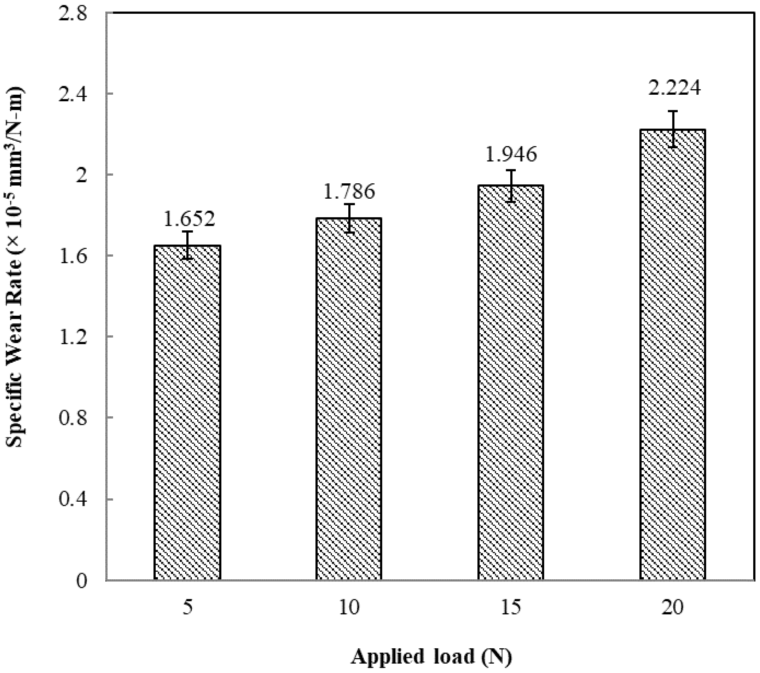

Figure 3 Effect of applied load on the specific sliding wear rate

The variation in the value of wear rate is noted as 1.652×10^{-5} mm^3/Nm to 2.224×10^{-5} mm^3/N-m when the load increases from 5 N to 20 N. This increase is obvious as with the increase in applied load, the pin applied more pressure on the composite body, which causes more wear on the composite body. So from the sliding wear test, it can be observed that with an increase in fibre content specific wear rate decreases, whereas, with an increase in either sliding velocity or applied load specific wear rate increases when the duration of test remains constant.

6. Conclusions

This experimental investigation on short sisal fibre reinforced epoxy composites has led to the conclusion that successful fabrication of epoxy matrix composites reinforced with short sisal fibre is possible by simple hand-lay-up technique. This study also reveals that short sisal fibre possesses good filler characteristics as it improves the sliding wear resistance of the polymeric resin. The specific wear rate as a function of filler content, sliding velocity and applied force is studied. From the experimental investigation, it was concluded that with an increase in filler content, the specific wear rate decreases, whereas, with an increase in sliding velocity and applied force, the wear rate increases.

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