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RESEARCH ARTICLE

BIO-WASTES (FISH SCALE AND PINE CONE) BASED HYBRID POLYMER COMPOSITES FOR TRIBOLOGICAL APPLICATIONS

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ABSTRACT

Increased environmental awareness and rising oil prices have contributed to the advance of research on and development of bio-particulate polymer composites. In our investigation we have chosen two natural particulates one is fish scale and other is pine cone to improve the mechanical properties of polymer composites with epoxy resin as the base material prepared by hand lay-up technique according to ASTM standards. The sample compositions of 5 wt% (fish scale/pine cone) and 5 wt%, 10 wt%, and 15 wt% with equal ratio combination of both particulates were prepared. Mechanical Properties such as tensile and hardness, and wear properties of mono-particulate (fish scale or pine cone) and hybrid-particulate composites were evaluated and compared. It was found that tensile strength decreased with increases of filler contents; and hardness behaviour was improved with increase in wt% of particulates reinforcements in epoxy resin. The wear resistance was investigated to improve with increase in weight percentage hybridization of epoxy resin with fish scale and pine cone powder. Improvement of hardness and wear properties mean that these natural fillers containing epoxy polymeric composites are suitable for tribological applications.

INTRODUCTION

Natural filler based polymeric materials have received considerable attention from industries during these decades. The ever-growing economic importance of these polymeric materials has expanded research efforts world-wide to estimate their physical, mechanical and tribological behaviour for exploring new tactics, practices and applications for cost-effective and green production of these composites. The enhancement of other properties such as thermal and electrical conductivity improve performance at elevated temperature, promote abrasive resistance and improve mach inability by particulates filled in neat polymer composites. Natural filler polymer composites have attracted the research community towards their use in structural applications as building materials such as forms for concrete placing, roofing board and interior wall materials. The improvement of erosive behaviour of plastic composites can be easily increased by the additions of bio-filler. Kumar *et al.*, (Kumar *et al.*, 2013) in his research, focussed on the effect of mustard cake filler on mechanical properties of glass fibre based hybrid epoxy composites, and showed that wear rate decrease with increase of fibre loading and also demonstrate some enhancement in mechanical properties of filled glass fibre composites (mustard cake as a filler) as compared to unfilled composites. In a report of pre-winkle shell reinforced bio composites (Ofem and Umar, 2012), the highest tensile and flexural strength were recorded at 30 wt% filler content with 400 µm particles size. Kangking *et al.*, (2012) studied the mechanical behaviour of natural rubber compound with use of bagasse fibre ash as secondary filler in silica or carbon black and revealed through the observation of ultimate mechanical strength and swelling measurement that the bagasse filler ash had more compatibility for addition than silica and carbon black filler. Kumar et al (1728) focussed on the mechanical and wear behaviour of grewia optiva fiber/bio particulate hybrid composites and observed that wheat straw/ grewia optiva composites delivered optimal hardness and impact energy. The enhancement in abrasive wear property of composites was easily provided by the usage of natural fillers. Cholachaguda *et al.*, (2013) in his research work, focused on hybrid polymer composites incorporated with coir and rice husk as reinforcements and vinyl ester as binding material. They observed that flexural strength increased with increase of fibre loading with optimum result at 20wt% coir whereas it decreased the tensile strength at that wt%. In hybridization with rice husk (3%), a 10.7 % improvement in flexural strength was achieved. Many research

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groups have aims of optimizing the various combinations of polymer matrix/natural fillers in order to promote new classes of composites with improved mechanical, physical and tribological properties, as well as to achieve a cost effective product with low hazards. The mechanical and physical properties of ground nut shell filled polymer composites were investigated by Raju *et al.,* (2012). The study investigated the feasibility of using 50wt% ground nut shell filler in polymer for manufacturing particles board or roofing materials.

Fish is aqueous species which is abundantly available in nature and its scale, regarded as waste materials can be used to obtained value added product. It has been expected to give contribution to improve the mechanical properties of neat polymer composites. Ikoma *et al.,* (2003) focussed on the micro-structural, mechanical and biometric properties of fish scale from Pagrus major, and revealed that tensile strength of the scale as high as 90 MPa. Although some earlier works studied fish body scales to strengthen their role in fish taxonomy. Satapathy *et al.,* (2009) studied the fabrication, mechanical characterization and FTIR spectroscopic analysis of fish scale reinforced epoxy composites. They observed that these composites had low porosity and improved hardness, and exhibited inferior tensile and flexural strength than those of neat polymer composites. Pine cone is a hard and dry part that is the fruit of pine tree which contains many seeds. Basturk *et al.,* (2015) fabricated acron and pine cone powder fillers mixed epoxy composites and observed that 20 wt% pine cone powder showed maximum tensile and hardness among all the specimens. In the present research, fish scale and pine cone powder at different wt% were reinforced to epoxy resin and the mechanical properties such as hardness and tensile properties were evaluated and compared with neat epoxy.

Experimental details

Materials

Thermoset based epoxy resin (Amtech Pvt. Ltd, India) with density 2.55 g/cm^3 was used as the matrix component in the polymer composites specimens. Fish scales and pine cone were collected from the local villages of Uttarakhand, India. Pine cone and fish scale were initially soaked in NaOH and then dried at 343 Kelvin in oven for 24 hours. The dried scales were then cut into short flakes of dimension, approximately 7-9 mm in length and 2 mm in width and were used as the reinforcing phase. Figure 1 shows pictorial view of raw reinforcing materials.

Figure 1. Pictorial View of Raw Materials

Sample Preparation

The fabrication of the various composite materials was carried out through the hand lay-up technique. The fabrication process of composite consists of three steps: (a) mixing of epoxy resin and filler using a mechanical stirrer, (b) mixing of the curing agent with the filled epoxy resin, and (c) fabrication of composites. Resin and hardener were mixed in a ratio of 10:1 by weight as recommended. The pictorials view of fabricated samples is shown in Figure 2. Five different types of composites were fabricated with 5 wt % of fish scale/pine cone powder filler contents and (5 wt %, 10 wt%, 15 wt %) combination of both minor filler contents. The designation of these composites is given in table 1.The specimens of suitable dimension are cut from the composites for the mechanical and wear testing.

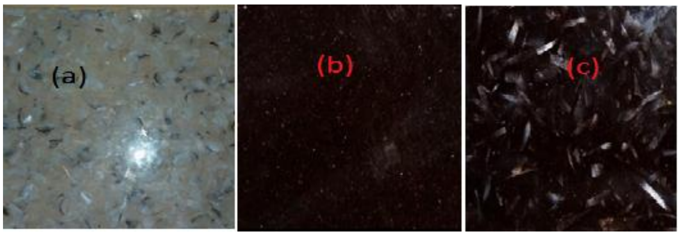

Figure 2. Pictorial View of Fabricated Composite

Table 1: Compositions and Designation of composites

Compositions (wt %)	Designation
95% Epoxy+ 5% Fish Scale	EFS
95% Epoxy + 5% Pine Cone	EPC
95% Epoxy + 2.5% Fish Scale + 2.5% Pine Cone	EFP1
90% Epoxy + 5% Fish Scale +5% Pine Cone	EFP2
85% Epoxy + 7.5% Fish Scale + 7.5% Pine Cone	EFP3

Mechanical and Wear Testing

The flat specimens are used for tensile test. A uniaxial load is applied through both ends. The dimension of the sample for the test is 150mm × 10mm and thickness of sample varies with different fiber compositions. The test is performed in the universal testing machine Instron-1195 at cross head speed of 10 mm per minutes and the test is repeated two times for each specimen to obtain mean value of tensile strength. Micro-hardness measurement is done using a Leitz micro-hardness tester. A diamond indenter, in the form of a right pyramid with a square base and an angle 136^o between reverse faces, is used with a load of 24.54 N. This test system describes a laboratory procedure for determining the tribological properties of materials during sliding using a pin on-disk apparatus. Specimens were tested in pairs under nominally non-abrasive conditions. Pin-on-disc type friction and wear monitoring test rig (TR-20 LE, supplied by DUCOM) was used to find out the wear behaviour of the various composites under dry sliding conditions as per ASTM G-99. The material losses from the composite surface were calculated by using precision electronic balance and the specific wear rate was evaluated by using the following equation.

$$W_s = \Delta m / \rho l f_n$$

Where W_s = specific wear rate (mm^3/N-m), ρ = density of specimen (g/cm^3), l = sliding distance (m) and f_n= normal load (N)

RESULTS AND DISCUSSION

These studies present the results of mechanical and wear properties of fish scale flakes/pine cone filler reinforced polymer composite. The results of various characterization tests include evaluation of tensile strength; Hardness and Sliding Wear rate.

Tensile Properties

The tensile properties of the composites EFS, EPC, EFP1, EFP2, and EFP3 are presented in Fig. 4 (a) and specimens for tensile test are shown in Fig 4 (b).The tensile strengths of the composites with mono (fish scale flakes/pine cone powder) content of 5 wt% was evaluated as 65.66 MPa and 63.08 MPa respectively. It was noticed that the tensile properties of combination of fillers fabricated polymer composites decreased with increase of filler/flakes loadings. The tensile properties of hybrid composites of EFP1, EFP2, and EFP3 were recorded as 60.09 MPa, 58.83 MPa and 55.04 MPa. The lower magnitude of tensile strengths of hybrid composites may be correlated to the increase of voids in polymer composite specimens with increase of filler wt% similar to the results as obtained by Atefi *et al.*, (2012). Atefi *et al.*, (2012) studied the mechanical characteristics of fish scale reinforced epoxy composites and observed that the tensile property decreased with increases of flakes loading. It is clear from this observation that there is no significant improvement sought by hybridization of fish scales and pine cone powders on tensile property of composites.

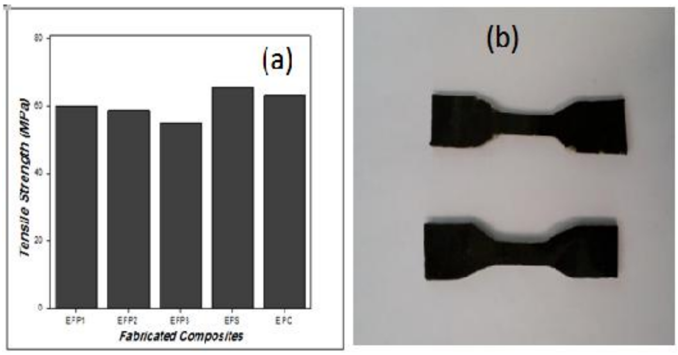

Figure 4. Variation of Tensile Strength with Fabricated Composites and Tensile Test Specimens

Hardness

The hardness of fabricated composites is shown in Figure 5. It was found that hardness properties of materials increased with increase in weight percentage of filler contents. EPC composite specimen (95% Epoxy + 5% Pine Cone) has better hardness than EFC (95% Epoxy + 5% Fish scale) which may be attributed to the better distribution of pine cone powder in the epoxy matrix and therefore providing more sites for better bonding than the fish scales. EFP3 delivered superior hardness among all the specimens (mono- filler/flakes composites as well as hybrid composites). The surface hardness increased with wt % of filler/flakes reinforced and hybridization of reinforcing components in polymeric material. The maximum surface hardness value of 50.5 Hv was obtained from EFP3. In a similar observation, Pradhan *et al.*, [11] used fly ash as natural filler in reinforced epoxy composites with the use simple hand layup technique and observed that the hardness of the composite increased with increase of filler wt% in it, and the highest hardness magnitude of 69 Hv was measured at 20wt% filler content.

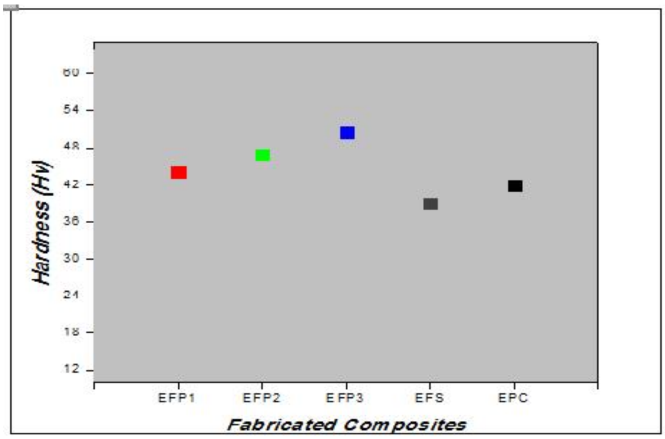

Figure 5. Variation of Hardness with Fabricated Composites

Dry Sliding Wear Test

The variation of specific wear rate with filler loading is shown in figure 6. The sliding distance is constant at 4500m and the applied loads are 5N, 10N, 15N and 20N. Specific wear rate was observed to decrease with the increase of filler loading, which may be attributed to better surface adhesion between filler and matrix. The higher contents of wt% of filler in neat epoxy composites are contemplated to reduce wear. A sample EFP3 showed lowest wear rate as among all polymer composites, which can be attributed to the fact that filler particles promoted adhesion of filler with matrix, thus increased the bonding strength and reduced the wear rate. It is seen that the 15 wt % of fish scale-pine cone reinforced epoxy composites at 20 N applied load revealed best wear resistance among other composite specimens. Therefore, it is possible to use such bio-fillers as reinforcing agents in polymer composites in low tribological applications. Nirmal *et al.*, [12] studied the effect of kenaf particulate fillers in polymer composites for tribological applications and revealed that the wear performance of neat epoxy can be increased significantly if it is reinforced with 15 wt% of kenaf filler particulate.

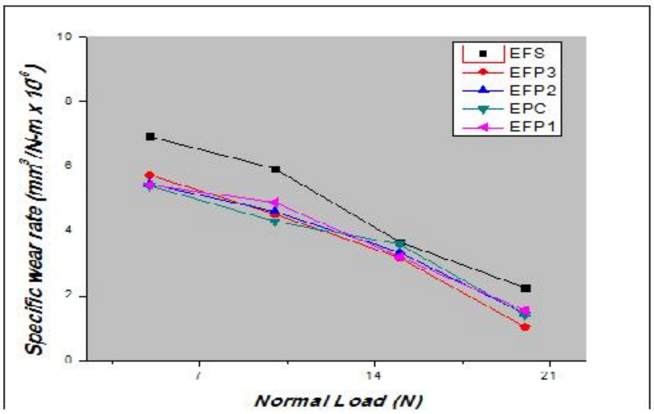

Figure 6. Variation of specific wear rate with filler loading

Conclusions

- The fabrication of epoxy matrix composites reinforced with pine cone powder and fish scale flakes was successfully achieved from the point of view of mechanical strength and wear resistance. This study opens up a new opportunity for utilization of bio-waste such as pine cone and fish scale in applications demanding high hardness and wear resistance.

- The tensile strength was not significantly affected by the pine cone and fish flakes wt%. The better tensile strength was achieved by reinforcements of epoxy with 5 wt% fish rather than pine cone powders.
- In the testing of hardness, it was observed that the hardness increased with increase of wt% hybridization of both bio-waste fillers and the maximum value of hardness was obtained at 85% Epoxy + 7.5% Fish Scale + 7.5% Pine Cone.
- After measurements of the specific wear rate of all samples, it was found that specimen EFP3 having highest contents of both bio-wastes showed lowest specific wear rate and Samples EFS shows highest specific wear rate at 20N. Increasing the wt % of natural fillers decreased the specific wear rate. Thus, the bio-wastes are investigated as useful reinforcements for fabrication of a hybrid composites exhibiting good hardness and wear resistant properties as required in many tribological applications like conveyer belts etc.

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