CHARACTERISTICS ANALYSIS OF COCONUT SHELL HUSK REINFORCED POLYMER COMPOSITES

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ABSTRACT

The effect of Coconut shell powder on the mechanical properties of coconut fiber reinforced epoxy composites is presented in this paper. Coconut shell powder (filler) at different contents (4 v/v%, 8 v/v%, 12 v/v%, 16 v/v%) and various proportions (8 v/v%, 12 v/v%, 16 v/v% and 20 v/v%) of coconut fiber (reinforcement) had been used to prepare the epoxy composites. Composite samples were prepared using hand lay-up method and the test specimens were cut as per ASTM standards. Initially, tensile, flexural and impact properties of the samples were evaluated. It was found that the addition of filler had an insignificant effect on the mechanical properties. Maximum tensile strength was found as 26.7 MPa at 16 v/v% of coir fiber with 8 v/v% of filler. Flexural and impact properties also exhibited similar trends. Wear test was conducted using a pin on disc method with the velocity of 2 m/s and varying loads of 10N, 15N, 20N and 25N. It was found that the addition of filler reduced the wear rate of the composite but adding the filler beyond 12 v/v% increased the wear rate slightly.

Keywords: natural filler, coconut shell powder, coconut fiber reinforced epoxy composites, flexural and impact properties.

1. INTRODUCTION

The thrust for the development of light weight, low cost and better strength materials for automotive applications led to the rapid growth of natural fiber composites [1-3]. Thus, natural fibers are widely accepted as a suitable replacement for synthetic fibers such as glass fiber and carbon fiber in polymer matrix composites [4-6]. The interest in using natural fibers as reinforcement in plastics has increased dramatically during the last few years. Natural fibers have many advantages compared to glass fibers, they have low density, and they are recyclable and biodegradable. Natural fibers such as banana, hemp, sisal, jute, bamboo and coir fiber are widely studied for their application as reinforcement in polymer composites. Among several natural fibers, coconut fiber is abundantly available in tropical countries. Several researchers have carried on studies on coconut fiber reinforced composites [7-9].

Harish *et al.* [10] studied the tensile, flexural properties of coir fiber reinforced epoxy composites and he had shown that coir fiber can be used for medium load applications. Sapuan *et.al.* [11] have studied the tensile and flexural properties of composites made from coconut shell filler particles and epoxy resin. He reported that the tensile and flexural strengths of the epoxy coconut filler composites were affected by the amount of filler in the composites. Maximum properties were observed at 15% filler loading. Alok Singh *et al.* [12] developed coconut shell powder incorporated epoxy and evaluated its tensile strength, flexural property and hydrophilic behaviour of the resulting composite.

The results showed that maximum tensile strength was obtained for composite with 20 % of coconut shell powder. Bhaskar, *et al.* [13] evaluated the physical property and mechanical properties of coconut shell powder (size between 200-800μm and varying wt% of 20, 25, 30 & 35) reinforced epoxy composite. He reported that, increase of wt% of reinforcement requires a pressurized fabrication technique or the addition of any adhesion increasing additive. Increase of the proportion of particle size less than 200μm would be helpful to increase density as well as tensile properties. Coconut fiber reinforced vinyl ester composite had been developed by Naveen *et al.* [14] evaluated the dynamic mechanical properties of coconut fiber reinforced polyester composites. It was reported that dynamic characteristics such as the natural frequency of the composite can be predicted by analyzing the mechanical properties of the composite. The tensile strength of composite was found to be a linear proportional to natural frequency.

CSP has some of the advantages like low cost low density, low abrasion and environmental friendly when compared with mineral filler materials such satalc, calcium carbonate, mica etc.. Composites were developed using Coconut shell powder (CSP) incorporated in ultrahigh molecular weight polyethylene (UHMWPE) [15]. The composite had been studied for its mechanical properties and compared with pure UHMWPE (0 vol% CSP). It was found that the composite with 20% CSP had better ductility, and any further addition of CSP decreased ductility. Hence, for optimum notch impact strength 20 vol% CSP composite is ideal. H. Salmah *et al.* [16] The effect of untreated and treated Coconut Shell (CS) reinforced Unsaturated Polyester (USP) composites were studied. The alkali treatment with sodium hydroxide has enhanced the mechanical and thermal properties of USP/CS composites. The treated USP/CS composites indicate higher tensile strength, modulus of elasticity, flexural strength, flexural modulus and thermal stability compared to untreated composites. SEM study, exhibit that wettability and interfacial interaction enhanced between CS and USP matrix with presence alkali treatment was proven by FTIR spectra studied.

Tribological studies on coir fiber composites had been carried by Ibrahem [17]. He developed composites with coir fiber and filler reinforced in polyester matrix and the results were compared with carbon fiber and filler reinforced composites. The results had shown that fiber reinforced composites exhibited better wear resistance than powder filler reinforced composites.

Coir fiber, Coconut Shell powder and Epoxy LY556 with the Hardener HY951 were selected as the materials for this work. The materials used in this study were purposefully selected based on their availability, environmental advantages, affordable costs, anticipated mechanical performance, and their anticipated compatibility as composite constituents.

2. MATERIALS AND METHODS

In our current work Epoxy LY556 of density 1.15–1.20 g/cm3, mixed with a hardener HY951 of density 0.97–0.99 g/cm3 is used to prepare the composite sample. The weight ratio of the epoxy and hardener is 10:1 resin was purchased from M/s. Javanthee Traders, Chennai, India. The coconut fiber is a natural fiber. The fiber is extracted from the outer layer of the coconut shell. The individual fiber cells are narrow and hollow, with thick walls made of cellulose. The chemical composition of typical coir fiber is shown in Table-1.

Table-1. Chemical composition of coir [9].

Items	Composition %
Lignin	45.84
Cellulose	43.44
Water soluble	5.25
Pectin and related compounds	3
Ash	2.22
Hemi cellulose	0.25

Coconut shell powder is made from the hard coconut shell, which is powdered to around 50 - 200 microns. The density of coconut shell powder is 1.60g/cm^3. The contents of coconut shell powder is presented in Table-2.

Table-2. Chemical composition of CSP [9].

Content	Composition %
Lignin	29.4
Pentosans	27.7
Cellulose	26.6
Hemi cellulose	21
Solvent extractives	4.2
Ash	0.6
Uronic anhydrides	3.5

a) Composite fabrication

Initially coir fiber was cut to a length of 10mm, and calculated volume of fiber is weighed and it is mixed with the resin thoroughly. Coconut shell powder was also weighed as per volumetric fraction and mixed with the resin. Hand lay-up method was followed to fabricate the composite samples. The final mixture is gently mixed to avoid any formation of bubbles. Finally the mixture is poured into the mould and allowed to cure. A light compression is applied by placing a weight of around 200N over the mould. After curing, the composite samples were taken and they were cut as per ASTM standards for mechanical properties testing. To prepare samples for wear testing, two halves of steel mould was used in the shape of a hollow cylinder. The mixture of resin, fiber and filler was poured into the mould for specimen preparation. Pin type specimen of length 35mm and 10mm diameter was prepared for wear test.

3. TESTING METHODS

a) Tensile testing

Tensile testing of the hybrid composite was carried out as per the ASTM D638 standard with the test speed of 2 mm/ min using the Instron Universal testing machine. In each case 5 specimens were tested to obtain the average value.

b) Flexural testing

Flexural testing of the hybrid composite was carried out at the three point bending mode, as per the ASTM D790 standard using the Instron Universal testing machine.

c) Impact test

Impact testing of the composite was carried out in the izod mode as per the ASTM D256 standard using the impact testing equipment.

d) Wear test

Wear testing of the composite was carried out in the dry sliding conditions as per the ASTM G99 standard using pin on disc wear testing machine. The testing specimens were fixed to the sample holder, and a track radius of 40mm was selected for this experiment.

e) SEM images

SEM images had been taken to study the fracture behaviour of the composite samples and to study the matrix-fiber interaction.

4. RESULTS AND DISCUSSION

a) Mechanical properties

The tensile test results obtained for the composites are shown in Figure-1. It was observed that the value of tensile strength showed an increasing trend with increase in fiber loading. Whereas, CSP filler loading exhibited negligible effect on the variation of tensile strength of the composite. Maximum value of tensile strength (29.8 MPa) was obtained for the composite with 16% coconut fiber volume fraction and 8% of CSP. Since the fiber acts as the chief stress transfer element in the composite, the increase in fiber volume had a direct impact on the strength of the composite. But, the composite with 20% fiber volume fraction showed less value than that of composites with 16% fiber volume fraction. This is due to the poor surface wetting of the coconut fiber by the epoxy resin. The addition of filler on the other hand showed a mixed response on the tensile behaviour of the composite. Addition of CSP filler up to 12 v/v% had slightly increased the tensile strength of the composite, but further addition, decreased the tensile strength of the composite, again this is due to the poor surface adhesion of reinforcements with the Epoxy matrix.

The flexural strength also increased with the increase in coconut fiber loading. The maximum value of flexural strength (35.5 MPa) was observed for the composite with 16% coconut fiber volume fraction and 4% CSP filler volume fraction. Similar to tensile strength in this case also the filler exhibited insignificant effect on the flexural properties. At higher fiber volume fractions the addition of filler actually reduced the flexural strength of the composite. Since the fibers at the extreme surface are subjected to maximum stress during the flexural test, addition of filler didn't effectively strengthen the composite. The energy absorbed during the sudden fracture is known as impact strength of the material. Figure-3 shows the impact strength values of the CSP filled composite. The impact strength also exhibited maximum value (3.45 J/cm^2) for the composite of 16 % fiber and 8% filler volume fraction. Higher addition of filler leads to filler agglomeration and hence weakening of the epoxy matrix.

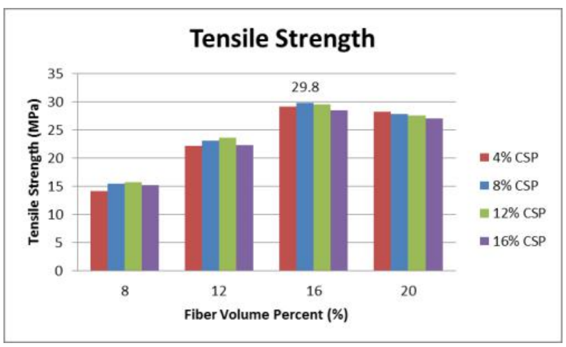

Figure-1. Tensile strength of CSP filled coir epoxy composite.

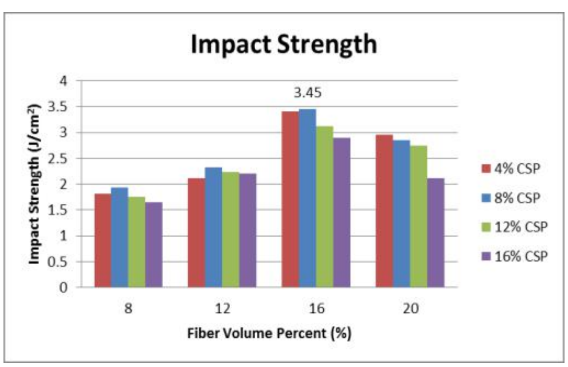

Figure-2. Tensile strength of CSP filled coir-epoxy composite.

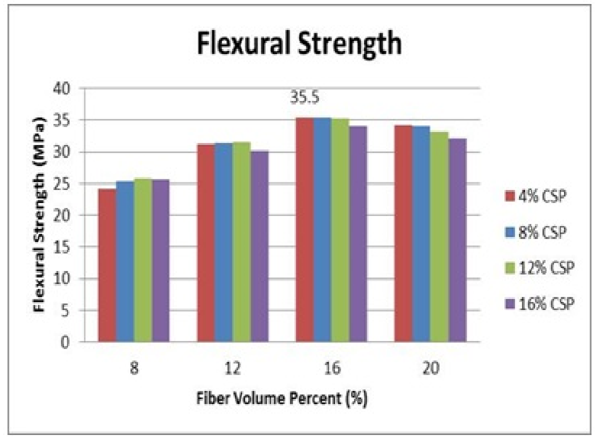

Figure-3. Fluctural strength of CSP filled coir-epoxy composite.

b) SEM analysis

The SEM images of test specimens are presented in Figures-4 – 7. The Figure-4 shows the SEM image of a tensile specimen with 16 % coir fiber and 8% CSP filled epoxy matrix. The fiber fracture and matrix fracture were observed from the image. The coconut shell particles were also observed from the image. Fiber fracture was observed from the image which shows better fiber matrix interaction. The voids present in the image were also observed. Figure-5 shows the specimen with 16 % fiber and 16% filler. The fiber pull out from the matrix shows the poor matrix fiber interaction, hence weakening of the composite material. Figure-6 shows the test specimen used for flexural study. The image presents the fiber damage through lateral direction, which shows that the fiber broken due to bending stress. Figure-7 shows the SEM image of the impact test specimen. The debris due to sudden impact test also seen in the SEM images.

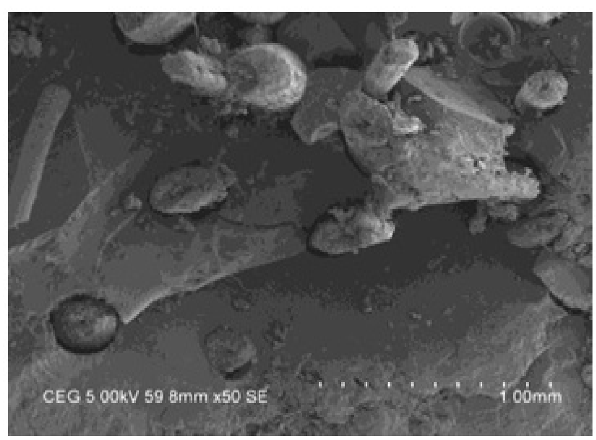

Figure-4. SEM image of tensile specimen with 16% v/v coir fiber and 8% CSP.

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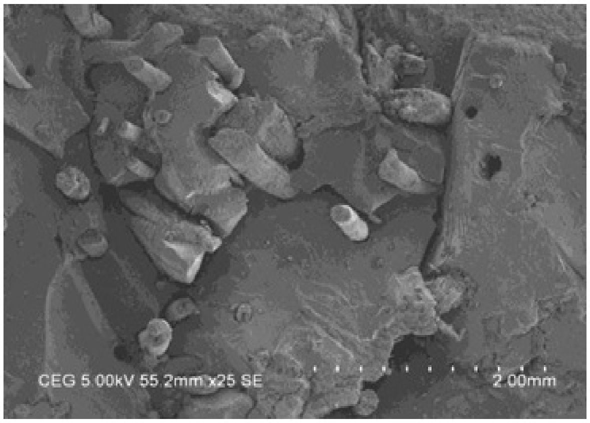

Figure-5. SEM image of tensile specimen with 16% v/v coir fiber and 16% v/v CSP.

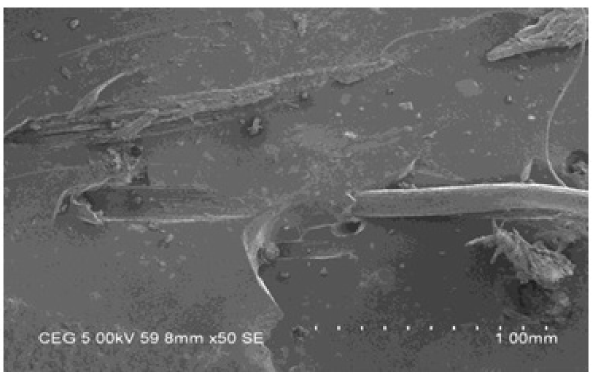

Figure-6. SEM image of flexural specimen with 16% v/v coir fiber and 8% CSP.

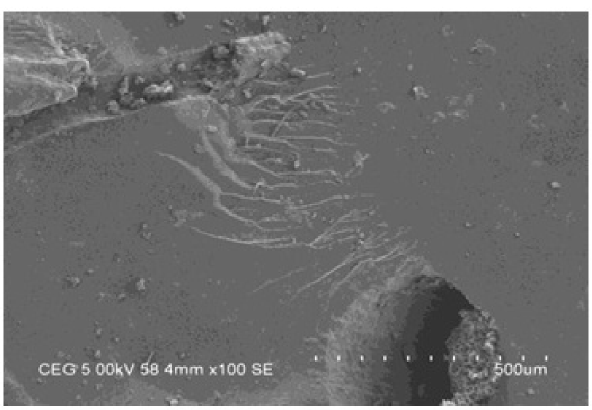

Figure-7. SEM image of impact specimen with 16% v/v coir fiber and 8% CSP.

c) Wear tests

Based on the results of mechanical properties, the composite specimen with a fiber volume fraction of 16 % with different filler volume fraction was used for wear testing. The coefficient of friction is given by the ratio between the normal reaction and frictional force, the frictional force is directly given by means of the load cell. The values of coefficient of friction are given in Figures-8 – 11 for different loads. It was observed from the figures that the addition of the CSP filler reduced the coefficient of friction at lower levels of volume fraction. Also the increase in load reduced the coefficient of friction of the composite. The decrease in the value of coefficient of friction may be because of, the coconut shell particle could be acting as solid lubricant in between the contact surfaces. Whereas the addition of more amount of filler beyond 12 v/v% resulted in an increase of coefficient of friction across all wear loads. This is due to the wear caused by the particles which came out of the rubbing surface of the specimen. The lower value of coefficient of friction was obtained for the Epoxy composite with 12% volume fraction CSP and 16 v/v % of coir fiber. It was also observed that at higher load the value of the coefficient of friction marginally increased, this is due to the change of wear behavior from adhesive friction into abrasive friction. The filler particles come out of the matrix at higher loads which get crumbled in between the surfaces. This produces more abrasion and hence the coefficient of friction increased at higher loads.

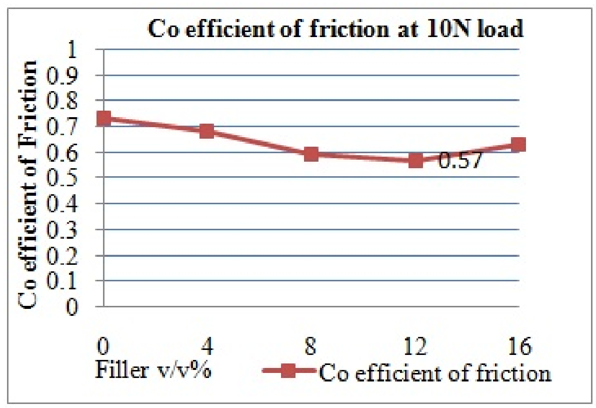

Figure-8. Effect of CSP on the coefficient of friction of epoxy-coir composite at 10N wear load.

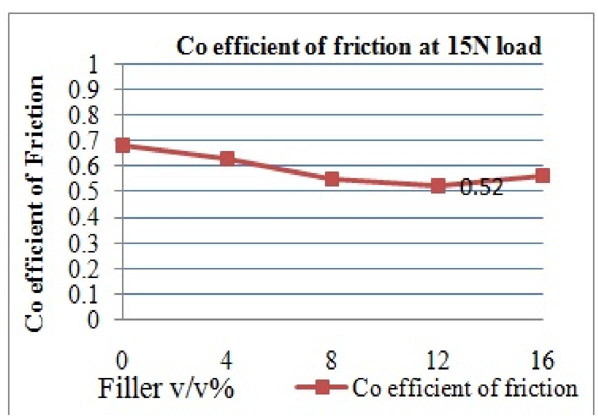

Figure-9. Effect of CSP on the coefficient of friction of epoxy-coir composite at 10N wear load.

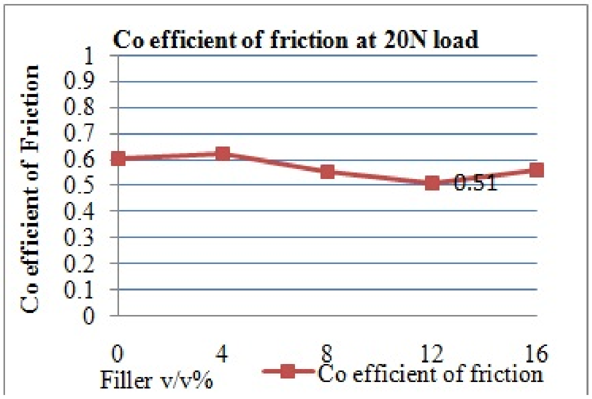

Figure-10. Effect of CSP on the coefficient of friction of epoxy-coir composite at 10N wear load.

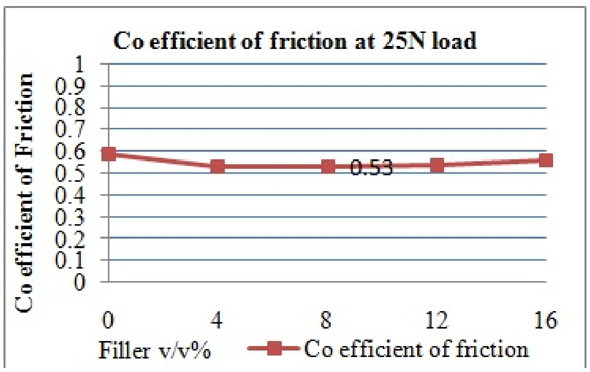

Figure-11. Effect of CSP on the coefficient of friction of epoxy-coir composite at 10N wear load.

5. CONCLUSIONS

Mechanical tests had been conducted on the CSP filled coir reinforced epoxy composites. The effect of CSP filler loading on the mechanical and tribologucal properties was studied. The mechanical properties exhibited less significance towards the addition of filler on the tensile strength and Impact strength. Flexural strength exhibited reduction in value at higher fiber volume fractions. It was concluded from the experiments that the composite with 16 % volume fraction of coir fiber and 8% CSP filler gives better mechanical properties. Analysis of SEM images also revealed the less fiber-matrix interaction at higher fiber loading, which leads to the reduction in strength. Wear tests have shown that the addition of CSP up to 16 v/v% resulted in reduction of the coefficient of friction between the contact surfaces. Addition of filler at a higher volume fraction resulted in an increase of coefficient of friction due to change of wear behavior caused by separation of filler particles from the matrix.

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