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PREPARATION AND CHARACTERIZATION OF ARECA BAST FIBER REINFORCED EPOXY AND VINYL ESTER COMPOSITES

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ABSTRACT

In this research work natural fiber reinforced polymer composites were prepared by reinforcing short areca bast fibers in epoxy and vinyl ester resin. Different blend composites were prepared by varying weight fractions of areca bast fibers. Their mechanical, physical and thermal properties were studied and compared. It has been found that the compressive strength of areca bast fiber reinforced vinyl ester composites were more than that of epoxy composites. It was also observed that the type of compressive failure in epoxy/bast and vinyl ester/bast composites at all wt% of fibers was breaking and bulging respectively. The erosive wear strength at 90º and 75º nozzle angles weredetermined. The properties such as water absorption capacity and density were determined. The Thermo gravimetric analysis (TGA) was also carried out .The ruptured surface of both types of composites which exhibited highest compressive strength was analyzed by Scanning electron microscope (SEM).

Keywords: Areca Bast, Epoxy, Vinyl Ester, Erosive Wear, TGA, SEM.

INTRODUCTION

During the last few years, natural fibers have received much more attention than ever before from the research community all over the world. Increasing needs for different engineering applications invite the development of new polymeric materials reinforced with synthetic fibers such

as glass, carbon, aramid etc., provide advantages of high strength to weight ratio as compared to conventional constructional materials, i.e. wood, concrete & steel. But the synthetic fibers have adverse environmental impact. Hence natural fiber reinforced polymer composites play a vital role with respect to environment by possessing a property of biodegradability and highstrength with light weight. In recent years, natural fibers are introduced as possible replacement for synthetic fibers [1 to 3]. Recent studies showed that the development of fiber reinforced composite material using plant-based natural fiber such as flax hemp, bamboo, pineapple, kenaf, sisal, banana, jute, coir etc., showed much attention to the researchers due to their availability, cost effectiveness & wide range of properties[4- 9].Polymers and their composites form a very important class of engineering materials & are invariably used in mechanical components such as gears, cams, wheels, impellers, brakes, electrical contact bushes, cylinder liners, artificial joints, helicopter blades etc.

The compressive strength is one of the most important and widely measured properties of materials used in various applications. The value of compressive stress reached when the material fails completely is designated as the compressive strength of that material [10]. AzimShahzad prepared composites with hemp reinforced in thermoset and biodegradable matrices which exhibited good mechanical properties[11].Srinivasa and Bharath found that the mechanical properties of areca husk fiber-reinforced epoxy composites depend on the nature of matrix material and the distribution and orientation of the reinforcing fibers, the nature of the fiber-matrix interfaces and of the interphase region [12].

Erosive wear can be described as an extremely short sliding motion and is executed within a short time interval. Erosive wear is caused by the impact of particles of solid against the surface of an object. The impacting particles gradually remove material from the surface through repeated deformations and cutting actions [13]. The rate of erosive wear is dependent upon a number of factors. The material characteristics of the particles, such as their shape, hardness, impact velocity and impingement angle are primary factors along with the properties of the surface being eroded. The impingement angle is one of the most important factors and is widely recognized in literature [14].JyotiPrakash Dhal andS. C. Mishraprepared brown grass flower broom fiber reinforced epoxy composites and found that as the fiber reinforcement increases the density of the composite decreases and the hardness of the composite increases [15].

Moisture absorption of natural fiber plastic composites is one major concern in their outdoor applications. Traditionally diffusion theory is applied to understand the mechanism of moisture absorption [16]. G.C. Mohan Kumar prepared composites with random distribution of areca husk fibers in Maize stalk fine fiber and Phenol Formaldehyde as a matrix and observed that the amount of moisture in the composite increased with time and later it became constant and he predicted that the water is predominantly absorbed at the fiber and matrixinterface [17].BharathK.N,Rajesh A.M have studied the moisture absorption property of different weight fraction of randomly distributed areca fiber & maize powder reinforced urea formaldehydecomposites [18].The results showed that moisture absorption decreased with decrease in the fiber to maize powder ratio & moisture absorption was improved with the weight ratio of fibers to maize powder . Chkkol et al, carried out water absorption capacity test for the composites made of Urea formaldehyde, Melamine urea formaldehyde and epoxy reinforced with areca husk fibers. Out of these three types of composites least amount of water absorption was found in epoxy reinforced areca husk composites [19].B.H.Manjunath and Dr. K PrahladaRao prepared the composites made from areca fibers, maize powder as filler particles & found out that the moisture absorption increases with the fiber, filler content and duration of immersion in water[20].Amuthakkannan et al, prepared basalt fiber reinforced polymer matrix composites and found that the water absorption behavior of the composites mainly depends on the voids present in the composites, interfacial adhesion between the fiber and matrix, and type of fibers reinforced [21].AnkitaPritamPraharajet al. Studied the water

absorption of randomly oriented paper pulp reinforced Bisphenol-Aglycidyldimethacrylate (BisGMA).They found that the composites with less paper pulp content absorbed less moisture [22]. Thermal analysis of natural and synthetic polymers gives us good account of their thermal stability. Thermal analysis comprises of various methods such as thermogravimetric analysis (TGA)/differential thermal analysis (DTA), derivative thermogravimetry (DTG) etc [23].

In coastal Karnataka the areca is the main commercial crop. The areca bast obtained from the areca tree is a waste material. Hence, in, this present study, areca bast fiber reinforced epoxy and vinyl ester composites have been prepared with varying weight percentages. Their physico-thermo-mechanical and tribological properties have been studied, owing to scientific interest and technological competence.

EXPERIMENTAL

Raw materials

The clean areca bast obtained from the areca field were dried under sunlight till all of its moisture content was removed. Then they were washed with distilled water and kept in an oven for the drying purpose. The epoxy LY 556 was used as matrix material with hardener HY 951 and also vinyl esterwas used as matrix material with respective catalyst, accelerator and promoter.

Sample preparation

Epoxy Composites

Required quantities of fibers and resin were weighed, mixed and stirred properly. Hardener was added to the epoxy- fiber mixture in the proper ratio and stirring was continued till uniform mixture was obtained. The composites were prepared with varying weight percentages of fibers and cured for 24 h at room temperature. Then the samples werecut into required size and shape according to the ASTM standard for different testing purposes and post cured.

Vinyl ester composites

In this, definite quantities of vinyl ester and fibers were mixed. Then the respective catalyst, accelerator and promoter were added in the required amount. The similar procedure used in the preparation of epoxy composites was followed.

Testing methods

The Compression test was carried out in an Universal Testing Machine (ZwickRoell, Jerman make,Model-Z0200) according to ASTMD695 standard and Wear test was conducted in Air Jet Erosion Test Rig as per ASTM G76 standard at 90^0& 75^0 nozzle angle. Density was determined by simple water immersion technique according to ASTM D792 standard.

Water absorption capacity was found out according to the procedure described in the ASTM D570 standard. The percentage increase in weight was calculated as,

$$\% \text{ Water absorption} = \frac{\text{Wet weight} - \text{Reconditioned weight}}{\text{Reconditioned weight}} X\ 100$$

The decomposition temperature of fibers of the composites having highest compressive strength was found out by conducting TGA test. The fracture behavior of the composites which exhibited highest compressive strength was also investigated by SEM micrographs.

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RESULTS AND DISCUSSION

Compressive Strength

All epoxy and vinyl ester composites with varying weight percentages of areca bast fibers were subjected to compression test. The results are shown in Figure1.The type of failure in epoxy composites was found to be breaking. In case of vinyl ester composites the failure was bulging. In the case of epoxy composites, the compressive strength started increasing in the beginning as the weight percentage of fibers increased up to 10 wt% and later it decreased and in vinyl ester composites also the compressive strength started increasing up to 12wt% and afterwards decreased as shown in Figure1. Maximum compressive strength of 61.12MPa and 145.64 MPa was found in epoxy and vinyl ester composites at 10wt% and 12wt% respectively. This clearly indicates that the fiber-matrix interfacial bonding was optimum at 10 wt% and 12wt% of fibers in epoxy and vinyl ester composites respectively. The percentage increment of the compressive strength for vinyl ester composites was found to be 137.03% over that of epoxy composites at 10 wt% of fibers. The vinyl ester composites showed an increment in the strength of 168.07% over epoxy composites at 12 wt% of fibers.

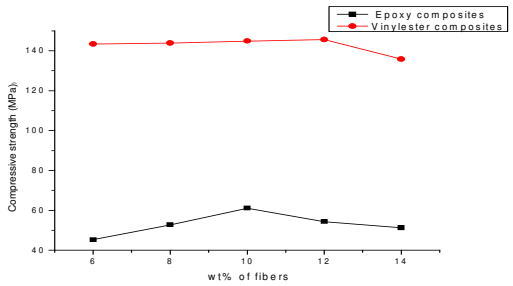

Figure 1. Compressive strength of epoxy and vinylester composite

Wear Test

The percentage loss in weight due to erosive wear at 90° and 75° nozzle angles inepoxy and vinyl ester composites are shown in Figure 2and3respectively. The rate of erosive wear is dependent upon a number of factors such as type of matrix material, type of fibers used, orientation of fibers, size of fibers and the nozzle angle. The percentage loss in weight at 90^0 nozzle angle was found to be less than at 75^0 nozzle angle in both types of composites which is clearly indicated in the Figure 2and3.It is also observed that the minimum percentage weight loss of 0.0200 and 0.0325 at 10wt% and 8wt%of fibers in epoxy composites at 90^0 and 75 ° nozzle angle respectively. But at 90 ° and 75 ° nozzle angle the minimum percentage loss in weight of 0.0270 and 0.0635 was observed at 6wt% and12wt% of fibers in vinyl ester composites respectively. These results indicate that the minimum percentage loss in weight was found in epoxy composites.

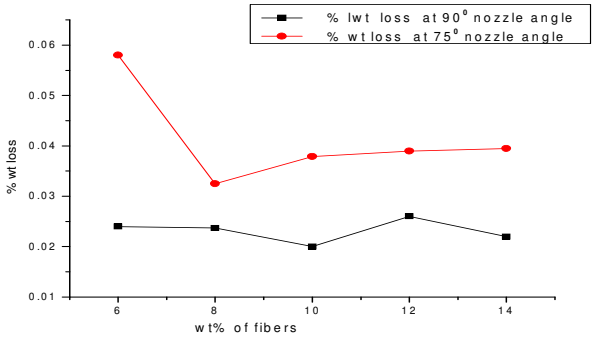

Figure 2. Wear test results ofepoxy composites at 90^0 and 75^0nozzle angle.

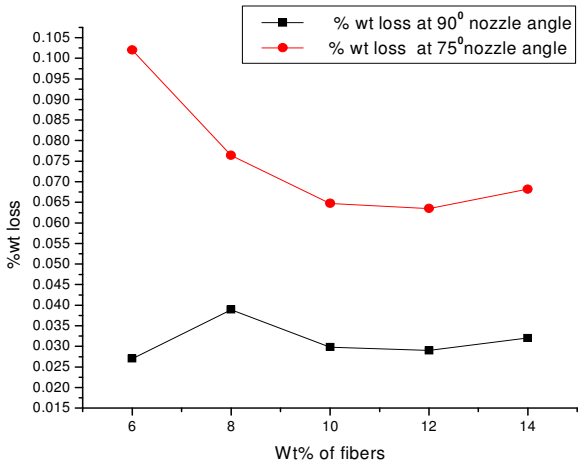

Figure 3. Wear test results of vinyl ester composites at 90^0 and 75^0 nozzle angle

Density Test

The density of epoxy and vinyl ester composites at different wt% of fibers is shown in Figure 4. The density was found to decrease with increase in fiber content in both types of composites. From the Figure 4, it is clear that a minimum density of 864.10Kg/m^3 and 827 Kg/m^3 was found at 14wt% of fibers in epoxy and vinyl ester composites respectively. The density of vinyl ester composites was found to be less than epoxy composites at all percentages of fibers. This is because the density of vinyl ester is less than epoxy.

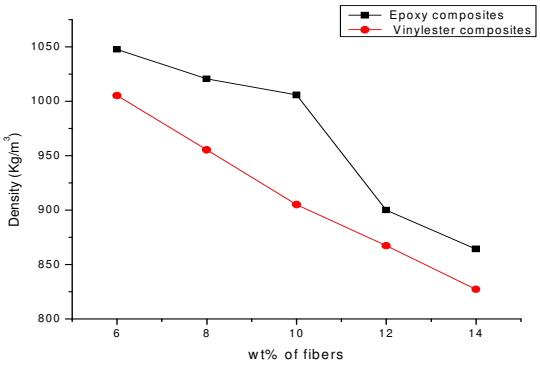

Figure 4. Density of epoxy and vinyl ester composites.

Water Absorption Test

The water absorption capacity of the composite was measured by the weight gain of the material in regular 24 hrs. of intervals over the period of 15 days.. The water absorption test results of the epoxy and vinylestercomposites are shown in Figure5&6respectively. These results indicate that the water absorption capacity of the composites increases as the weight percentage of fibers increased and later it becomes constant after reaching the saturation level. After analyzing the water absorption capacity of all the composites it is found that the water intake capacity of epoxy composites is less compared with vinyl estercomposites. From the Figure 5&6, it is clear that a least amount of water absorption of 7.56 %and8.91% was found at 6wt% of both types of composites.

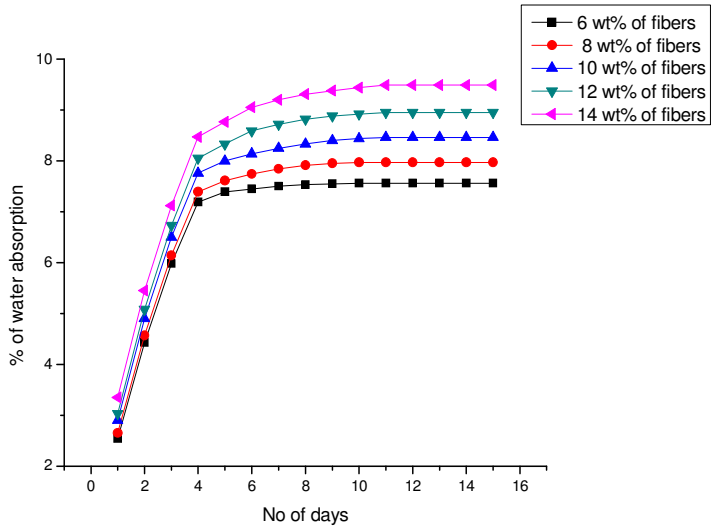

Figure 5. Water absorption capacity of epoxy composites.

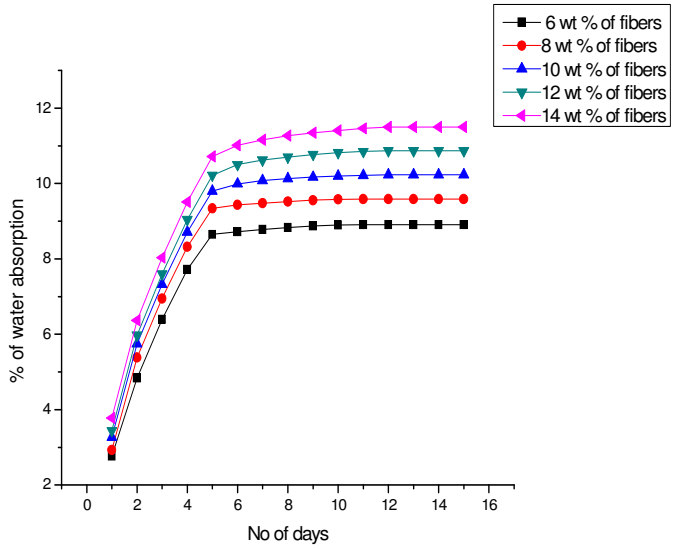

Figure 6. Water absorption capacity of vinyl ester composites.

Thermal Analysis

The Thermo gravimetric analysis (TGA) of 10wt% of epoxy and 12wt% vinyl ester composites which exhibited highest compressive strength was studied as a function of percentage weight loss with increase in temperaturewhich is shown in Figure 7and8respectively.In case of epoxy composite the initial decomposition temperature was 261.77ºC and final decomposition temperature was 436.21ºC.On the other hand, in case of vinyl ester composite, the initial decomposition temperature was 300ºC and final decomposition temperature was 461.88ºC .In both types of composites the decomposition was single stage.

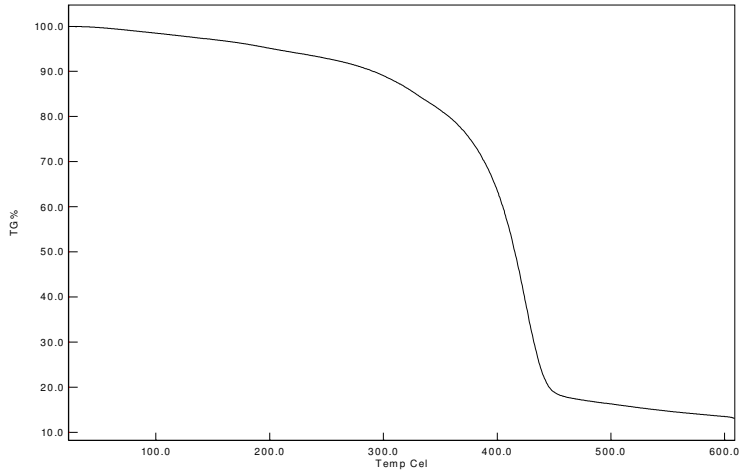

Figure 7. Thermogravimetric analysis of epoxy composites

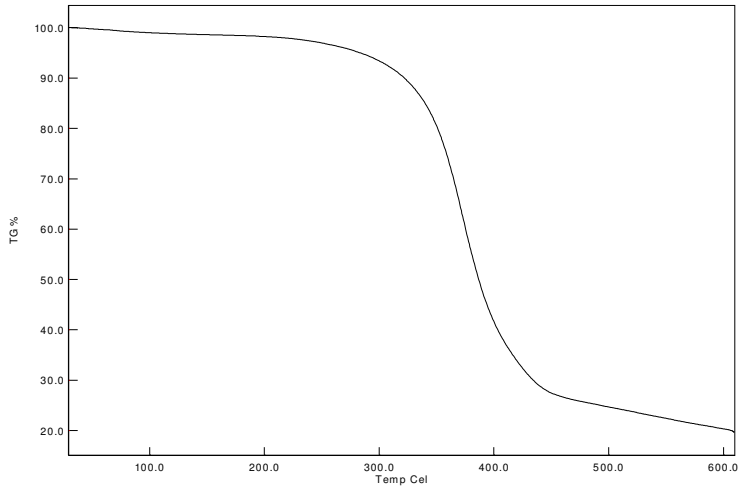

Figure 8. Thermogravimetricanalysis of vinyl ester composites.

SEM Observations

Morphology of fractured surface of the 10 wt% of epoxy and 12 wt% vinyl ester composites which exhibited highest compressive strength was examined by Scanning Electron Microscope.The nature of failure was not uniform in both types of composites at the fractured surface. In epoxy composites, brittle type of fracture due to formation of cracks was observed which is evident from Figure 9.No such kind of failure was observed in vinyl ester composites because the failure was bulging without the cracks as shown in Figure 10.This clearly indicates that the bonding between fibers and matrix is stronger in vinyl ester composites than the epoxy composites. Hence compressive strength of vinyl ester composites was higher than the epoxy composites. Agglomeration of fibers took place in epoxy composites during the compressive failure as indicated in the Figure 11. At some regions on the fractured surface of both types of composites the fibers were crushed into small circular pieces which are evident from the Figure 12& 13.This is due to the reason that the bast fibers are flexible in nature. The crushed matrix surface due to the compressive failure in epoxy composite is shown in Figure 14. It is evident from the SEM images that a combination of matrix cracking, bulging and breakage are the predominant failure modes.

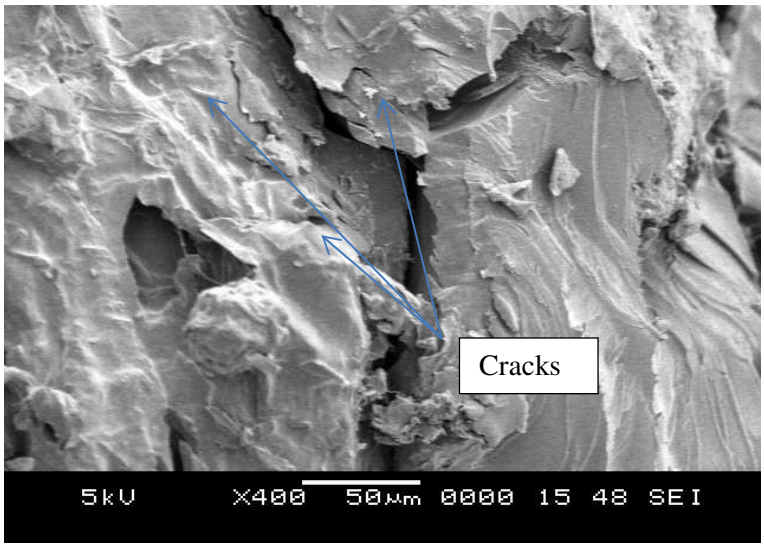

Figure 9. Cracks formed in the epoxy composite.

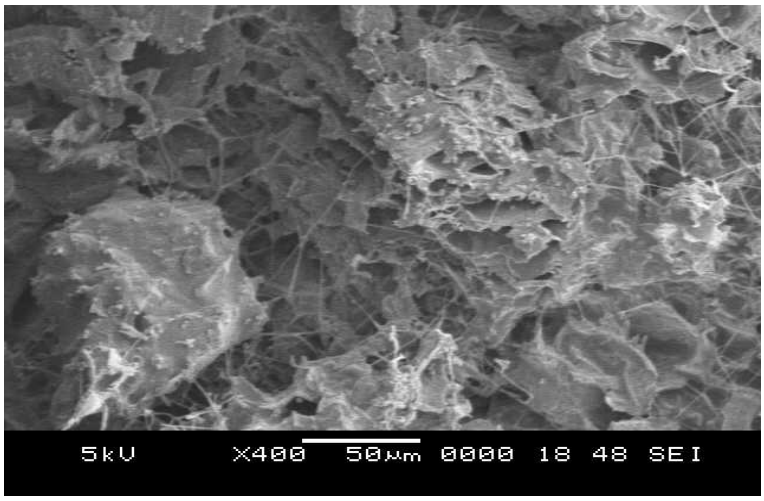

Figure 10. Bulged surface of the vinyl ester composite.

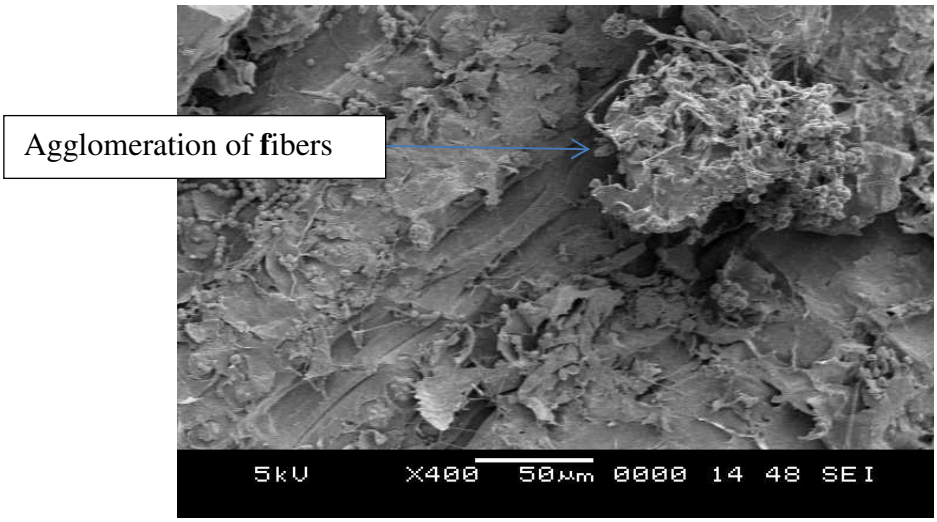

Figure 11. Agglomeration of fibers in the epoxy composite.

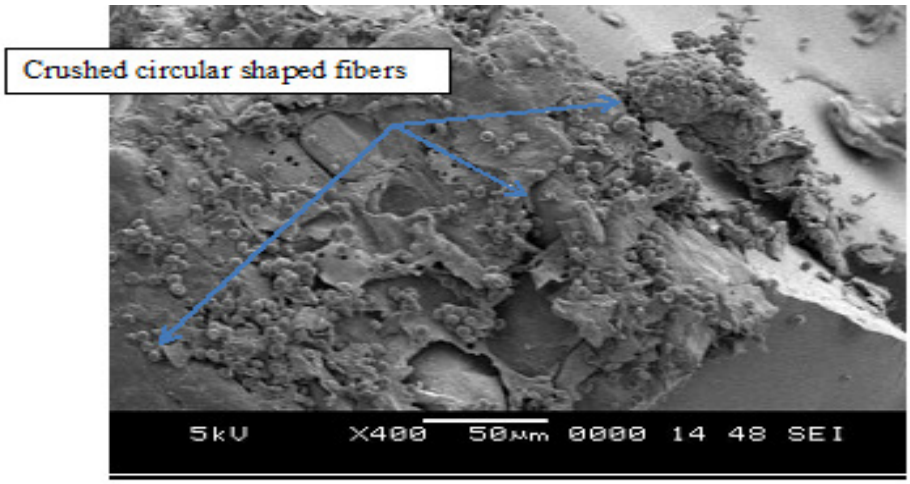

Figure 12. Fibers crushed into small circular shapes in the epoxy composite.

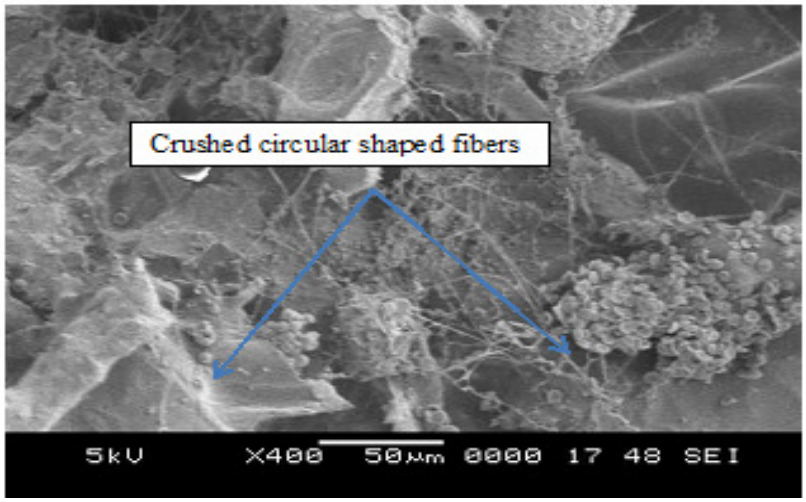

Figure 13. Fibers crushed into small circular shapes in the vinyl ester composite.

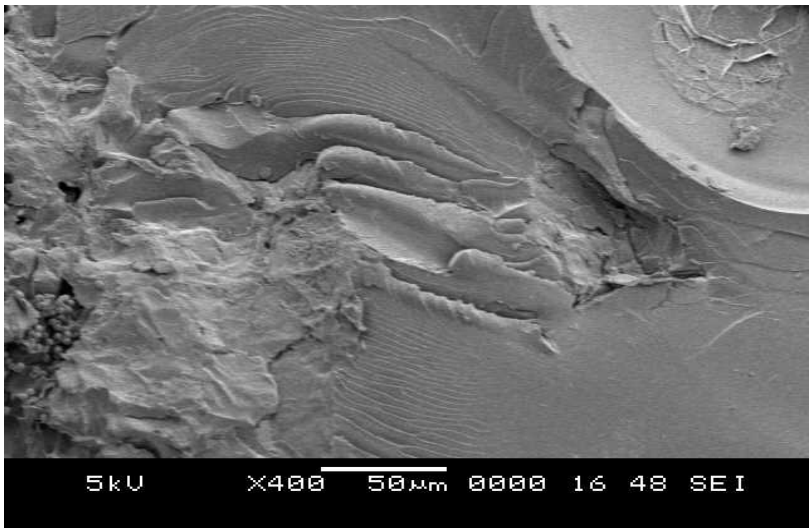

Figure 14. Crushed matrix surface of the epoxy composite.

CONCLUSION

The results showed that the brittle type of failure occurred in epoxy composites and bulging occurred in vinyl ester composites. The vinyl ester composites exhibited higher compressive strength than the epoxy composites because of the good interfacial bonding between matrix and fibers. The percentage loss of weight during wear in epoxy and vinyl ester composites was found to vary randomly .The reason is due to the uneven distribution and orientation of fibers. Minimum percentage loss of weightwas foundin epoxycompositesat 90 ° nozzle angle. Density of vinyl ester composites was found to be less than epoxy composites.

The water absorption capacity of both composites was found to increase with increase in fiber content which is due to the more affinity of fibers to water .The water absorption capacity of epoxy composites was found to be less than the vinyl ester composites at all weight percentages.

The SEM images indicate that the combination of matrix cracking, bulging, fiber pull out, fiber orientation and breakage are the predominant failure modes.

Vinyl ester composites were found to be more stable than epoxy composites because of higher compressive strength, lower density and higher decomposition temperature.

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