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A COMPARATIVE STUDY ON TENSILE PROPERTIES OF COCONUT SHELL POWDER REINFORCED EPOXY COMPOSITE

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ABSTRACT

The use of natural fibres as reinforcement in composites is an important area of research. This paper presents the preparation of coconut shell powder composite and tensile behaviour of coconut shell powder reinforced epoxy resin matrix composite with 10%, 20%, and 30% volume fraction of coconut shell powder. The values obtained are compared with values determined by other researchers. The water absorption test is also carried out and the results are discussed. The wear behaviour of the composite is also studied.

Keywords: Coconut shell powder, wear, absorption, epoxy, volume fraction, tensile strength.

I. INTRODUCTION

Natural fibre-composites have considerable potential to replace conventional materials like metals, plastics, and wood in structural and non-structural applications, especially in furniture industry. Such composites impart strength and stiffness to the product, besides having advantages such as low cost, environment friendliness, abundant availability and renewable nature [1].

Epoxy resins (ER) are one of the most important classes of thermosetting polymers which are widely used as matrices for fiber-reinforced composite materials and as structural adhesives. They are amorphous, highly cross-linked polymers and this structure results in these materials possessing various desirable properties such as high tensile strength and modulus, uncomplicated processing, good thermal and chemical resistance, and dimensional stability. However, it also leads to low toughness and poor crack resistance, which should be upgraded before they can be considered for many end-use applications. One of the most successful methods of improving the toughness of epoxy resin is to incorporate a second phase of dispersed rubbery particles into the cross-linked polymer. Using natural fillers to reinforce the composite materials offers the following benefits in comparison with mineral fillers:

- Strong and rigid
- Light weight
- Environmental friendly
- Economical
- Renewable and abundant resource

On the other hand, the disadvantages of the materials are summarized below:

- Degradation by moisture
- Poor surface adhesion to hydrophobic polymers
- Non-uniform filler sizes
- Not suitable for high temperature application
- Susceptibility to fungal and insect attack

Coconut shell is one of the most important natural fillers produced in tropical countries like Malaysia, Indonesia, Thailand, and Sri Lanka. Many works have been devoted to use of other natural fillers in composites in the recent past and coconut shell filler is a potential candidate for the development of new composites because of their high strength and modulus properties. Composites of high strength coconut filler can be used in

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the broad range of applications as, building materials, marine cordage, fishnets, furniture, and other household appliances [2].

Natural lignocellulosics such as coconut shell powder (cocosnucifera) has outstanding potentials as reinforcement in plastic. Coconut shell is important filler for the development of new composites as a result of its inherent properties such as high strength and high modulus. Increased in coconut shell content increases the tensile strength, Young's modulus and water absorption rate but reduces the elongation at break of coconut shell filled polyester composites. Incorporating coconut shell powder reduces the damping property of Pu/Ps bio-composite with a significant improvement in the tensile strength and tensile modulus [3].

The use of natural fibre for the reinforcement of the composites has received increasing attention both by the academic sector and the industry. Natural fibres have many significant advantages over synthetic fibres. Currently, many types of natural fibres have been investigated for use in plastics. These include flax, hemp, jute straw, wood, rice husk, wheat, barley, oats, rye, cane (sugar and bamboo), grass, reeds, kenaf, ramie, oil palm empty fruit bunch, sisal, coir, water, hyacinth, pennywort, kapok, paper mulberry, raphia, banana fibre, pineapple leaf fibre and papyrus. Thermoplastics reinforced with special wood fillers are enjoying rapid growth due to their many advantages; lightweight, reasonable strength and stiffness.

Natural fibres, as reinforcement, have recently attracted the attention of researchers because of the advantages over other established materials. They are environmentally friendly, fully biodegradable, abundantly available, renewable, and cheaper and have low density. Plant fibres are light compared to glass, carbon and aramid fibres. The biodegradability of plant fibres can contribute to a healthy ecosystem while their low cost and high performance fulfils the economic interest of industry [4].

The interest in natural fiber-reinforced polymer composite materials is rapidly growing both in terms of their industrial applications and fundamental research. The natural fiber-containing composites are more environmentally friendly, and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc. Coconut shells are available in abundance in tropical countries as a waste product after consumption of coconut water and meat. Such abundance can fulfill the demand of filler based composites while reducing waste. Procurement and processing of coconut shell powder is cost effective than other artificial fillers [5].

II. MATERIALS USED AND METHOD OF PREPARATION

Coconut shell particles

The locally available coconut shells are first dried in open air and heated to remove the moisture content in the shell. The dried shells are crushed into small pieces and then fed into the pulverizing machine to produce finer particles. The particles removed from the pulverizing machine consist of finer as well as coarser particles. Hence the particles are sieved to separate different sizes. The particles obtained after sieving were of three different sizes, via, >300 microns, 150-300 microns, and <150 microns. The particles of size <150 microns are used in this study for the preparation of composites.

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The chemical composition of coconut shell is as shown in the Table 1 [6].

Fig. 1 Coconut Shell Powder

Table 1. Chemical composition of coconut shell

Composition	Wt %
Lignin	29.4
Pentosans	27.7
Cellulose	26.6
Moisture	8
Solvent extractives	4.2
Uronic Anhydrides	3.5
Ash	0.6

Epoxy Resin

The epoxy resin used is LAPOX B 11, supplied by J.K. Epoxies & Maintenance Technologies Private Ltd. It is a general purpose BIS – A based liquid epoxy resin with medium viscosity. When it is used with appropriate epoxy hardener it provides excellent mechanical, thermal, chemical, and physical properties. The density of LAPOX B 11 at 250C is 1.15 g/cc (kg/l).

Hardener

The hardener suitable for LAPOX B 11 is MSDS H – 140, as suggested by the supplier of epoxy and, is used in this study. The density of the hardener at 250C is 1.015 g/cc (kg/l).

Preparation of composite

The preparation of the composite is made by the use of best combination of stirring parameters as revealed in the study conducted by Mohan Kumar et. al. [7]. The coconut shell powder particles of size less than 150 μm is used in this study. The particles are first dried by heating in a pan to remove the moisture content. The tensile test specimens are prepared according to ASTM-D3039/D3039M-00E02 standard with 30%, 20 % and 10% volume fraction of coconut shell particles. The epoxy and hardener are mixed in the proportion 2:1 by volume. The desired amount of coconut shell particles, epoxy resin and hardener are stirred using a mechanical stirrer with predetermined stirring parameters to produce a homogeneous mixture. This homogeneous mixture is then poured into the mould cavities of required dimensions and allowed to dry. Suitable releasing agents are applied on the surfaces of mould cavities for the easy removal of casting after drying.

Tensile Test

The specimens for tensile test are prepared according to the ASTM 3039D standards. The tests are conducted in a 40 Ton capacity Universal Testing Machine. The specimens are loaded gradually till failure and the load verses deflection plots are constructed.

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Water Absorption test

The water absorption index is an important parameter which determines the suitability of the use of material in moist conditions and underwater applications. In the present study the samples with 10%, 20%, and 30% volume fraction of coconut shell powder are immersed in water for various periods of time. The initial weights of the samples are measured. The weights of the immersed samples at the intervals of 24 hours are measured. The percentage of water absorbed is calculated using equation (1).

$$\%\ water\ absorbed = \frac{Final\ weight - Initial\ weight}{Initial\ weght} \times 100 \quad (1)$$

Wear behaviour study

Wear test is conducted in a pin on disc wear testing machine at a constant speed of 500 rpm over a duration of 3 minutes. The wear rate, specific wear rate, and wear resistance are calculated and tabulated.

III. RESULTS AND DISCUSSIONS

The results of tensile tests show that the average maximum load taken by 10% volume fraction of coconut shell powder composite is 3.6 kN, for 20% volume fraction, the average tensile load taken is 2.6 kN, and for 30% volume fraction the maximum load taken is 1.95 kN. This indicates that as the volume fraction of coconut shell powder increases, the tensile strength decreases. This is because as the number of coconut shell particles increases, the continuous bonding between the epoxy molecules gets broken The load verses deflection for 10%, 20%, and 30% volume fractions are plotted as shown in the fig. 2, fig. 3, and fig. 4 respectively.

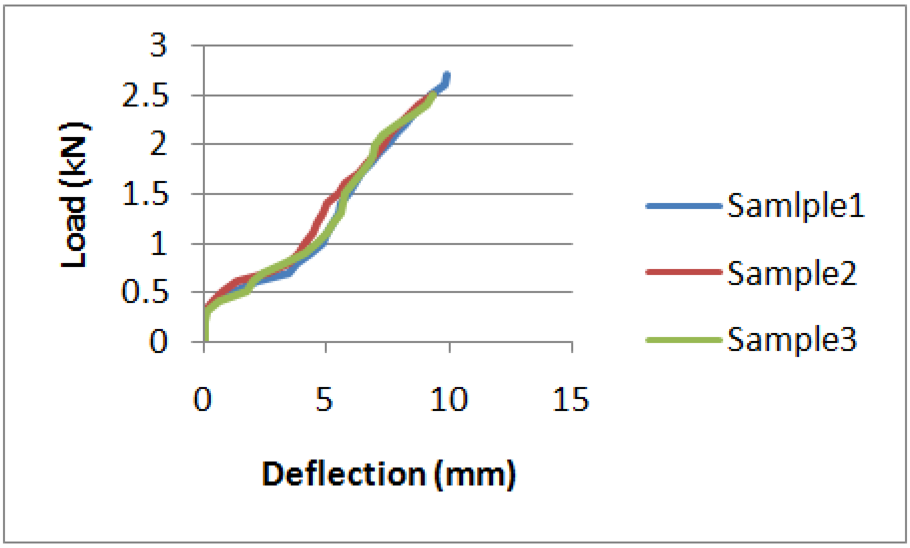

Fig. 2 Load verses deflection curves for 20% volume fraction

From the load verses deflection graphs it can be observed that the maximum load carried by the composite decreases with increase in the volume fraction of coconut shell powder. The Ultimate Tensile strengths are found to be 46.154 MPa, 32 MPa, and 25 MPa for 10%, 20%, and 30% volume fraction respectively.

The total elongation decreased from 10.6 mm at 10% volume fraction to 8.2 mm at 30% volume fraction, being 9.5 mm at 20% volume fraction. This indicates the decrease in ductility with increase in volume fraction of the composite. The variation of total elongation with respect to volume fraction is as shown in the fig. 6.

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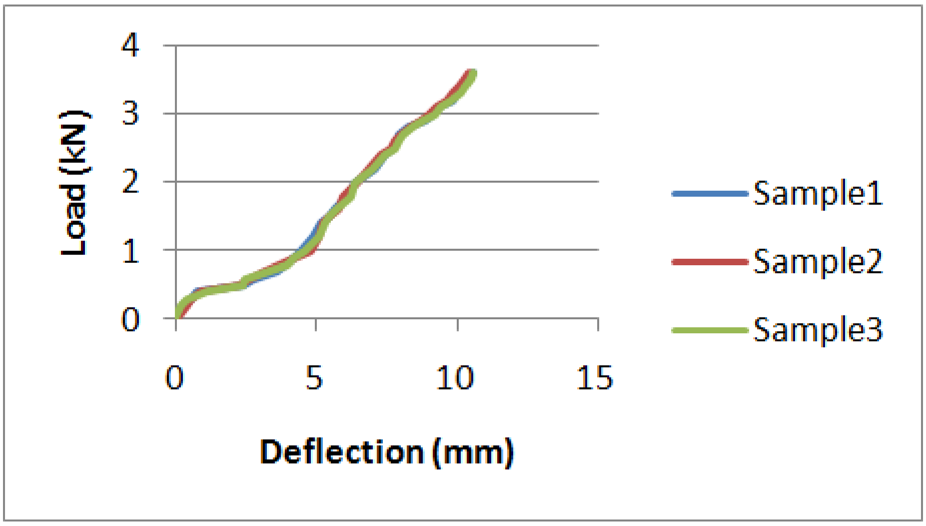

Fig. 3 Load verses deflection curves for 10% volume fraction

The variation of ultimate tensile strength with respect to the volume fractions is as shown in the fig. 5. The variation seems to be almost linear.

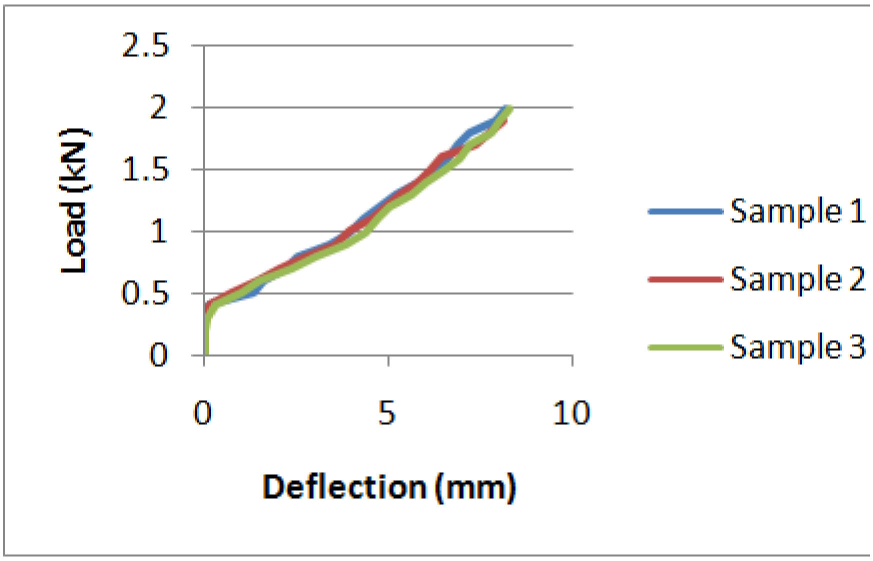

Fig. 4 Load verses deflection curves for 30% volume fraction

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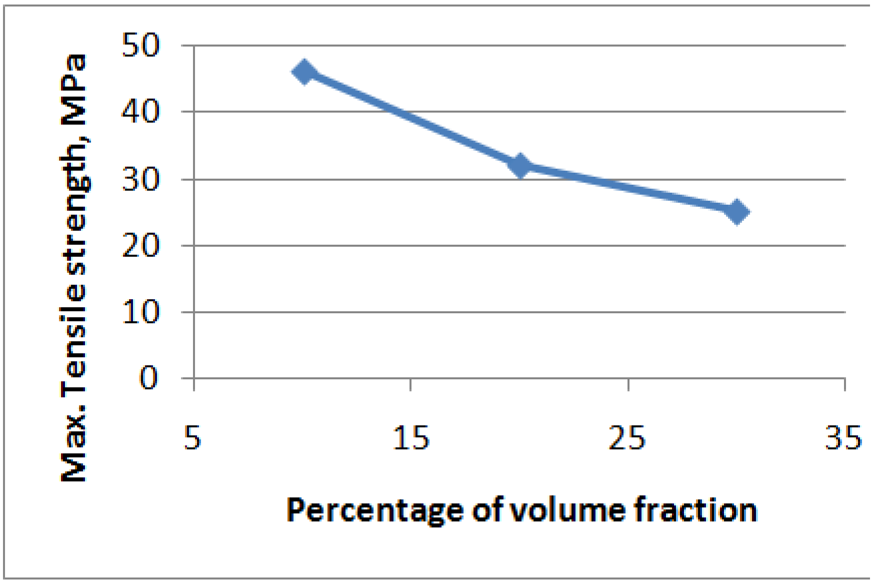

Fig. 5 Variation of Tensile strength with volume fraction

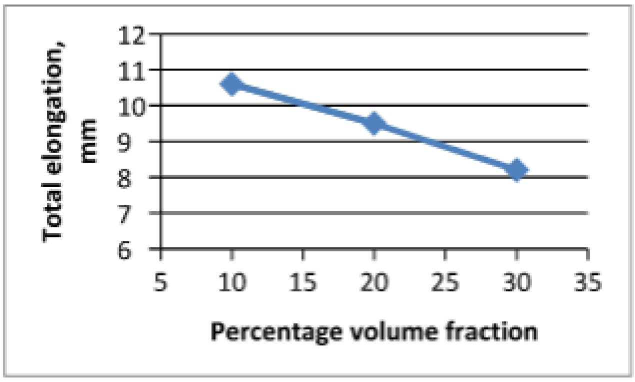

Fig 6. variation of total elongation with volume fraction

Comparative study

In the study conducted by Alok Singh et. al. [5] the tensile strength for 20% volume fraction was found to be 19.23 MPa which is very small with the value obtained in the present study. It is also revealed in their study that the tensile strength decreases beyond 20% volume fractions, which are found to be 17.05 MPa and 14.64 MPa at 30% and 40% volume fractions respectively. So in this study 10% volume fraction is considered which proved to be having high tensile strength of 46.154 MPa.

S M Sapuan et. al. [2] conducted a test on coconut shell powder reinforced epoxy resin composite and obtained the maximum tensile stress values at 5%, 10%, and 15% volume fractions as 27.1736 MPa, 30.718 MPa, 35.4824 MPa respectively.

J O Agunsoye et. al. [3] conducted tensile tests on coconut shell powder composite containing 5%, 10%, 15%, 20%, and 25% volume fractions of reinforcement. But the values of ultimate tensile stress were found to be very small. The maximum tensile stress at 10% volume fraction was found to be only 7.5 MPa which is smaller than the value obtained at 10% volume fraction by any other researchers.

The results obtained in the present study shows the highest value of ultimate tensile strength for 10%, 20%, and 30% volume fraction of coconut shell particles when compared to other works. This is mainly due to the

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contribution of stirring parameters used in this study as revealed by Mohan Kumar et. al. [7] in their previous study.

Water Absorption test

The percentage of water absorbed at various intervals for the three types of samples is calculated using the equation (1). The graph shown in the fig. 7 is plotted over a total duration of 240 hours (10 days).

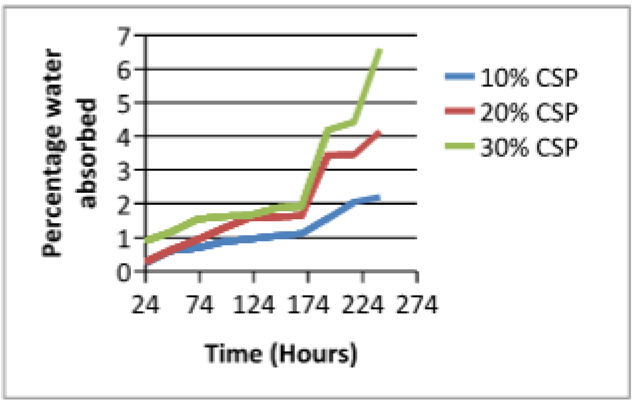

fig. 7 Percentage og water absorbed with respect to time

It can be observed from the graph that as the volume fraction increases the percentage of water absorbed also increases. Further in all the three cases the rate of water absorption is low until 168 hours (7 days) and then it increases sharply. The same trend is observed in all samples. But the rate of water absorption is slower in the case of 10% volume fraction composite. This is because the water absorption takes place in natural filler reinforced composites by hydrophilic effect. Coconut shell powder is natural fibers, natural fibers are strongly hydrophilic materials with many hydroxyl groups (–OH) in the fibers structure and moisture absorption. The hydrophilic nature of CSP causes the water uptake by these lignocellulosic materials which due to the formation of hydrogen bonds between filler and water molecules. It is well known that filler absorbs water by forming hydrogen bonding between water on the all cell wall of the filler. With the presence of hydroxyl groups, coconut shells tend to show low moisture resistance [6].

After 10 days of immersion in water the percentage of water absorbed by 30% volume fraction composite is 6.6% and that for 10% volume fraction is only 2.188%.

Wear test results

The wear test results obtained are as presented in the Table 2.

Table 2. Wear results for different volume fractions of coconut shell particles.

% of CSP	Wear rate mm^3/m	Specific wear rate $(mm^3/Nm)(10^{-3})$	Wear resistance (m/mm^3)
10	0.03	1.53	33.33
20	0.04	2.03	25
30	0.0485	2.47	20.577

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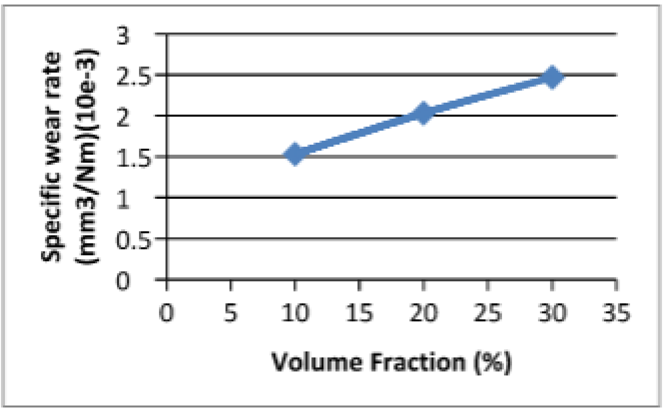

Fig. 8 Variation of specific wear rate

It is observed from the Table 2 that as the volume fraction of coconut shell powder increases the wear rate and specific wear rate increases, and the wear resistance decreases.

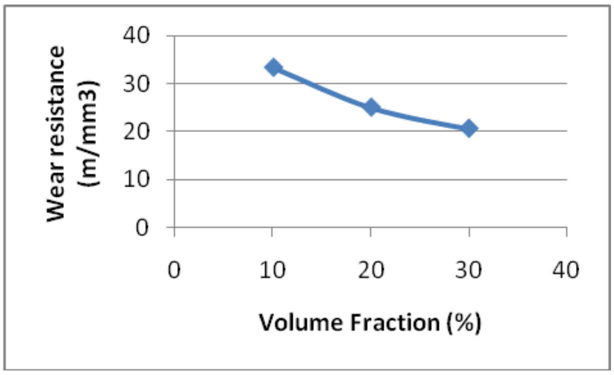

Fig. 9 Variation of wear resistance

This indicates that the coconut shell particles wear out at a faster rate than the epoxy matrix. The variation of specific wear rate and wear resistance at three different volume fractions are as shown in the fig. 8 and fig. 9 respectively.

IV. CONCLUSIONS

The coconut shell powder reinforced composite is prepared and tensile tests are conducted. The results of the tensile tests indicate that the material prepared by using the combination of best stirring parameters can yield composite with high tensile strength. The composites with all three different volume fractions yielded high tensile strengths. The ultimate tensile stress for 10% volume fraction showed highest value of 46 MPa and as the volume fraction increased the ultimate tensile stress decreased. The result of tensile test obtained in the present study is compared with the results obtained by other researchers. It is found that the values obtained in this study are much larger than the highest values obtained in any other work. At all three volume fractions the ultimate tensile stress value is around minimum 1.5 times the maximum values obtained by others for the same volume fractions. This proves that the preparation method of composite used in this study is the major reason for the improved tensile strength. It is also found that the ductility of the composite decreases with increase in volume fraction.

The water absorption test conducted revealed the ability of usage of the material in the moist condition without absorbing much water up to 7 days. The rate of water absorption is slow at initial periods and after 7days the rate of water absorption increases rapidly. However, at 10% volume fraction, even after 7 days the rate remains slower than that at other volume fractions.

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The wear tests conducted at three different volume fractions indicates that the specific wear rate increases with increase in volume fraction or in other words, the wear resistance decreases with increase in volume fraction of coconut shell powder.

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