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Fabrication and Testing of Coconut Shell Powder Reinforced Epoxy Composites

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Abstract — *Polymers are the one of the most essential components used in daily life. In recent times conductive polymer composites achieved by filling polymer matrixes with different carbon blacks were also described. In polymer industry carbon black is most widely used as reinforcing filler to achieve desirable and strengthen the product service qualities. As the carbon black is expensive due to its dependence on supply of crude oil. So it is important to develop alternate source of fillers from renewable source such as bamboo stem, oil palm empty fruit bunches, agricultural waste and coconut shells which are carbonaceous in nature and rich in organic materials. Over the past two decades, there has been a shift in research for an effective application of coconut shell, from which shell is particularly valuable due to its high contains 70% carbon, 1% ash, 30.1% lignin, 19.8% cellulose and 68.7% hemicellulose. The present work has been under taken to study mechanical behaviour and develop a polymer matrix composite (epoxy resin) using coconut shell powder. Composites having different percentage weight fraction of coconut shell for different grain sizes were made using hand layup method. The fabricated composite samples were cut according to the ASTM standards for different experiments and its mechanical properties like density, hardness, tensile strength and short beam strength are performed*

Keywords-*Polymer matrix composites, Coconut shell, Desity, Hardness, Tensile strength, Short beam strength*

I. INTRODUCTION

Environmental awareness and studies of natural fiber-reinforced polymer composite have triggered an enormous interest in utilizing natural fiber as environmentally friendly and sustainable materials as an alternative to existing materials. Many advantages are associated with the use of natural fibers, including low cost, abundance, low density, high specific properties and lack of residues upon incineration. Thus, the combination of natural fibre with polymer composite offers an answer to maintaining the sustainable development of economical and ecological technology. Bone is a simple example of a natural composite material having the best properties of its constituents. Bone must be strong and rigid; yet flexible enough' to resist breaking under normal use. These requisite properties are contributed by its components. A mature bone is made up of two basic kinds of materials organic and inorganic. The organic component, consisting mostly of proteins, carbohydrates and fats, makes it pliable and gives the required softness. The inorganic component, made up of calcium phosphate, gives it the required strength and rigidity. Due to high lignin content in coconut shell particles the composites are more weather resistant and are also well suited in application of materials such as plywood, laminated board industry etc. In the present investigation involves preparation of raw coconut shell powder and sieving it to different grain sizes, fabrication of a new class of epoxy based composite reinforced with coconut shell particulate fillers, evaluation of mechanical properties and characteristics of coconut shell powder reinforced composite. Besides the above all objectives is to develop a new class of composites by incorporating coconut fiber reinforcing phases into polymeric resin. Also this work is expected to introduce a new class of polymer composite that might find many engineering applications.

II. LITERATURE REVIEW

Products manufactured from carbon are very important in our everyday life. The production of carbon black demand high cost processes and energy consumption. Therefore, an alternative for developing new starting materials for carbon material is needed in order to reduce the cost and fulfill every need of the carbon black consumer. Many researchers have evaluated the by-products of agricultural waste in a new way for the next carbon black generation [1, 2]. Carbon black is commercially used as filler and has its own grades and characteristics. The properties of carbon used in the composites mainly depend on the origin, processing conditions and chemical treatments. The particle size, surface activity, degree of interactions with polymer, chemical composition, and degree of irregularity of filler shape was the factors affecting the behaviour of the composites [3]. Madhukiran.J et al [4] in their work have chosen banana and pineapple as the raw material for preparation of carbon black and activated carbon and used the same as a filler material in polyester composites. Their results show good mechanical properties and high stiffness. Due to the low density of proposed natural fibers compared to synthetic fibers (glass fibers, carbon fibers, etc...), the composites can be regarded as a useful materials in light weight applications. S. Luo and A.N. Netravali [5] studied the tensile and flexural properties of the green composites with different pineapple fiber content and compared with the virgin resin. H. Belmares, A. Barrera, and M. Monjaras [6] found that sisal, henequen and palm fiber have very similar physical, chemical, and tensile properties. M. Cazaurang, P. Herrera, I. Gonzalez, and V.M. Aguilar [7] carried out a systematic study on the properties

of henequen fiber and pointed out that these fibers have mechanical properties that are suitable for reinforcing thermoplastic resins. In India there are many potential natural resources, Most of it comes from the forest and agriculture. Among all natural fibers, Coconut shell particles have high strength and modulus properties along with the added advantage of high lignin content [8]. The high lignin content makes the fiber suitable for manufacturing composites. Coconut shell flour is also extensively used to make products like furnishing materials, rope etc. The shells also absorb less moisture due to its low cellulose content. R.D.T. Filho et al. [9] while studying on the effectiveness of coconut shell particles as a source of natural material for reinforcing epoxy resins towards their flexural properties. Currently, various materials are used to produce activated carbon and some of the most commonly used agricultural wastes such as coconut shell [10], pistachio shell [11], and saw dust [12]. Walnut shell [13] and tropical wood [14]. Flexural and tensile properties of biomass carbon black as filler material in epoxy Composites have been studied by Abdul Khalil et.al. [15] They performed several Characterization studies on composites prepared from bamboo stems, coconut shells and oil palm fiber bunches. Their results indicate better flexural stability of carbon black reinforced epoxy composites compared to un-reinforced samples.

Coconut shells are available in abundance in tropical countries such as Sri Lanka, India, Thailand, Burma, Malaysia, and Indonesia as waste products following consumption of coconut water and meat [16]. Such abundance will be able to meet the gradually increasing demand of filler based composites while reducing natural waste. Procurement and processing of coconut shells to generate coconut char is highly cost effective than most other man made carbon. Prof. Sandhyarani Biswas, Sanjay Kindo [17] studied the mechanical behaviour of coir fiber reinforced polymer matrix composites and observed that that the mechanical properties of the composites such as micro-hardness, tensile strength, flexural strength, impact strength etc. Of the composites are also greatly influenced by the fibre lengths. Prof. Sandhyarani Biswas, Sanjay Kindo studied the processing and characterization of natural fiber reinforced polymer composites and observed that impact velocity, erodent size and fiber loading were the significant factors in a declining sequence affecting the erosion wear rate.

III. MATERIALS AND METHODS

Materials used in this experimental work are listed below:

- Coconut shell powder
- Epoxy resin
- Hardener
- Teflon sheet
- Silicone spray
- Wooden mould

3.1 Processing of coconut shell powder

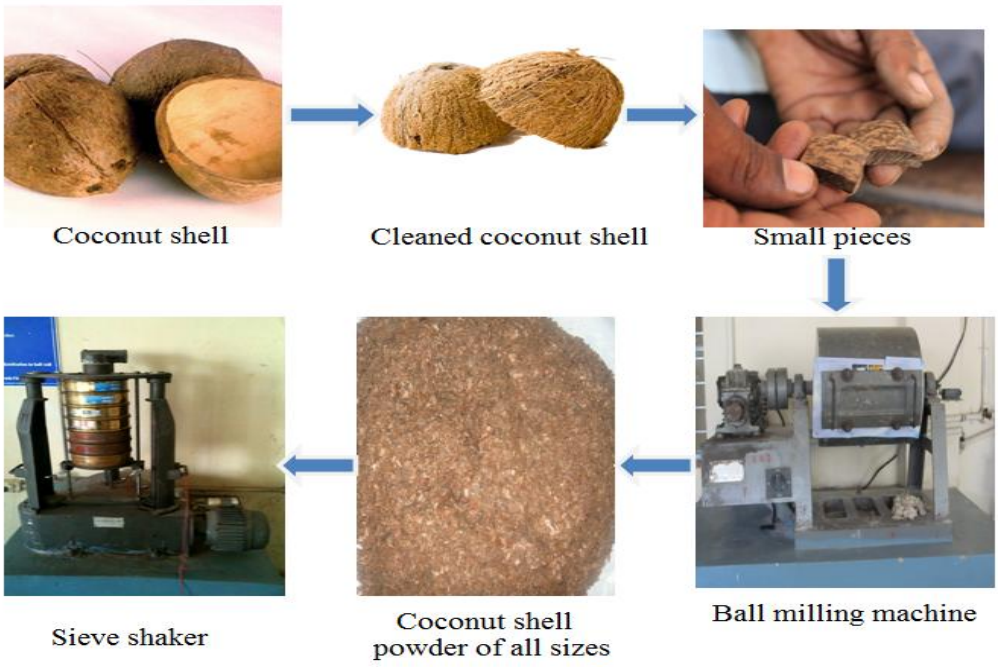

Figure .1.1 Procedure of making raw coconut shell powder

Figure.1.2 Coconut shell powder of three different sizes

3.2 Preparation of Composites

A wooden mould was used for casting the composite sheet. For quick and easy removal of the specimen a Teflon sheet was attached to the inner and outer surfaces the mould. Mould release spray was also applied at the inner surface of the mould wall. The weight percents of coconut shell powder (ie.10, 20 and 30 wt %), were mixed with the matrix material consisting of epoxy resin and hardener in the ratio of 10:1. During pouring care should be taken to avoid formation of air bubbles and also while applying the pressure some polymer comes out from the mould so care should be taken while pouring. After 24 hrs the samples are taken out from the mould and made in to different sizes for further experimentation as shown in the figure 1.3 (a) and (b).

Figure .1.3 (a) Specimen for tensile test

Figure.1.3 (b)Specimen for short beam test

IV. RESULTS AND DISCUSSIONS

The characterization of the composites reveals that the volume % of fiber is having significant effect on the mechanical properties of composites. Mechanical testing includes testing of micro-hardness, tensile strength and flexural strength respectively.

4.1 Density measurement

Mesh size	Fibre volume %	Density (gm/cm^3)
100	10	1.221
	20	1.161
	30	1.142
170	10	1.150
	20	1.103
	30	1.089
240	10	1.124
	20	1.095
	30	1.127

Table 1.1 Density of different samples

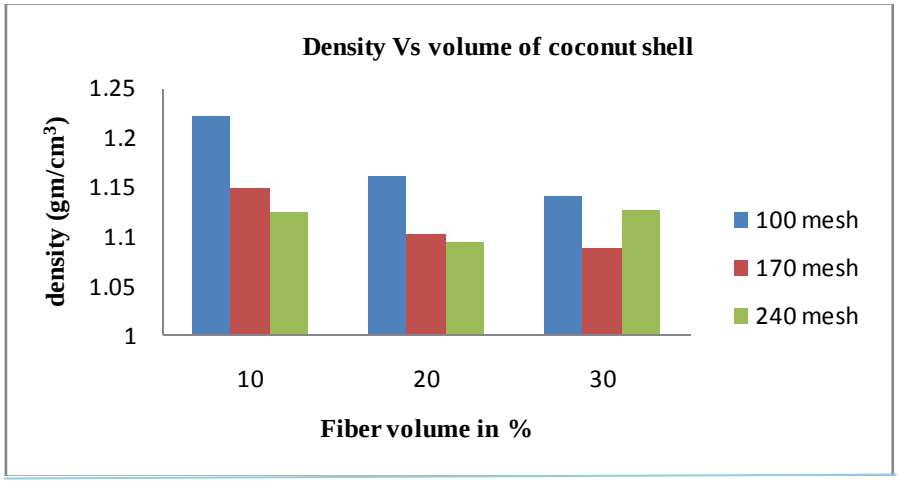

Figure 1.4. Variation of density with different fiber contents

From the table 1.1 it is observed that as the density decreases as the weight percentage of fiber increases and with the increase of mesh size. The decrease in density can be related to the fact that the coconut particles are light in weight but occupy substantial amount of space. Figure 1.4 is the graph drawn between the measured densities of the composites and weight fraction of fiber for different meshes.

4.2 Hardness Measurement

Vickers hardness number is measured by Leitz Micro hardness tester. The results are tabulated in the table 1.2. Figure 1.5 drawn between the hardness values of composite and the weight percentage of composite for different grain sizes. It is observed that as the reinforcement increases the hardness increases the maximum value is obtained for composite prepared with the 30% composite of 240 mesh.

Mesh size	Fibre volume %	HV
100	10	168
	20	192
	30	185
170	10	192
	20	212
	30	258
240	10	202
	20	215
	30	226

Table 1.2. hardness of different samples

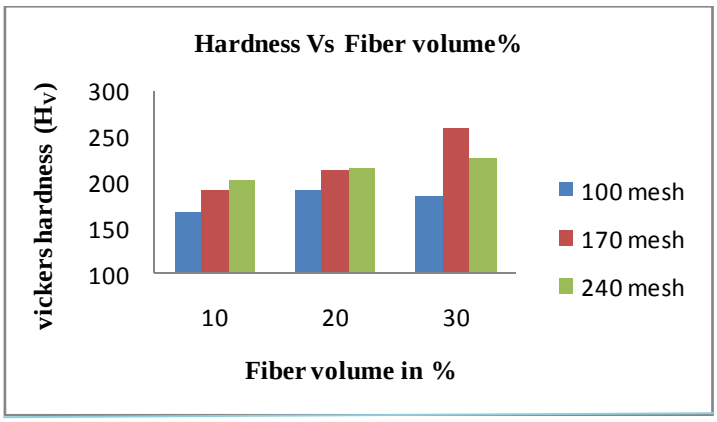

Figure 1.5. Variation of hardness value with different fiber contents

4.3 Tensile Test and Short-beam Test

The results of tensile test and short beam test are conducted on universal testing machine are tabulated below:

Fiber volume %	Tensile strength (MPa)	Short beam strength (MPa)
10	19.75	4.95
20	24.51	6.15
30	18.15	7.35

Table 1.3. Mechanical properties of coconut shell powder fibre epoxy composite of 100 mesh

Fiber volume %	Tensile strength (MPa)	Short beam strength (MPa)
10	20.07	8.25
20	28.87	10.35
30	25.64	10.05

Table 1.4. Mechanical properties of coconut shell powder fibre epoxy composite of 170 mesh

Fiber volume %	Tensile strength (MPa)	Short beam strength (MPa)
10	24.92	9.30
20	22.48	8.70
30	20.89	7.90

Table 1.5. Mechanical properties of coconut shell powder fibre epoxy composite of 240 mesh

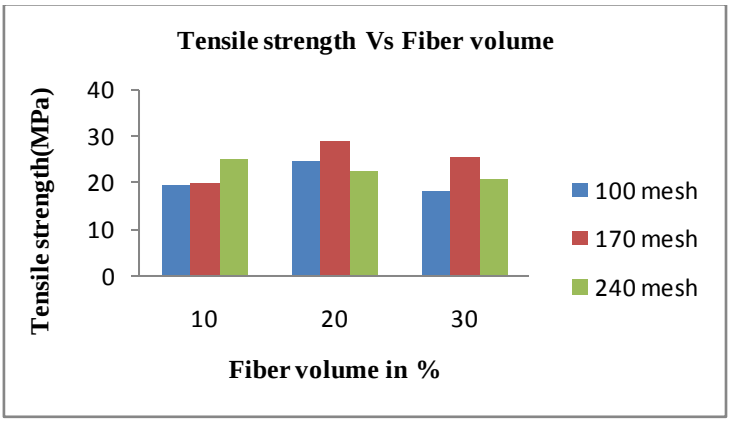

Figure 1.6. Variation of tensile strength values with different fiber contents

The tensile strength results for various specimens which were prepared with raw coconut shell powder particles with different weight fraction for different grains sizes were plotted in figure 1.6. The plot shows that, the maximum tensile strength is obtained for the composite prepared with the 20wt % of 170 mesh coconut shell particulate filled epoxy composite.

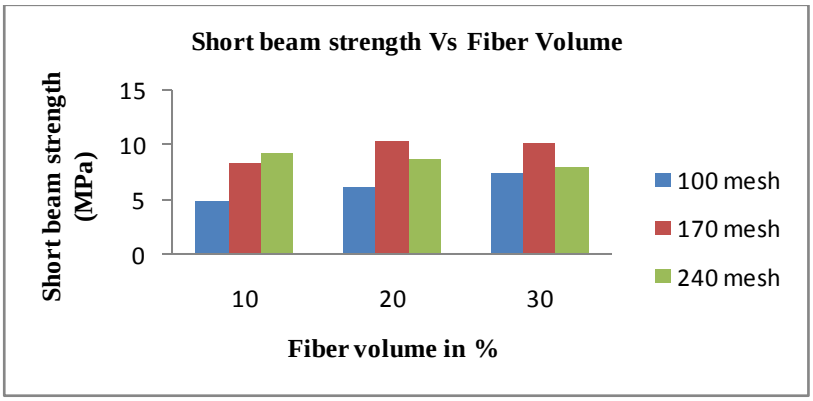

Figure 1.7. Variation of short-beam strength values with different fiber contents

Figure 1.7 shows the variation in flexural strength for different volume fraction of particulate composites. The plot shows that, the maximum flexural strength is obtained for the composite prepared with the 20wt % of 170 mesh coconut shell particulate filled epoxy composite.

4.4 Comparison of coconut shell powder reinforced composite with other natural fiber reinforced composite

A.S. Ferreira et al. conducted the experiments on natural fiber reinforced composites like sisal, ramie, curaua, jute, bamboo and coir and their mechanical properties like tensile strength are obtained as in shown in table 1.6 [18]

Fiber	Sisal	Ramie	Curaua	Jute	Bamboo	Coir
A (MPa)	39	21	17	19	54	13

Table 1.6. Tensile properties of different natural fiber composite-1

Myrtha Karina et al. conducted experiments on natural composites that are prepared from Kenaf, Acacia, water hyacinth, Banana, polymer and empty fruit bunch (EFB) of oil palm found out the mechanical properties of like tensile strength are shown in the table 1.7 [19]

Composites	Tensile strength (MPa)	
	PP	RPP
Kenaf	16.85	14.87
Acacia	13.03	15.36
Water hyacinth	14.72	13.69
Banana	16.18	16.39
EFB	13.61	14.36
Polymer	30.71	28.86

Table 1.7. Tensile properties of different natural fiber composite-2

From the above results it is analysed that the maximum coconut shell powder reinforced composite is 28.87 MPa. It is high when compared to other natural fiber composites made up of Kenaf, acacia, water hyacinth banana, EFB, ramie, curaua, coir and jute. And it is having less strength compared to polymer, sisal and bamboo because of its fiber strength which exhibits naturally. As the coconut shell composite exhibits good mechanical properties when compared to other natural composites researchers are showing interest and developing its for future use.

V. CONCLUSION

The present work deals with the preparation of characterization of coconut shell reinforced epoxy composite. The mechanical behaviour of the composite lead to the following conclusions

- This work shows that successful fabrication of a coconut shell powder reinforced epoxy composites by simple hand lay-up technique.
- The density of the composite gradually decreases with the increase of weight percentage of fiber content.
- The hardness value of the composite increases with increasing of the fiber content. The highest hardness value observed is 258Hv for 170 mesh composite and content of coconut shell powder found to be maximum i.e. 30 %
- Maximum tensile strength value is observed for the composite prepared with coconut shell powder of 170 mesh and the weight percentage of the fiber is 20%.
- Maximum short-beam strength value is observed for the composite prepared with coconut shell powder of 170 mesh and the weight percentage of the fiber is 20%.

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