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Tensile Properties of Natural Fiber-Reinforced Epoxy-Hybrid Composites

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ABSTRACT

A study has been carried out to investigate the tensile properties of composites made by reinforcing sisal, coconut spathe and ridgegourd as the new natural fibers into epoxy resin matrix. The natural fibers extracted by retting and manual processes were subjected to alkali treatment. The composites fabricated consist of reinforcement in the hybrid combination like sisal-coconut spathe, sisal-ridge gourd and coconut spathe-ridge gourd with the weight fraction of fibers varying from 5% to 30%. It has been observed that the tensile properties increase with the increase in the weight fraction of fibers to certain extent and then decreases. The hybridization of the reinforcement in the composite shows greater tensile strength when compared to individual type of natural fibers reinforced. For all the composites tested the tensile strength of the composite increased for approximately 25% of weight fraction of the fibers and further for the increase in the weight fraction of fiber the strength decreased, also it is found that for the hybrid combination of ridge guard and sisal fibers there is 65% increase in the tensile strength.

***Key Words**: Sisal, Ridge gourd, Coconut spathe, Epoxy, Hybrid composite, Tensile Strength*

1. INTRODUCTION:

Natural fibers, as reinforcement, have recently attracted the attention of researchers because of their advantages over other established materials. They are environmentally friendly, fully biodegradable, abundantly available, renewable, cheap and have low density. Plant fibers are light compared to glass, carbon and aramid fibers. The biodegradability of plant fibers can contribute to a healthy ecosystem while their low cost and high performance fulfills the economic interest ofindustry. When natural fiber-reinforced plastics are subjected, at the end of their life cycle, to combustion process or landfill, the released amount of CO_2 of the fibers is neutral with respect to the assimilated amount during their growth. Polymeric materials reinforced with synthetic fibers such as glass, carbon and aramid provide advantages of high stiffness and strength to weight ratio as compared to conventional construction materials, i.e. wood, concrete and steel. In spite of these advantages, the widespread use of synthetic fiber-reinforced polymer composite has a tendency to decline because of their high-initial costs and also production of synthetic composites requires a large quantum of energy and quality of environment suffered because of the pollution generated during the production and recycling of these synthetic materials.

In recent time plant fibers have been receiving considerable attention as substitutes for synthetic fiber reinforcements. Unlike the traditional synthetic fibers like glass and carbon these lignocellulosic fibers are able to impart certain benefits to the composites such as low density, high stiffness, low cost, renewability, biodegradability and high degree of flexibility during processing. Cellulosic fibers like sisal, coconut (coir) and bamboo in their natural form as well as several waste cellulosic products such as shell flour, wood flour and pulp have been used as reinforcing agents of different thermosetting and thermoplastic composites [1-4]. Yan Li.,et al [1] reported the chemical composition, properties of sisal fibers and their composites by incorporating the fiber in different matrices before and after treatment by different methods, along with this they present a summary of recent developments of sisal fiber and its composites. The properties of sisal fiber interface between sisal fiber and matrix, properties of sisal fiber-reinforced composites and their hybrid composites. K. Murali Mohan Rao., et al [2] aims at introducing new natural fibers used as

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fillers in a polymeric matrix enabling production of economical and lightweight composites for load carrying structures. An investigation of the extraction procedures of vakka (Roystonea regia), date and bamboo fibers has been undertaken. The cross-sectional shape, the density and tensile properties of these fibers, along with established fibers like sisal, banana, coconut and palm are determined experimentally under similar conditions and compared. The fibers introduced in the present study could be used as an effective reinforcement for making composites, which have an added advantage of being lightweight. S.M. Sapuan,et al [4] have studied the tensile and flexural strengths of coconut spathe and coconut spathe-fiber reinforced epoxy composites and evaluated the possibility of using it as a new material in engineering applications. Samples were fabricated by the hand lay up process (30:70 fiber and matrix ratio by weight). Tensile strength for the coconut spathe-fiber-reinforced composite laminates ranged from 7.9 to 11.6 MPa and flexural strength ranged from 25.6 to 67.2 MPa, implying that the tensile strength of coconut spathe-fiber is inferior to other natural fibers such as cotton, coconut coir and banana fibers and also found that fiber treatment will improve the interfacial bonding between fiber and matrix leading to better mechanical properties of the spathe-fiber-reinforced composite laminates. Mohd zuhri mohamed yusoff,.et al [6] studied the mechanical properties of short random oil palm fiber reinforced epoxy (OPF/epoxy) composites. Empty fruit bunch (EFB) was selected as the fiber and epoxy as the matrix. Composite plate with four different volume fractions of oil palm fiber was fabricated, (5 vol%, 10 vol%, 15 vol% and 20 vol%). The fabrication was made by hand-lay up techniques. The tensile and flexural properties showed a decreasing trend as the fiber loading was increased. The highest tensile properties were obtained for the composite with fiber loading of 5 vol% and there were no significant effect for addition of more than 5 vol% to the flexural properties.

2. MATERIALS AND METHOD

2.1. Selection of Matrix material

Matrix material selected is Epoxy resin CY-230 and HY-951 as binder for the resin. The tensile strength of Epoxy resin CY-230 is 38 MPa.

2.2. Extraction of natural fibers

The natural fibers such as Sisal (in the form of fibers), Ridge gourd (in the form of natural woven mat), and Coconut leaf sheath (in the form of natural woven mat) were extracted by the process of retting and decorticating.

Scheme 1: Optical photographs of Sisal and Coconut spathe fibers.

2.3. Surface treatment

Alkali treatment of cellulosic fibers, also called mercerization, is the usual method to produce high quality fibers. Alkali treatment improves the fiber-matrix adhesion due to the removal of natural and artificial impurities. Moreover, alkali treatment leads to fibrillation which causes the breaking down of the composite fiber bundle into smaller fibers. In other words, alkali treatment reduces fiber diameter and thereby increases the aspect ratio. Therefore, the development of a rough surface topography and enhancement in aspect ratio offer better fiber-matrix interface adhesion and an increase in mechanical properties. Alkali treatment increases surface roughness resulting in better mechanical interlocking and the amount of cellulose exposed on the fiber surface. This increases the number of possible reaction sites and allows better fiber wetting. Surface Treatment of the natural fibers was performed by rinsing the fibers in 10% NaOH solution for 24 hours and followed by washing with water. NaOH treatment removed wax and fatty substances and changed surface topography of the fibers [12]

2.4. Preparation of the Specimen

2.4.1. Mould

A mould made up of GI (gauge 25) sheet of dimension 170X15X3 mm is prepared. Casting of the composite materials is done in this mould by hand lay up process. Later specimens are cut from the prepared casting according to the ASTM (D 638 M) Standard.

2.4.2. Weight fraction of the fiber

The weight of the matrix was calculated by multiplying density of the matrix and the volume (volume in the mould). Corresponding to the weight of the matrix the specified weight percentage of fibers is taken. For hybrid combination the corresponding weight of fiber obtained is shared by two fibers.

2.4.3. Specimen

Mixing the Epoxy resin CY-230 and the hardener HY-951 with a ratio of 10:1. This solution is used as Matrix and the different types of natural fibers are used as reinforcements; the types of composites manufactured are Sisal- Epoxy CY-230, Ridge Guard- Epoxy CY-230, Coconut leaf sheath-Epoxy CY-230 and various hybrid combinations of natural fibers such as Sisal-Coconut leaf sheath-Epoxy CY-230, Sisal -Ridge gourd- Epoxy CY-230, Ridge gourd- Coconut leaf sheath- Epoxy CY-230. The natural fibers are used in varying weight percentages of 5%, 10%, 15%, 20%, 25% and 30%.

2.5. Testing of composite Material

Tensile test specimens were made according to the ASTM (D 638 M) to measure the tensile properties. The samples were 160 mm long, 12.5mm wide and 3mm thick. The size of the test specimen is eight and average tensile strength has been taken. GI sheet tabs were glued to the ends of the specimen with epoxy resin so as to prevent the compression of the sample at the grip. The samples were tested at a cross speed of 0.5 mm/min and the corresponding strain occurred was measured using an extensometer.

3. RESULTS AND DISCUSSION

The variation of the mean tensile strength verses fiber percentage is represented in Fig: 1 to Fig: 3. Fig: 4 represent the variation of tensile strength of the composites with individual reinforcements namely Sisal fibers, Coconut leaf sheath and Ridge gourd and also the hybrid combinations. The graphs have been plotted taking weight fraction of fiber along the X-axis and Tensile strength (MPa) along the Y-axis.

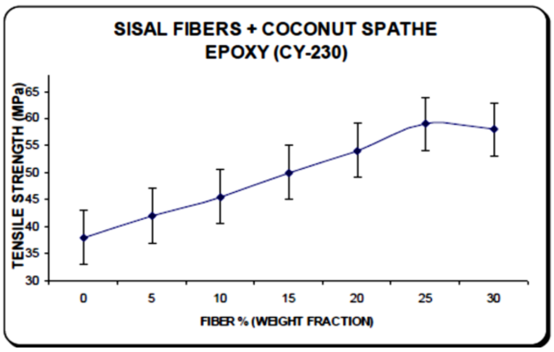

Figure1. Tensile Strength of Epoxy-Sisal-Coconut spathe-Hybrid- Composite.

Figure 1 the combination of fibers used is Sisal and Coconut Spathe. In these composites there is a considerable increase of tensile strength as the percentage of fiber increases to a maximum of 25% and then the strength decreases. The maximum Tensile strength of 59 MPa is obtained for 25% fiber reinforcement, there by 54 % increase in the tensile strength compared with pure Epoxy.

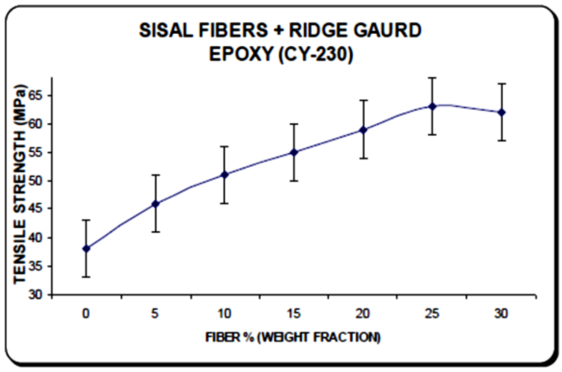

Figure 2. Tensile Strength of Epoxy-Sisal-Ridge Gourd-Hybrid- Composite.

Figure 2 the combination of fibers used is Sisal and Ridge Gourd. In these composites there is a considerable increase of tensile strength as the percentage of fiber increases to a maximum % of 25 and then the strength decreases. The maximum Tensile strength of 63 MPa is obtained for 25% fiber reinforcement, which is the highest tensile strength obtained for the hybrid combination. There is an overall increase of 65% in the tensile strength when compared to pure Epoxy-CY-230 which is used in this work. The increase of tensile strength is due to the increased area of bonding at the interfacial region of the matrix and the reinforcement.

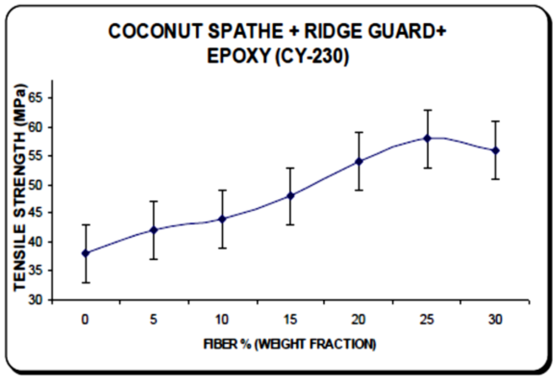

Figure 3. Tensile Strength of Epoxy-Coconut Spathe - Ridge Gourd-Hybrid-Composite.

Figure 3 the combination of fibers used is Ridge gourd and Coconut Spathe. In these composites there is a considerable increase of tensile strength as the percentage of fiber increases to a maximum of 25% and then the strength decreases. The maximum Tensile strength of 58 MPa is obtained for 25% fiber reinforcement. This combination

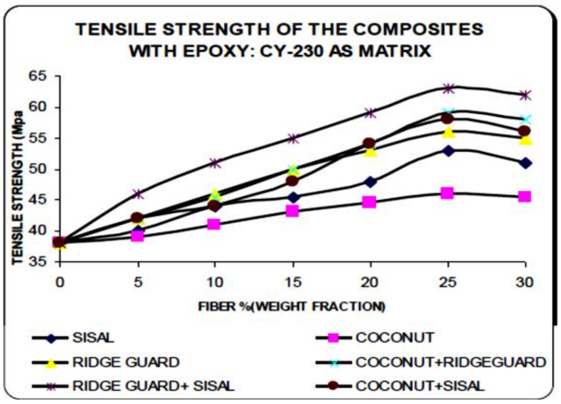

Figure 4 Tensile strengths of the composites with EPOXY-CY-230 as Matrix.

gives the lowest tensile strength among the hybrid combinations.

Figure 4 shows the variation of tensile strength of all the combination of fibers used. The individual reinforcements like Sisal, Ridge gourd and Coconut spathe have a maximum tensile strength of 53 MPa, 46 MPa and 56 MPa respectively. The variation of tensile strength with respect to the percentage of fiber shows that beyond 25% of fiber the tensile strength decreases. The reason is as the percentage of fibre increases the interaction between the fibers inside the composite increases i.e. there will be higher fiber to fiber contact which leads to poor interfacial bonding between the fiber and the matrix. Due to this poor interfacial bonding effective load transfer will not takepalce and leads to failure quickly.

4. CONCLUSION

Sisal fibers, Coconut leaf sheath and Ridge gourd are effective reinforcement of polymers thus creating a range of technological applications beyond its traditional uses such as ropes, carpets, mats etc. The incorporation of natural fibers such as Sisal (in the form of fibers), Ridge gourd (in the form of natural woven mat), and Coconut leaf sheath (in the form of natural woven mat) in to the Epoxy matrix shows the moderate improvement in the tensile properties of the composites. The hybridization of these natural fibers has provided considerable improvement of tensile strength when compared to individual reinforcement; this is mainly due to transfer of loads and shearing of loads among the fibers. For all the composites tested the tensile strength of the composite increased for approximately 25% of weight fraction of the fibers. The values decrease further for the increase in the weight fraction. The tensile strength increased by 65% (maximum) for the hybrid combination of Sisal and Ridge guard as reinforcements. Due to the low density of the natural fibers used compared to the synthetic fibers (Glass fibers, carbon fibers, etc.), the composites can be regarded as a useful light weight Engineering Material.

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