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STUDY OF THE MECHANICAL, PHYSICAL AND THERMAL PROPERTIES OF COCONUT SPATHE FIBER REINFORCED UNSATURATED POLYESTER COMPOSITE.

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Abstract- *This study was carried out to assess the possibility of developing coconut spathe fiber as a new engineering material .Coconut spathe fiber reinforced unsaturated polyester resin composites were prepared by hand layup compression molding by varying fiber weight percentage from 30 to 50 to the total weight of the composite. Five fiber layers were used to fabricate the composites. Tensile, flexural, hardness, water absorption tests and thermal analysis (TG/DTA) were carried out. The results of the tests on mechanical properties showed that incorporation of coconut spathe fiber in unsaturated polyester resin in the range of 35 to 40 by weight considerably improves the mechanical properties with improved thermal stability. With the increase of fiber addition with respect to resin, the density decreases and rate of water absorption increases.*

Keywords: Coconut spathe fiber, unsaturated polyester resin, fiber reinforced composite, natural fiber.

1. INTRODUCTION

Natural fibers have got potential with their high specific strength, low specific weight, and easy availability. Nowadays natural fiber composites are becoming embedded in replacing conventional material like wood, plastics and even in many structural applications for their low material cost, biodegradability, renewable sources ,high filling effect. [1] Unsaturated polyester resin is a widely used thermosetting polymer and has been used extensively in fabricating fiber reinforced polymer composites good chemical corrosion resistance, better strength and good thermal properties. Although for its high degree of crosslinking nature and shrinkage it shows brittle nature to create poor resistance to crack propagation. [2] .The production of natural fiber reinforced unsaturated polyester resin composites strengthens bonding between fiber and matrix which is greater than unreinforced plastics. [3]

Coconut spathe is a leaf like sheath that covers the coconut inflorescence. The coconut spathe of palm inflorescences may be a couple of feet long and therefore woody [4]. Coconut spathe fiber at present is a waste product without any economic value. The potential of coconut spathe fiber has not been studied extensively as a reinforcing material in polymer composites. This promising material imparts high strength and stiffness with their additional low cost, easy availability and biodegradable feature. By considering these features, this research work has been initiated to study the mechanical and physical properties of coconut spathe reinforced unsaturated polyester composite. Effect of different fiber weight addition with unsaturated polyester resin have been studied.

Sapuan et al [5] has investigated the tensile and flexural strengths of coconut spathe fiber reinforced epoxy composites. It was reported that the strength of the fiber reinforced with epoxy resin was inferior to other natural fibers.

2. EXPERIMENTAL

2.1 Materials

The commercially available raw material for matrix was unsaturated polyester resin supplied by KEMROCK Industries (KPR 6100 grade) with a density of 1258 Kg/m^3, specific gravity of 1.12 and viscosity of 500 cps [6].Methyl Ethyl Ketone Peroxide (MEKP) manufactured by SAMUH LAXMI Chemicals Ltd. with a density of 1170 Kg/m^3 was used as hardener for accelerating and and possessing excellent bonding abilities.Coconut Spathe fiber was collected from local sources by hand.

2.2 Fabrication Of The Composite

The composites were prepared by hand lay-up method. The extracted coconut spathe fibers were washed with distilled water in order to remove inclusions and foreign particles and then dried in sunlight for 2 days in daylight. After that, the dried fibers were cut into a size of 18cm×12cm mat. They were dried in oven for 24 hours to remove moisture and to improve bonding. Two SS plates of 30cm × 20cm were used for the lay-up method. The SS plates were used to cover and compress the composite and let the matrix flow into the fiber uniformly. 2 weight percentage of methyl ethyl ketone peroxide (MEKP) was blended with the unsaturated polyester resin matrix and stirred slowly with a spatula for 1 minute to form a uniform mixture. The mixture was immediately poured onto the SS plate covered with a milt paper. After that ,the coconut spathe fiber layer was laid on the mixture. Covering that layer with another so that it is evenly distributed matrix layer. The matrix was laid upon the fiber with a roller. All of the composites were prepared using 5 layers of coconut spathe fiber. The stainless steel mold was then pressed in a hydraulic press machine at a pressure of 120 KN to let the matrix flow into the coconut spathe fiber. The mold was kept under that constant pressure for 6 hours for uniform thickness of the composite and it was cured for another 24 hours. Fibers of different weight percentage (ranging from 30-50) were mixed with the unsaturated polyester resin to prepare the composite. Table 1 presents the ratio of coconut spathe fiber to unsaturated polyester resin of different samples with their respective IDs.

Table 1: Different Sample ID's with their fiber to matrix (wt %) ratio

Sample ID	Fiber : Matrix (weight percentage)
F30	30:70
F35	35:65
F40	40:60
F45	45:55
F50	50:50

3. CHARACTERIZATION OF COMPOSITES

3.1 Determination of Physical Properties

Density of the samples were carried out by taking the mass to volume ratio of the samples using the following formula, D=m/lwh,;where m is the mass and l,w,h are the length, width and thickness of the samples respectively.

Water absorption test of coconut spathe reinforced unsaturated polyester resin was performed in accordance with ASTM 570-98 standard. At first weight of the dried samples were taken .The samples were immersed in distilled water and kept there for 10 days while being taken out ,wiped the surface water and weighed everyday. Water absorption was calculated by the following formula

Water Absorption (%) = $\frac{W_2-W_1}{W_1}$ where W_2 is the wet weight in gm and W_1 is the conditioned weight.

3.2 Mechanical Analysis

The tensile strength was measured according to the ASTM D-3039 standard[7] and the flexural strength was measured according to the ASTM D-790 [8] standard by using a software based UTM, HOUNSFIELD H10KS equipped with a 10 KN loadcell with a crosshead speed of 2mm/min. Dumbbell shaped specimens with a width of 10 mm were prepared for the tensile test and rectangular specimens with a length of 10 cm and width of 1 cm were used for the flexure test.5 samples of each composition were tested for measuring the tensile and flexural strength

Hardness of the samples were determined in accordance with ASTM E384.Five Vickers impressions were taken on each sample with an applied load of 0.1 kgf(980 mN) having a dwell time of 10 seconds by using SHIMADZU HMV-2 series machine. [9]

Measuring the diagonal lengths of the diamond shaped indentation Vickers Hardness was calculated using equation (1)

$$H.V.=1.854*F/d^2 \qquad (1)$$

Where F is the load in N and d is the average length of the diagonals in meter.

3.3 Thermal Analysis

The thermal stability of the composites were observed by EXSTAR TG/DTA 6300.The test was performed at a heating rate of 20° C/min from 30 °C to 600 °C with an inert environment of nitrogen.

4. RESULTS AND DISCUSSION

4.1 Mechanical Properties Analysis

The tensile and flexural properties of the coconut spathe fiber reinforced unsaturated polyester composite are shown graphically in Figure 1.

The increase in fiber content leads to improved tensile properties up to some extent. Figure 1 indicates that the tensile strength of the composites increase with addition of fiber content up to35 wt % of fiber exhibiting the highest tensile stress of 27.9 MPa for 40 wt% fiber content of the composite. The incorporation of further fiber content results in a decrease in tensile strength. However the addition of 50 wt% of fiber dramatically decreases the tensile strength of the composite.

The flexural strength exhibits the similar trend of tensile strength. The flexural strength increases significantly by the incorporation of 35 wt % of fiber while exhibiting the highest flexural strength of 77.3 MPa for 40 wt% of fiber into the composite. Further incorporation of coconut spathe fiber into the composite gradually decreases the flexural strength.

These results suggest that the incorporation of 35 to 40 wt% fiber enhances the strength of the coconut spathe fiber reinforced unsaturated polyester composite. Better interfacial stress transfer ability between fiber and matrix is achieved for this fiber addition with fiber compatibility.

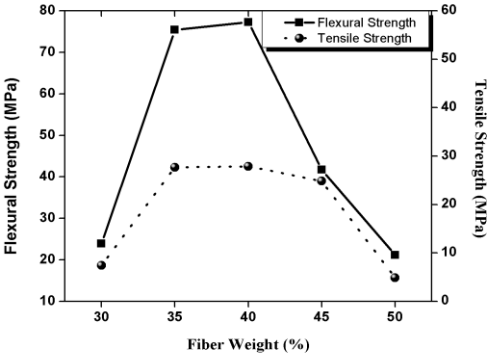

Fig. 1: Tensile and flexural properties of coconut spathe reinforced unsaturated polyester composite

The hardness of the composites are shown in Figure 2.There is an increase in hardness value with increment of fiber content from 30 wt% to 35 wt%. When the fiber content is of 40 % of the weight of the composite it shows the highest hardness value of 170.2 MPa. The improvement of the interfacial bonding between matrix and fiber phase is the reason of enhancement of hardness with the increase of fiber content. At the 40 wt% fiber content the composite shows better stress transfer giving the highest hardness values. With further increment of fiber content up to 50 wt% the hardness value deteriorates gradually. This is due to the presence of porosity. With further addition of fiber content beyond 40 %, air is entrapped for higher ratio of fiber to resin. The entrapped air due to higher porosity lowers the hardness value.

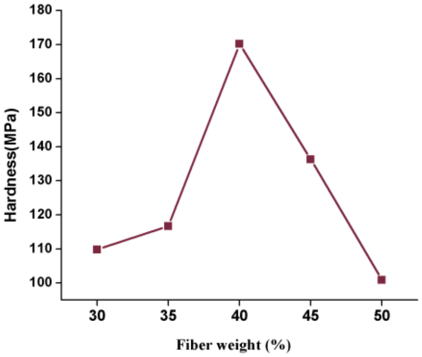

Fig. 2: Hardness of coconut spathe reinforced unsaturated polyester composites.

Table 2 summarizes the mechanical properties of coconut spathe reinforced unsaturated polyester composite

Table 2: Effect of fiber addition on mechanical properties of coconut spathe reinforced unsaturated polyester composite.

Sample ID	Tensile Strength (MPa)	Flexural strength (MPa)	Hardness (MPa)
F30	7.39	23.91	109.8
F35	27.7	75.4	116.7
F40	27.9	77.3	170.2
F45	24.85	41.69	136.3
F50	4.87	21.15	100.9

4.2 Physical Property Analysis

Figure 3 and Figure 4 shows the effect of fiber addition on the density and water absorption of the composite respectively. Density of the composites decreases with fiber addition. The enhancement of fiber ratio into the composite increases the amount of pores in the composites therefore giving a lower density ratio with increasing fiber weight. From Figure 4 it is evident that the water absorption increases with increase of soaking time for all the compositions .For a certain period of time the water absorption is saturated for all the composites. The percentage of water absorption also increases with the addition of fiber.

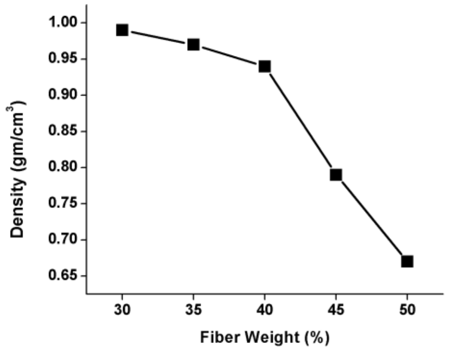

Fig. 3:Density as a function of fiber weight of coconut spathe reinforced unsaturated polyester composite

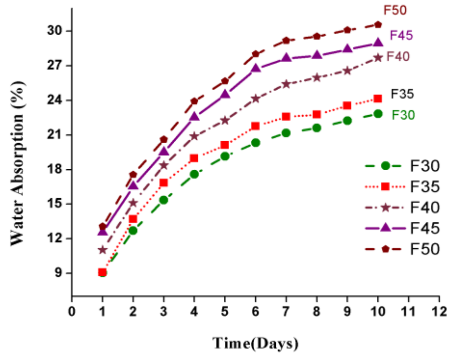

Fig. 4: Water Absorption characteristics of coconut spathe reinforced unsaturated polyester composite

4.3 Thermal Property Analysis

Thermal properties of the coconut spathe reinforced unsaturated polyester composite was determined by thermo - gravimetric analysis .The thermo-gravimetric (TG) curve in Figure 5 exhibits a three stage thermal degradation process. The first stage degradation occurs at a range of 40^{O}C to 130^{O}C which occurs due to the loss of moisture and volatile material. The second stage degradation occurs between 160^{O}C to 230^{O}C which is the result of decomposition of matrices and fibers. The final stage decomposition take place between 315^{O}C to 390^{O}C and results in the major degradation of mass due to the transformation of fibers and matrix into ash

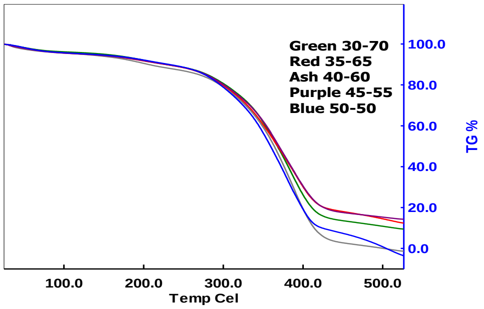

Fig. 5: TGA curves of coconut spathe reinforced unsaturated polyester composite

Table 3 summarizes the thermal degradation temperature of the composites.

Table 3: Thermal Properties of coconut spathe reinforced unsaturated polyester composite

Sample ID	Degradation Temperature			Total Degradation(weight percentage at 600 ^{O}C)
	T_{onset}	T_{end}	T_{max}	
F30	326.9	413.3	386.9	91.5
F35	316.5	415.0	390.3	87.6
F40	336.9	416.4	387.8	85.7
F45	322.0	416.9	369.1	Degrades Completely
F50	315.6	409.1	386.8	Degrades Completely

The DTA curve is exhibited in Figure 6 of the composites showing three endothermic peaks at three different temperature range. Figure 7 shows three different peaks indicating three degradation stages.

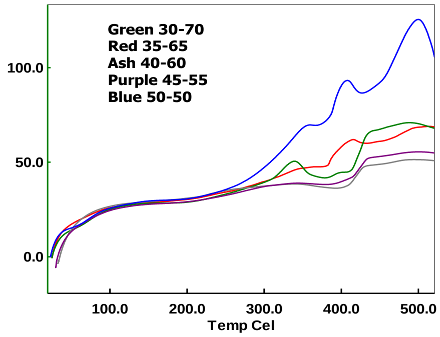

Fig. 6: DTA curves of coconut spathe reinforced unsaturated polyester composite

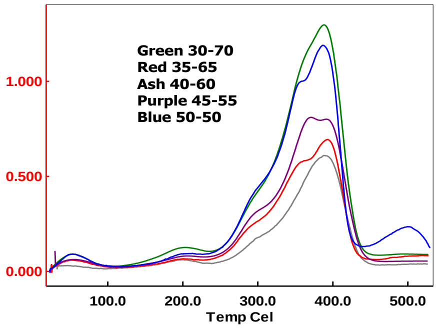

Fig. 7: DTG curves of coconut spathe reinforced unsaturated polyester composite

5. CONCLUSION

The effect of addition of coconut spathe fiber in unsaturated polyester resin composite has been studied by evaluating the mechanical, thermal and physical properties. With increasing the fiber content to coconut spathe fiber/unsaturated polyester composite the mechanical properties increased. The tensile and flexural strength and hardness increased upto a certain ratio of fiber to matrix. Optimum results of mechanical properties have been noticed for 35 to 40 weight percentage of fiber into the composite. Further addition of fiber into the matrix resulted in gradual decrease in mechanical properties due to low adhesion bonding of excessive pores of the composites. The thermal stability got better with fiber addition. The density of the composites decreased and rate of water absorption increased with fiber addition due to its porous nature. After a certain period of soaking time the rate of water absorption became saturated.

So considering mechanical properties ,better thermal stability and moderate water absorption behavior as the quality important parameters this study suggests to select 40:60 (fiber: matrix) composite for the best properties.

The decrease in mechanical properties are due to poor interfacial bonding between matrix and fiber. Interfacial Bonding can be improved by surface treatment of the fibers. Further study can be initiated for surface treatment of coconut spathe fiber

6. ACKOWLEDGEMENT

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.8. NOMENCLATURE

Symbol	Meaning	Unit
F	Load	Newton(N)
H.V.	Vickers Hardness number	Unitless
D	Density	gm/cm^3