MECHANICAL CHARACTERIZATION OF PINEAPPLE LEAF FIBER REINFORCED EPOXY COMPOSITES FILLED WITH CORN HUSK POWDER

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Abstract

Composites are lightweight, fatigue resistant, easily moldable materials that are attractive alternative to metals in various engineering applications. Composites have the ability to meet diverse design requirements with significant weight reduction of parts yet offering high strength to weight ratio as compared to conventional materials. The need of new materials for applications demanding lighter construction materials, automobile parts and seismic resistant structures has motivated the use of advanced composite materials that can not only be an advantage in decreasing the dead weight but also in absorbing the impact load and vibration. Further, the reduction in weight of vehicle results in decrease in dead weight of the engine ensuring less power requirement and thereby lowering the fuel consumption. Natural fiber based composites are under intensive study due to their light weight, eco friendly nature and unique properties. Due to the continuous supply, ease of handling, safety and biodegradability, natural fibers are considered as better alternatives in replacing many structural and non structural components. Although natural fibers exhibit admirable physical and mechanical properties, the composites fabricated using natural fibers are found to vary in their properties with respect to the plant source, species, geography, and henceforth. Corn Husk Powder (CHP) and Pineapple Leaf Fiber (PALF) can be a new source of raw material to the industries and can be potential replacement of the expensive and nonrenewable synthetic fiber. In the present work, three different composites were fabricated with bidirectional PALF mat as the reinforcement material, corn husk powder as the filler material and epoxy as the matrix material by changing weight fraction of reinforcement and filler (10:20, 15:15 and 20:10 % of PALF and CHP respectively). PALF were subjected to alkali treatment for improving adhesion properties with matrix material. Composites were prepared using hand layup technique by maintaining constant fiber and matrix volume fraction. The samples of the composites thus fabricated were subjected to tensile, flexural and impact tests for finding the effect of corn husk powder in different concentrations. Tensile fractured surfaces of composites were analyzed for determining bonding ability of fiber with matrix using Video Measuring System (VMS). The test results showed that the Tensile properties of composite B (15%PALF & 15% CHP) and Composite C (20%PALF & 10% CHP) reached the maximum tensile strength than composite A (10%PALF & 20% CHP). Composite C is found to have a maximum flexural strength of 76.26 MPa. The maximum impact strength of 1.96 joules is obtained for the sample C composite material. From the results, composite with more PALF showed maximum mechanical properties than composite with more corn husk powder. Microstructural image from VMS showed fiber pull out and internal cracks in the broken surface of the tensile test specimen of composite A.

Keywords: Pineapple Leaf Fiber (PALF), Corn Husk Powder (CHP), Epoxy, Mechanical Properties. Natural composites

1. INTRODUCTION

For the past few decades, Fiber Reinforced Composites (FRC) have found wide usage in advanced applications with its market growing continuously. It is known that the addition of fibers to polymers has several advantages, especially in increasing the mechanical properties of the composites. Synthetic fibers such as carbon/glass are reinforced in polymers to be used in high performance applications such as automobiles and aircraft industries. The performance of these composites has been improved continuously through rigorous research, often through mixing of two or more reinforcements/polymers or fillers. However, these high-performance composites are mostly of non bio-degradable nature posing serious threat to the environment[1]. It is interesting to note that natural fibers are abundantly available in developing countries like India, Malaysia, Philippines, Korea and Indonesia but is not optimally utilized. Plant fibers are nowadays exploited as reinforcement materials owing to their low cost, fairly good mechanical properties, high specific strength, non-abrasiveness, availability, eco-friendly and bio-degradability characteristics [2, 3]. Hybrid composites provide combination of material properties of those individual fibers and the reinforcement used. Carlos et al. [4] described the chemical composition, physical characteristics, thermal resistance, mechanical properties, crystallinity index and morphology of corn husk residue. As per the results, corn husk has low lignin content and equivalent amount of hemi cellulose and α-cellulose to those of the other fibers considered. In addition, the corn husk biomass showed better tensile property than piassava palm fiber and coir. The crystallinity index of corn husk is 21-26% and a large number of micro fibrils are present in its structure [4]. This increases the transfer of stress between the fiber and the matrix interface region. Nazire et al. [5] evaluated the effects of extraction process parameters on the physical properties, mechanical properties and thermal durability of corn husk fiber. The samples provided good tensile Strength that were obtained from 5-10g/L NaOH treatment for 60-90 min. Alkalization under harsher conditions results in higher thermal durability up to 320ºC with higher cellulose fraction, but lower durability above this temperature. The Fourier transform infrared spectrum analysis proves the presence of higher cellulose content but lower hemicelluloses and lignin with harsher treatment conditions. Yaning et al. [6] determined the physical properties (moisture content, particle size, bulk density and porosity) of corn cobs, leaves and stalks and analyzed the suitability for reinforcement. A positive relationship between the average particle size and porosity was observed for the corn residues. From this study it was concluded that the corn residues (cobs, leaves and stalks) observed to be suitable as reinforcement in composite. Nasmi Sari et al. [7] developed composites with 1%, 2%, 5%, and 8% NaOH treated corn husk fiber and found that the tensile properties of the treated composite panels were better than those of raw fiber composite panels. Khwanthi et al. [8] analyzed suitability of corn husk fiber and fiber glass for insulation material considering cost and performance. Results indicated that corn husk was found to be technically and financially more suitable insulating material than fiber glass.

Kloykam et al. [9] investigated the compatibility and composite properties of alkaline and silane treated pineapple leaf fiber and polyamide 6 composites. Effect of fiber surface treatment and fiber loading on the properties of the composites was investigated. The thermal characteristics of the composites have not been affected by PALF types. From the results, it was found that alkali treatment is sufficient to improve compatibility and properties of the PALF/polyamide 6 composites at fiber loading of 30% wt. Madhukiran et al. [10] carried out an investigation on the flexural properties of banana and pineapple fiber reinforced composites (0/40, 15/25, 20/20, 25/15, and 40/0 Weight fraction ratios of banana and pineapple respectively). The hybridization of the reinforcement in the composite shows greater flexural strength, when compared to individual type of natural fibers reinforced composites. Epoxy resins are being widely used in many of the advanced composites due to their excellent adhesion to wide variety of fibers, and high performance at elevated temperatures [111]. Abdul et al. [12] fabricated the composites with bamboo fiber reinforced with the different polymeric resins, such as, polyester, epoxy, phenolic, polypropylene, Poly Vinyl Chloride and polystyrene. Tensile and flexural properties showed a maximum for composite with epoxy resin when compared to the other polymeric resins. Pickering et al. [13] reported that the tensile strength and young's modulus of the flax fiber reinforced epoxy composites to be 136 MPa and 10.5 GPa respectively. This Shows the effect of the epoxy resin on the fiber involved. Arunkumar et al. [14] fabricated the composite with glass fiber, filled with rice husk in epoxy matrix and investigated the mechanical properties and erosion wear response of these composites and made a comparison between the unfilled and filled samples. Results found to be better in rice husk filled composite due to increased bonding ability between fiber and matrix was achieved during fabrication. Haameem et al. [15] characterized the mechanical properties of NaOH treated Napier grass fiber reinforced composites. 10% alkali-treated Napier grass fibers yielded the highest tensile strength than other concentrations. The maximum tensile and flexural strengths of the composites were obtained at 25% fiber loading. In general, up to a certain value of volume fraction, the mechanical properties of the composites increased as the fiber volume fractions increases, following which, there was a reduction in properties.

The present work focuses on fabricating composite with pineapple leaf fiber and corn husk powder as the reinforcement and epoxy as the matrix material. Pineapple leaf fibers treated with 2 5 NaOH and corn husk powder with a size of approximately 75 microns were used at a fiber percentage of 10:20, 15:15 and 20:10 % by volume. Characterizing the fabricated cellulose fiber reinforced polymer composite has been attempted by testing tensile, flexural and Impact strength to determine the effect of corn husk powder when increasing filler percentage.

2. MATERIALS AND METHODS

The materials used for fabricating the composites and the methodology involved are discussed in detail as follows.

2.1 Raw Materials Used

Pineapple leaf fibers (PALF) in mat form and Corn husk in powder form were used as the reinforcement material. Corn husk (outer leaf) was collected from local market. Pineapple leaf fiber (PALF) was purchased in the length of 20 – 30 mm. The Matrix material used for the present work, Epoxy Ly 556 and corresponding hardener HY951 were purchased from Javanthee Enterprises, Chennai, India. The physical properties of the raw materials used for the present work is shown in Table 1.

Table.1 : Physical Properties of Epoxy Resin [10, 16]

Sl. No	Properties	Epoxy	PALF	Corn Husk

1	Density, g/cm³	1.1-.14	1.44	1.12 – 1.32
2	Tensile Strength, Mpa	35-100	413-1627	140-450
3	Elastic Modulus, Gpa	3-6	60-82	45-70
4	Elongation , %	1-6	1.6-4	1.1-3
5	Water Absorption (24 Hrs in %)	0.1-0.4	11-12	12-14

2.2 Composite Fabrication

Corn husk was dried in sunlight for three days and then manually chopped into short fibers. Alkali treatment (NaOH) of corn husk fibers was carried for an hour with 2g/l of NaOH in distilled water. The treated fibers were dried in sunlight for two days, hammered and sieved in 75 micron sieve to get fine powder of corn husk. Pineapple leaf fiber (PALF) procured in the form of strands was made into a bidirectional mat of size 300 x 300 x 5mm. Hand lay-up technique was used for fabrication of composites. Composite were fabricated using the mould made of silicon rubber. The cast of each composite was cured under a load of about 50 kg for 24 hours before it was removed from the mould. Three different composites were fabricated by maintaining constant fiber matrix weight fraction (30:70 % of fiber and matrix respectively). The weight fraction and fiber composition used are shown in Table 2.

Table.2 : Weight Fraction of PALF and CHP in Each Composite

S.No	Composite Designation	Weight Fraction Distribution (%)			Total Weight of composite (g)	Weight of PALF mat (g)	Weight of corn husk powder (g)
		PALF	CHP	Epoxy			
1.	A	10	20	70	589.5	88	88
2.	B	15	15	70	595.8	59	118
3.	C	20	10	70	588.08	118	59

2.3 Mechanical Testing of composites

Test Samples were prepared according to ASTM standard using vertical zigzag cutting machine. For average values three samples per composite were prepared. Experiments to find the mechanical properties such as tensile, flexural and double shear strength were found by tensile test (ASTM D638), and Flexural test (ASTM D790) conducted on universal testing machine. Impact energy was determined by performing Izod impact test (ASTM D256). Finally Video Measuring System (VMS) was used for analyzing the internal bonding between fiber and matrix and the microstructure of fractured surfaces.

3. RESULTS AND DISCUSSION

3.1. Tensile Strength

The results indicated that the sample C (20% PALF and 10% CHP) specimen gives better tensile strength than the other two composite A (10% PALF and 20% CHP) and composite B (15% PALF and 15% CHP). The addition of more amount of CHP shows comparatively low tensile strength than the other composites considered. The addition of corn husk powder (amorphous in nature) reduced the tensile strength which continuously decreased with increasing filler content (Figure 1). The reduction in tensile strength could be due to filler-filler interaction, which becomes more pronounced than that of the filler-matrix interactions [17].

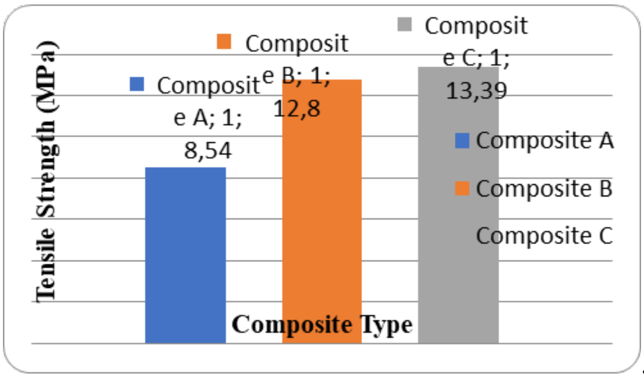


Figure 1: Average Tensile strengths of PALF - CHP/Epoxy composite

It is evident from the table 3 that the elongation at breaking strength decreases with increasing filler loading. Reduction of elongation at breaking point is common since, weak interfacial bonds due to poor filler/Epoxy interaction facilitated crack propagation and thus composites fracture at lower value of elongation was observed with increasing filler content [18].

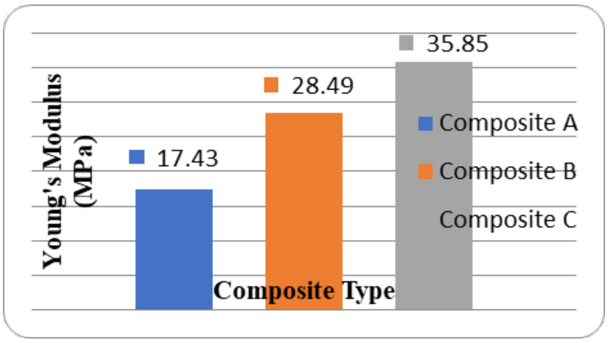


Figure 2: Average Young's Modulus of PALF - CHP /Epoxy composite

The Young's modulus of composites increase with increase in filler content (shown in figure 2).The presence of fillers hindered the polymer chain mobility of epoxy matrix, in addition to the stiffness of the composite [19]. The rigidity of the composite could also be linked to the cellulose contents of the peanut husk fillers. The increase in Young's modulus with filler content was in agreement with other reported works [20, 21].

3.2. Flexural Strength

The maximum average flexural strength (76.26MPa) was observed in Composite C (20% PALF -10%CHP). The result indicated that the displacement increases with the increase in applied load up to around 302.6 N, after which it tends to decrease and break. The maximum average displacement observed was 2.25 mm. Flexural strength of composite A

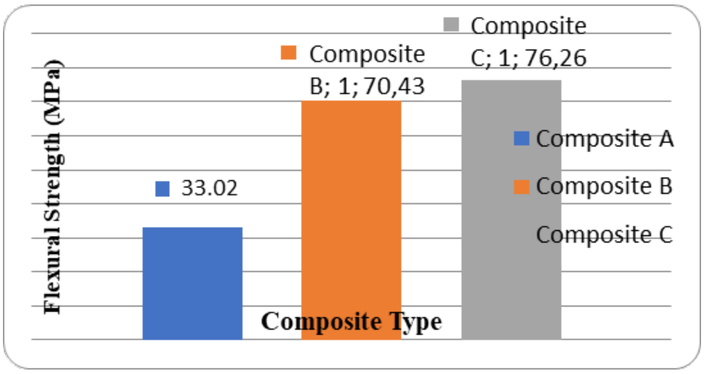


Figure 3: Average Flexural of PALF - CHP /Epoxy composite

and composite B was 33.04 MPa and 70.43 MPa respectively. When increasing corn husk powder to 20% by volume, flexural strength was decreased up to 130%. This result agrees with the findings of many researchers who have used natural fillers with polymers; Henry [17] observed an appreciable increase in the flexural strength of the composite when increasing fiber content with low filler material. This is because of well formed interface that allows better stress transfer from the matrix to the fiber [22].

Table.3 : Average Values of mechanical properties of each composites

Properties	Composite A	Composite B	Composite C
Tensile properties(MPa)	8.54	12.80	13.39
Elongation at Max (%)	49	44.92	37.35
Young's Modulus (MPa)	17.43	28.49	35.85
Flexural Strength (MPa)	33.02	70.43	76.26
Impact Energy (J)	1.86	2.53	2.97

3.3. Impact Energy

The mean of the maximum of the tensile, flexural and impact strengths of different specimen tested are tabulated in the table 3. The results indicated that the maximum impact strength was obtained for the composite C (shown in the Figure 4). Impact strength was decreased when corn husk filler content in composite increases. The decrease in impact strength indicates that the amount of matrix is probably not sufficient to transfer the stress effectively during a sudden impact in combination with the lower absorption characteristic of the filler [23]. It has been observed that high filler content increases the chances of fiber agglomeration, which results in regions of stress concentration requiring less energy for crack propagation [24]. The impact strength of fiber filled polymer composites depends on the nature of the filler, the polymer, and fiber matrix interfacial bonding [3, 17 and 19].

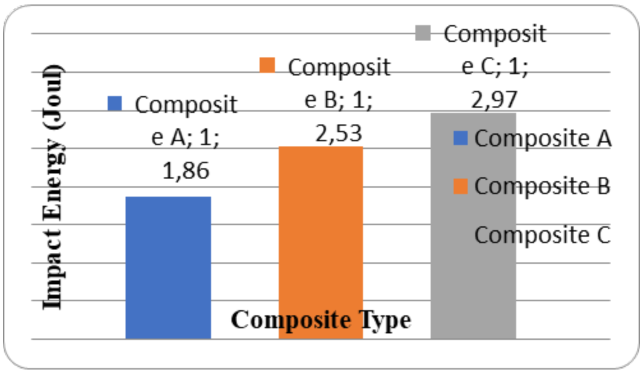
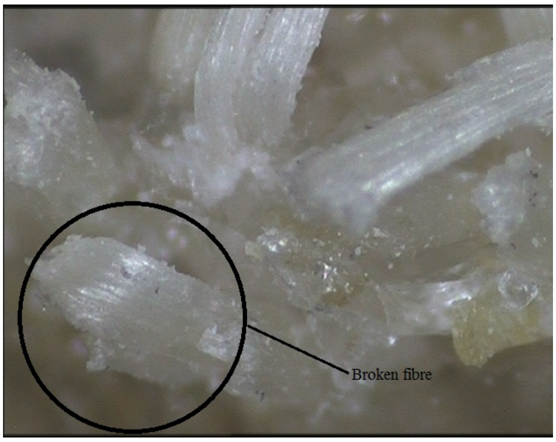


Figure 4: Average Impact Energy of PALF - CHP /Epoxy composite

3.4. Microstructure Analysis

In order to determine the factors affecting the tensile properties of PALF-CHP/epoxy composites, tensile fractured surfaces were analyzed using Video Measuring System (VMS). Figure 5 shows fractured surface of the composite B which depicts the breakage of pineapple leaf fiber at certain points due to tension but not pull out indicating good bonding nature with the matrix. The formation of grooves roughens the fiber surface, thus increasing the interfacial bonding between fiber and matrix by interlocking mechanism. Similar mechanisms



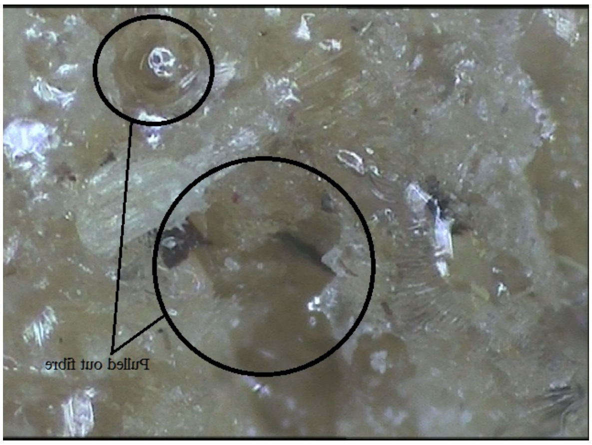


Figure 5 : Fractured surface of sample B **Figure 6: Fractured surface of sample A**

were due to interlocking as observed in our previous research works [25-28]. Figure 6 shows fractured surface of the composite A which is due to fiber pull indicating the weak bonding of fiber with the matrix. Poor interfacial adhesion results because of relatively ineffective force transfer between the matrix and the fiber. This results in poor mechanical properties that are inferred from the tensile and flexural test results.

4. CONCLUSION

This work has shown the fabrication of the pineapple leaf fiber reinforced epoxy composites filled with corn husk powder using hand lay-up technique. Composites were fabricated with three different fiber and filler volume fraction (10:20, 15:15, and 20:70 ratio of PALF/CHP respectively). Mechanical properties such as the tensile, flexural and Impact strength were determined. The results indicated that the composite B (15% PALF and 15% CHP) showed the maximum tensile strength and can hold the strength up to 13.29 MPa. The results indicate that the composite C (20% PALF and 10% CHP) gives better tensile strength than the other two composite samples . Adding corn husk powder with fiber reduces the tensile strength which continuously decreased with increasing filler content. The elongation at breaking strength decreases with increase in the filler content in the composite . At higher filler content, a drastic reduction of elongation at breaking strength was observed due to poor filler/Epoxy interaction facilitated crack propagation and thus composites fracture at lower value of elongation was obtained with increasing filler content. The maximum average flexural strength (76.26MPa) was observed in Composite C (20% PALF and10%CHP). When increasing corn husk powder to 20%, flexural strength was decreased up to 130%. Increase in the flexural strength of the composite with higher fiber content and low filler material is because of well formed interfacing that allows better stress transfer from the matrix to the fiber. From impact test results, the maximum impact strength was obtained for the composite C. The impact strength was found to decrease when corn husk filler content in composite increases. The decrease in impact strength indicates that the amount of matrix is probably not sufficient to transfer the stress effectively during sudden impact. This is also attributed in combination with the lower absorption characteristic of the filler. From the results, composite with higher fiber content and lower filler content showed better mechanical properties. Presence of more fiber content in composite ensures the stress transfer at the interface between the fiber and the matrix thus providing better mechanical properties of the composites.

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