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Indian
Journal of Advances in
Chemical Science

Indian Journal of Advances in Chemical Science S1 (2016) 118-121

Study on Tensile and Hardness behavior of Sawdust Impregnated on Short Coir Fiber Reinforced Epoxy Composite

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Received 05th February 2016; Revised 10th February 2016; Accepted 10th February 2016

ABSTRACT
Modern technology requires materials with distinctive combination of properties that is not possible to meet the requirements by conventional metal alloys, ceramics, and polymer materials. Synthetic fibers such as E-glass, carbon fibers are widely used due to their high stiffness and weight to strength ratio. These had a proclivity to reduce due to high cost and increased environmental awareness which have diverged attention toward organic/natural fibers composite adding advantages such as low cost, ease in availability, low density, enhanced energy recovery, co_2 neutrality, biodegradability, and satisfactory mechanical properties as well. In this study, short coir fibers reinforced polymer composites were developed by hand layup with varying percentage of matrix (85, 80, 75, and 70%) and sawdust filler (0, 5, 10, and 15%) by weight. The developed composites were tested for tensile and hardness property as per ASTM standards. The results showed an increase in tensile property by 12.75% with addition of filler and with further increase in filler percentage, tensile property dropped by higher percentage. Hardness property increased by 17.25% with an increase in filler percentage as sawdust led to an increase in matrix surface resistance toward indentation. Microstructure analysis was carried out to study specimen surface morphology. The results show that tensile property and hardness are greatly influenced by incorporating the percentage by weight fraction of filler and suggest that coir reinforced polymer matrix composite impregnated with sawdust filler has much structural and non-structural application.

Key words: *Epoxy, Hardness, Sawdust, Short coir fiber, Tensile strength.*

1. INTRODUCTION

Due to increased environmental awareness, natural fibers have gained importance due to its unique properties such as ease of availability, light weight, strong, renewable, eco-friendly, low cost, low density, and biodegradable. Most commonly used natural are plant fibers such as coir, jute, sisal, kenaf, banana, hemp, and pineapple. The major drawbacks of natural fibers are weak adhesion with the matrix material as a result of incompatibility, reduction in mechanical performance was noticed and high water absorption rate due to its hydrophilic nature. Hydrophilic nature of fibers led to weak bonding between fiber and matrix, dimensional instability, matrix cracking, poor mechanical property, and reduces the durability of the composite. Initial treatments are performed before the fabrication to roughen fiber surface so as to improve on adhesion and reduce the moisture intake percentage [1]. From the past few decades, many research works are carried out on coir fiber reinforced polymer composite due to its increased demand in applications. Coir fiber reinforced polymer composites are developed for industrial and socioeconomic applications such as automotive interior, paneling and roofing as building materials, storage tank, packing material, helmets, post boxes, mirror casing, paperweights, projector cover, and voltage stabilizer [2]. Sawdust is a major biological waste generated in wood polishing firms, stored in uncontrolled condition can be a factor responsible for environmental pollution [3]. From environmental point of view, it is very important to prevent pollution resulting from sawdust. This study focuses on improving the mechanical performance of short coir fiber epoxy composite with sawdust impregnation and conversion of waste to energy gaining an economical value.

2. MATERIALS AND METHODS

2.1. Alkalization of Coir Fiber

Coconut coir fibers were subjected to 6% NaOH treatment for 72 h to improve the compatibility between the fibers and matrix. Alkali treatment

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disrupts the hydrogen bonding in the fiber structure causing fiber surface roughness by removal of lignin and pectin to a certain amount and also inhibit water absorption rate.

2.2. Fabrication of Composite

Alkaline-treated natural coir fibers was cut to a length of 15 mm (density is 1.2 g/cm^3) and was used as reinforcement material in this investigation. Composite laminates were fabricated by weight proportion as shown in Table 1. The matrix material of epoxy resin (LY556) and the filler material of sawdust (density = 0.8 g/cm^3, specific gravity is 2.68, porosity is 0.37, particle size <65 µm) were used. Hand layup technique followed by compression molding was used for fabricating particulate filled coir epoxy composites. Petroleum wax (releasing agent) was applied to the mold surface before the fabrication. Epoxy and hardener (HY951) by ratio (10:1) by weight is mixed along with sawdust filler for 10 min. This mixture is laid into the mold of volume 300 mm × 300 mm × 3.2 mm. Short coir fibers are distributed throughout the mold volume along with remaining epoxy sawdust mixture. The mixture is now pressed under load for uniform distribution of matrix. Composites are then allowed to cure at room temperature for 24 h.

2.3. Testing of Composites

Fabricated composites are initially tested to determine the actual density. The change in density corresponds to the void content which shows negative outcome on mechanical performance. Percentage void content is determined using formulae (1) composite laminates fabricated were machined as per ASTM standards. Three tensile specimens of 250 mm × 25 mm × 3.2 mm for each sample was machined and tested according to ASTM D 3039 in universal testing machine (UTM). Hardness test was carried out using Matsuzawa Micro Vickers instrument using 100 gf as per ASTM D 2240. Tensile strength is calculated using formulae (2) Trinocular inverted metallurgical microscope was used to study specimen morphology and to analyze the effect of filler on composite laminate surface.

$$\text{Void content} = \frac{\rho^{\text{Theoretical}} - \rho^{\text{Actual}}}{\rho^{\text{Theoretical}}} \quad (1)$$

$$\sigma^{\text{stress}} = \frac{\text{Force at failure (N)}}{\text{c / s area of specimen (mm}^2\text{)}} \quad (2)$$

3. RESULTS AND DISCUSSION

3.1. Influence of Sawdust on Mechanical Properties

Figure 1 shows the effect of filler percentage on tensile strength. It can be noticed that a maximum tensile strength of 20.8 MPa was exhibited by sample with 5% filler. With further increase in filler, a drop in tensile strength was observed due to increase in interfacial area with worsening interfacial bonding between filler and matrix [4]. At higher filler percentage, a drop in tensile strength occurs due to agglomeration of filler, which results in improper curing of composites [5].

It is believed that fillers act as flaws at higher filler mass fraction, due to lack of resin that wetted fiber surfaces resulting in inept stress transfer. Increase in filler also increased micropores between filler and matrix which in turn weakens adhesion between matrix and filler interface affecting tensile behavior [6].

Fig 2a shows the fractured specimens subjected to tensile test. A higher loss in tensile strength was noticed in the 3rd sample, i.e., sample with 10% filler. From Table 2, it is evident that 3rd sample has higher void content which results in greater drop in tensile strength. Lack of resin and improper curing in 3rd and 4th sample has resulted in fiber pull out as observed in Figure 2b and c, respectively.

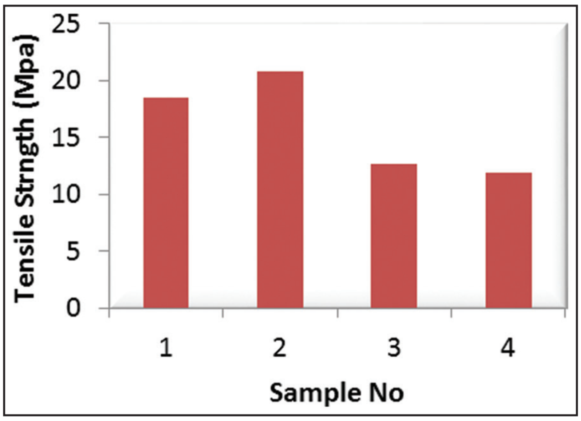

Figure 1. Tensile strength of the composite samples.

Table 1: Weight proportion used for composite processing.

Sample no	Reinforcement (%)	Matrix (%)	Sawdust (%)
1	15	85	00
2	15	80	05
3	15	75	10
4	15	70	15

Table 2: Percentage void content in composite samples.

Sample no	Theoretical density (g/cm^3)	Actual density (g/cm^3)	Percentage void content
1	1.15	0.88	23
2	1.15	0.87	23.8
3	1.15	0.83	27.7
4	1.15	0.85	25.6

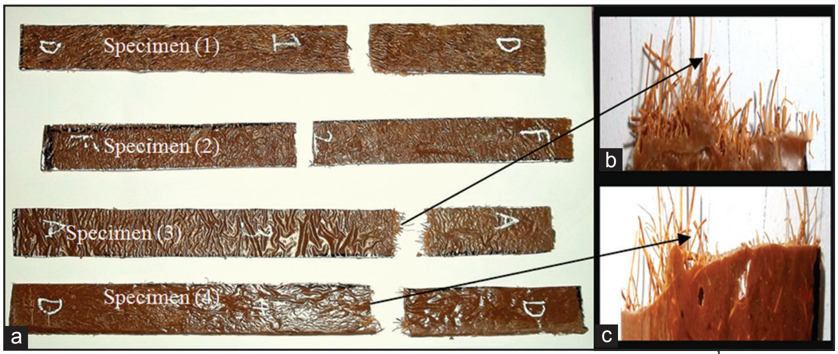

Figure 2: (a) Specimens subjected to tensile test, (b) Fiber pullout observed in the 3rd sample and (c) fiber pullout observed in the 4th sample.

About 7 set of trials for hardness values in each sample were conducted, and average of all these values exhibit the hardness value of each sample as observed in Fig 3. Due to agglomeration of filler at higher percentage, a larger variation in hardness value is noticed in the 3rd and 4th sample as in Table 3. Hardness value improved with increase in filler percentage as increase in filler loading improved matrix surface resistance to indentation. A maximum value of 30.6 was observed with the 4th sample.

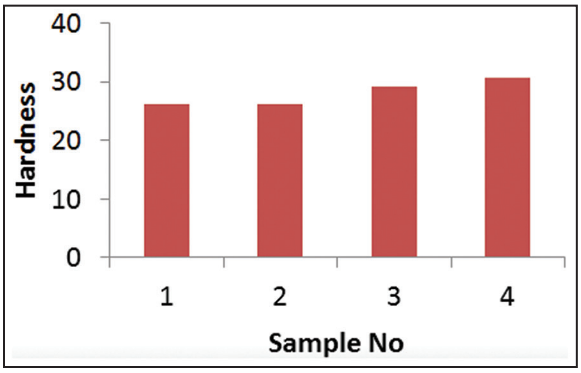

Figure 3: Hardness value of composite specimen.

3.2. Microstructure Analysis of Composite Sample

Microstructure analysis was carried out to study the surface morphology of the composite specimen.

Alkalization treatment of coir fiber has resulted in fiber roughness as in Figure 4a, which resulted in an improved adhesion between fiber and matrix concluding substantially higher mechanical properties. As filler percentage increases, agglomeration was noticed as in Figure 4b influencing improper curing of matrix, being a major rationale for varying hardness value and drop in tensile strength. It is more likely of the composites to have voids, cracks, and flaws made by hand layup process [7]. Figure 4c manifest voids formed due to gas porosity and sawdust porosity which has an out turn on mechanical performance. Voids can also be formed as a result of improper matrix wetting and by implementation of hand layup technique as it is person dependent.

4. CONCLUSION

Tensile and hardness behavior of short coir fiber reinforced epoxy composite with sawdust filler is investigated. This study shows an improvement in tensile strength and hardness behavior by 12.75% and 17.25%, respectively. Microstructure analysis and fractured area photographs clearly show the reason for drop in tensile strength and moderately higher variation in Hardness value at higher filler percentage, i.e., due to insufficient matrix wetting, agglomeration of sawdust, micropores at higher filler concentration.

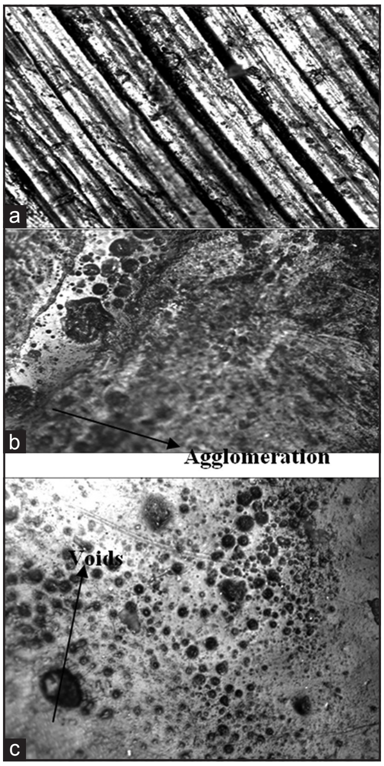

Figure 4: Microstructural analysis of composite samples. (a) Fiber roughness through alkalization, (b) agglomeration due to higher filler percentage, (c) air voids in the composite samples.

Table 3: Hardness value of composite specimen.

Sample 1	Sample 2	Sample 3	Sample 4
26.20	24.91	29.37	36.14
24.62	29.36	38.16	35.13
29.08	24.91	25.92	25.20
29.37	29.37	24.62	29.08
25.34	26.92	25.77	28.80
25.63	25.05	31.24	31.30
22.46	22.66	29.80	28.50

5. ACKNOWLEDGMENTS

Authors wish to acknowledge Mr. Padmaraj, Department of Aeronautical and Automobile Engineering, MIT - Manipal for providing technical support in performing Tensile test using UTM machine.

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***Bibliographical Sketch**

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