Reinforced Plastics
ISSN (online): 0034-3617

Mechanical and Water Absorption Behaviour of Jute/Nano - Sio_2 Reinforced Epoxy Composite

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Abstract
The jute/nano - SiO_2 reinforced epoxy composite was tested under tensile, impact, and water absorption tests. Optimum weight percentage / ratio of jute, nano – SiO_2 and epoxy were determined. Nano-SiO_2 was combined with jute and epoxy to increase mechanical properties. This study shows that addition of 2% nano – SiO_2 in jute/epoxy composite results increasing the mechanical property and decreasing the moisture absorption property.

Keyword: Jute, Nano – SiO_2, Epoxy, Hand-layup, Tensile Test, Impact Test, Moisture absorption Test.

1. Introduction

Conventional fibres offer strong reinforcement in polymer composites, but at a high cost for common and everyday applications. The use of such fibres can be justified in aeronautical and military applications when the high cost of the fibres is irrelevant. As a result, there has been an increase in interest in the use of natural fibres as reinforcement in polymer matrix composites in recent years. Additionally, natural fibres have some advantages over synthetic fibres such as glass, nylon, mica, etc. Natural fibres have advantages such as low density, low cost, biodegradability, acceptable particular characteristics, reduced wear during processing, low energy consumption, etc [1].

Jute fibre, when compared to other natural fibres, contains the highest amount of cellulose. Secondly, jute fibre offers high thermal and electrical insulating properties, significant strength and most importantly, wide commercial availability in a variety of forms at a low cost [2]. Previous research found that jute-reinforced composites have considerably better characteristics than epoxy resins alone.

Zhang *et al.* [3] discovered that the addition of polyfluo-150 wax (PFW), or nano-ZnO and nano-SiC at optimal concentrations, contributes to the mechanical properties of composites. Suresha *et al.* [4] observed an improvement in the mechanical properties of SiC-filled Glass–Epoxy composites. Mohan *et al.* [5] concluded that hard powders of tungsten carbide and tantalum niobium carbide filled Glass–Epoxy composites have higher mechanical properties than unfilled Glass–Epoxy composites. The current work is an attempt toward this goal, in which nano - fillers such as SiO_2 are used in jute / epoxy composites to investigate their mechanical and moisture absorption properties.

Moisture absorption in natural fibre composites has a negative impact on mechanical qualities and operational conditions [6]. Such research allows us to develop techniques for managing and reducing moisture absorption. Several studies on moisture absorption in hybrid jute composites or jute–polyester composites have been conducted [7, 8]. There have also been a few published investigations on water absorption in jute–epoxy composites [9]. In this paper, we introduced epoxy as the matrix material and nano-SiO_2 details of mechanical and water absorption properties in jute fabric composites constructed from epoxy resin and nano-SiO_2 filler.

2. Experimental details

2.1 Material

Jute fibre (Corchorus capsularis), a form of bast fibre, is derived from Corchorus plants. A regular woven jute fabric will be used for this experiment. In a weight ratio of 10:1, the resin system of Epoxy LY556 and Hardener HY951 will be utilized. Both the fibre and the epoxy resin are sourced locally. Sisco research laboratories pvt. ltd., Mumbai, India, provided nano – SiO_2 powder with a particle size of 15nm as a filler material.

2.2 Fabrication of composites

The hand lay-up technique was used to fabricate the composite material. Candle wax is applied to the bottom and top surfaces of the mould. The load is applied to the mould in order to prevent particles from entering the composite during the curing process. Table 1 lists five different composite combinations that were initially prepared for testing. Before applying epoxy, the moulds are cleaned and dried. Before applying any release agent or epoxy, the fibres were put out uniformly over the mould.

After evenly distributing the fibres, they were compressed in the mould for a few minutes using a roller. The compressed fibre was put over the coat of epoxy and nano - SiO_2, ensuring that the fibres were distributed uniformly. The epoxy mixture is then uniformly poured over the fibre and compressed for 24 hours to cure. Filler nano- SiO_2 was physically stirred with epoxy resin in three different weight ratios (2, 3 and 5 weight % of epoxy) to guarantee uniform dispersion of nano- SiO_2. Following the curing process, test samples were cut to the sizes specified in the ASTM standards.

Table 1: Composite sample composition and designation

Sample Composition	**Designation**
Pure epoxy resin composite	A
Jute fabric / epoxy resin composite	B
Jute fabric / epoxy resin + 2% nano-SiO_2 composite	C
Jute fabric / epoxy resin + 3% nano-SiO_2 composite	D
Jute fabric / epoxy resin + 5% nano-SiO_2 composite	E

2.3 Mechanical property

After fabricating, the prepared test specimens were submitted to mechanical tests in accordance with ASTM standards. Tensile tests were performed in accordance with the ASTM-D-3039 standard [8]. using a servo controlled universal testing machine Instron-5976. UTM load range of 0-30 KN and cross head speed of 0.5 mm/min at 18ºC. The impact strength of the composite specimens was measured using a Charpy impact tester in accordance with the ASTM-E-23 standard. A pendulum impact testing machine with a swing angle of 140º and an impact velocity of 5.182 m/s was used. The Charpy impact strength of the specimen was estimated using impact energy and the cross-sectional area of the specimen.

2.4 Moisture absorption behaviour

According to the ASTM D-570-98 standard [10], the composite sample is immersed in distilled water at room temperature for 10 days. A digital balances machine was used to determine the weight. Each specimen was dried in a 105°C oven for 2 hours. Before being immersed in distilled water, the weight of the dry samples was recorded. Every 24 hours, a sample of distilled water is collected and weighed. The percentage values of water absorption were calculated using the increase in weight percentage formula (Eq. 2.1).

$$\text{Increase in weight percentage (\%)} = \frac{\text{wet conditioned weight} - \text{Dry conditioned weight}}{\text{Dry conditioned weight}} \text{ X } 100 \qquad \ldots(2.1)$$

3. Results and discussion

3.1 Mechanical property of Jute/nano-SiO_2 epoxy composite

The effect of jute fabric and filler nano-SiO_2 powder reinforced with epoxy resin on tensile characteristics is shown in Table 2. Figure 1 presents an increase in tensile strength in composite sample C. The composite with jute fabric and a 2 wt.% SiO_2 nano powder infusion showed the highest tensile strength among the other composite samples (44.09 MPa). The interfecial bonding between the filler and the jute fabric / epoxy composite significantly influences the tensile characteristics of a filler-reinforced composite [11]. The loss in tensile characteristics at high filler weight percentages could be due to lack of proper interface bonding between the SiO_2 filler and the epoxy resin matrix [12]. Results shows that composite is a strong a material and it can be stretched before it breaks.

Table 2: Tensile and impact property of jute/nano-SiO_2 epoxy composite.

Sample	Tensile strength (MPa)	Tensile strain (mm/mm)	Impact strength (KJ/m^2)
A	32.61	0.0046	12.5
B	37.79	0.0102	46.3
C	**44.09**	**0.0114**	**50**
D	38.28	0.0096	47.5
E	35.46	0.0094	37.5

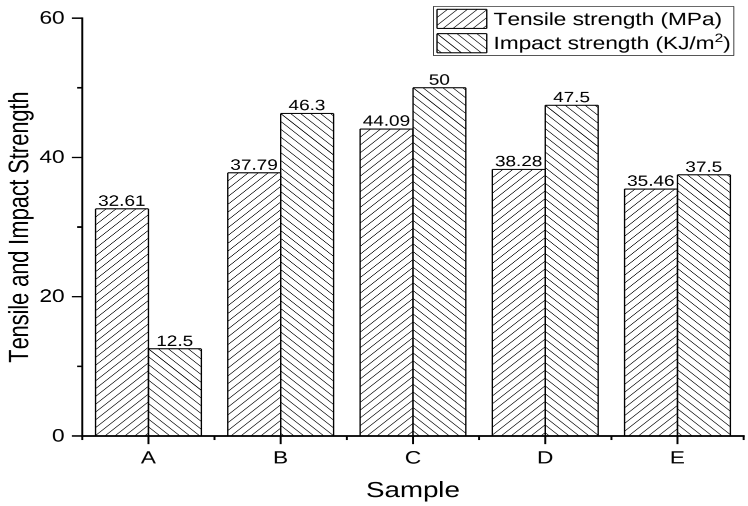

Figure 1: Tensile and impact property of jute/nano-SiO_2 epoxy composite.

The toughness of polymer composites determines their impact qualities significantly. The fiber-matrix interface, composite structure and geometry all have a significant impact on overall toughness [13]. Impact energy is measured by a material's impact resistance to resist breaking under shock loading and toughness. Table 2 shows the impact strength values of various composites and Figure 1 clearly shows the variation in impact strength with Jute and filler nano-SiO_2.

Jute and filler used in a composite material enhance resistance to crack development. When compared to other composite samples, the addition of 2% nano-SiO_2 / Jute composite displayed good impact strength. Impact resistance in filled composites was increased due to effective interfacial bonding between filler particles, jute fibre shock absorption properties and Epoxy matrix, resulting in superior fracture resistance and impact strength. The results demonstrate how much energy is absorbed by the composite material during fracture. This absorbed energy is a measure of the toughness of a composite material and can be used to research the brittle-ductile transition.

3.2 Moisture absorption property of Jute/nano-SiO_2 epoxy composite

The various composites water absorption capacities were evaluated by immersing them in distilled water at room temperature for 10 days. The moisture absorption rate of various laminates is shown in Table 3. The percentage values of water absorption were calculated using the increase in weight percentage formula (Eq. 2.1).

Table 3: Composite sample weight (gm) at various intervals in distilled water.

Hours	Sample A (gm)	Sample B (gm)	Sample C (gm)	Sample D (gm)	Sample E (gm)
0	7.000	7.060	7.318	7.365	7.298
2	7.005	7.113	7.358	7.465	7.377
24	7.006	7.166	7.408	7.501	7.402
48	7.011	7.195	7.452	7.524	7.433
72	7.011	7.196	7.491	7.553	7.442
96	7.016	7.211	7.522	7.588	7.448
120	7.020	7.245	7.543	7.621	7.495

144	7.023	7.251	7.550	7.617	7.498
168	7.025	7.257	7.557	7.633	7.500
192	7.027	7.263	7.559	7.649	7.507
216	7.028	7.278	7.565	7.658	7.514
240	7.029	7.283	7.570	7.663	7.521

Table 3 and Fig. 2 demonstrate the weight and percentage of moisture absorption of jute fabric and SiO_2 filler composite exposed in distilled water. Moisture absorption was observed to be in the 3 - 4% range for samples B, C, D and E. Because of their hydrophobic nature, pure epoxy resin composite samples had a minimal moisture absorption rate of 0.4 percent.

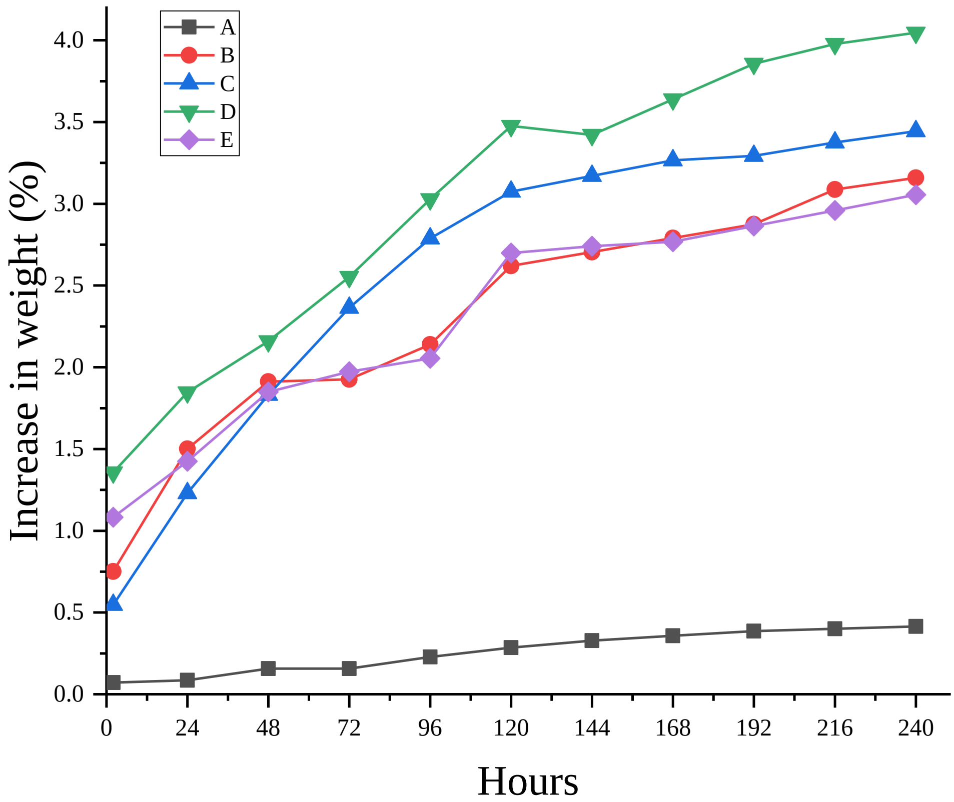

Fig. 2: Water absorption of composite for 240 hours.

When jute fabric is employed as reinforcement in a composite, the cellulose molecules have a polar group that attracts water molecules via hydrogen bonding, resulting in moisture buildup in the cell wall, which is observable as moisture absorption behaviour of jute fabric. Because jute fabric absorbs moisture, the mechanical properties of the composite will be reduced as a result of micro – cracks in the matrix generated by internal tension. According to the results, jute fibric composites with 2% nano-SiO_2 powder outperform other composite samples.

4. Conclusion

The effect of hybridization of Jute, nano-SiO_2 and epoxy resin on mechanical properties and moisture absorption property was studied in this research. A jute fabric reinforced epoxy composite's mechanical and moisture absorption properties are improved. Different weight ratios of nano-SiO_2 powder filler content have also been shown to have an influence on composite material. A common trend of composite sample can be determined using various test methods and result observation. On the other hand, a higher filler loading had a negative impact on the outcomes. The following are the study's findings:

- According to Table 2, the best composite composition is jute, 2% nano-SiO_2 and epoxy resin. Tensile strength and impact strength are calculated to be 44.09 MPa and 50 KH/m2 respectively.

- Tensile strength of Jute/2 % nano-SiO_2/epoxy resin composite is 8 % greater than woven jute fabric reinforced isothalic polyester composites [8], 90 % greater than NaOH treated jute fabric reinforced epoxy resin [14], 63 % greater than banana/jute fiber/epoxy resin composite [15] and 52 % greater than nano-SiO_2/ Epoxy (T-51) composite cured by mannich amine [16].
- Similarly, the impact strength of Jute/2 % nano-SiO_2/epoxy resin composite is 56% higher than that of woven jute fabric reinforced isothalic polyester composites [8], 85 percent higher than NaOH treated jute fabric reinforced epoxy resin [14], 66 percent higher than banana/jute fiber/epoxy resin composite [15] and 95% higher than nano-SiO_2/ Epoxy (T-51) composite cured by mannich amine [16].
- Moisture absorption studies of hybrid composites reveal that Jute/2 % nano-SiO_2/epoxy resin composite absorbs the minimum amount of moisture.

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