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ISSN (Online) 2456-1290

International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)

Vol 2, Issue 5, May 2017

Study On Water Absorption Behavior And Impact Properties Of Alumina Filled Jute-Epoxy Composites

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Abstract: -- In this paper, the effect of filler content is studied on water absorption behavior and impact strength for jute epoxy composite. Plain woven jute fabric is used as reinforcement. The resin system consists of Epoxy resin and Hardener in the ratio 10:1 by weight. Alumina (average particle size of 40 µm) is used as filler. The effect of filler content on water absorption behavior and impact properties studied by varying the filler content from 5%, 10%, 15% with respect to weight of epoxy resin. The composite laminates were fabricated using hand lay-up technique and cured under 30 bar pressure for about 24 hours. ASTM standards were followed to conduct these tests. It was clearly observed that unfilled specimen has the highest saturated moisture content and 15% filled specimen has lowest value. As filler content increases resistance to moisture absorption also increases. The water diffusion coefficient of composite was calculated using the diffusion coefficient equation. As filler content increases diffusion co-efficient decreases for alumina filled jute-epoxy composite. Impact strength was found to be increase with the increase in the filler content up to 10 wt%.

Keywords: Natural fibers, epoxy, Alumina, impact strength, hand-lay-up

1. INTRODUCTION

Composites have an increasing popularity in engineering materials, with their stiffness and strength combined with low weight and excellent corrosion resistance. By studying the variable properties of composite materials, engineers use the advantage of anisotropy included within composite materials. By building a structure by properly selected resin, fiber, layer orientation and curing, optimization is successful in most cases.

2. REVIEW OF LITERATURE

A brief survey on the literature has been carried out to know the current status in the field of jute fiber composites T R.M.V.G.K. RAO et al. (1984) The influence of internal factors like the fiber volume fraction and its orientation to the diffusion path on the moisture absorption trends of both the permeable (Jute-Epoxy) and the impermeable types (glass-epoxy) of composites were studied.

P. J. Roe et al, (1985). Raw jute fiber has been incorporated in a polyester resin matrix to form uniaxially reinforced composites containing up to 60 vol % fiber. The work of fracture determined by Charpy impact strength have been measured as a function of fiber volume fraction. The work of fracture is 22kJ m -2

Alok Satapathy et al, (2009) He focused on processing and mechanical characterization of a new class of multi-phase composites consisting of epoxy resin reinforced with jute fiber and filled with silicon carbide (SiC) particulates. The effect of filler in modifying the physical and mechanical properties of jute–epoxy composites has been studied. It is found that the incorporation of rice husk derived SiC modifies the Young's, flexural, and impact strengths of the jute–epoxy composites.

Prakash Yadav et al, He presented the water absorption behaviour of jute fiber composites. The water diffusion behaviour of the composites were determined by the method primarily developed by Shen & Springer for moisture absorption of composite materials. The water absorption by the composite sample was found dependence on its jute fiber weight fraction.

3. MATERIALS USED

3.1 Jute Fiber

Plain woven jute fabric 22×12(22 yarns of tex 310 in warp direction and 12 yarns of tex 280 in weft direction, per inch), having an average weight of 367 gm/cm2 and average thickness of 0.8 mm is directly procured from Kolkota, West Bengal, India.

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering
(IJERMCE)
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3.2 Resin System

The resin system consists of Epoxy resin (LY 556) and Hardener (HY951) in the ratio 10:1 by weight, both supplied by Petro Araldite Pvt. Ltd., Manali, Chennai.

3.3 Alumina (Al2O3)

In this study, the aluminum oxide particles with an average particle size of 40 µm were used as filler in 5%wt, 10%wt, 15%wt with respect to weight of Epoxy resin. Aluminum oxide is an electrical insulator but has a relatively high thermal conductivity for a ceramic material. In its most commonly occurring crystalline form. Its hardness makes it suitable for use as an abrasive and as a component in cutting tools.

3.4 Processing of the Composites

All the laminates were fabricated by Hand Layup/Wet layup technique using a mold and cured under pressure (30bar) using hydraulic press. The jute mats dried in sunlight for about 24hr were used for making jute composites.

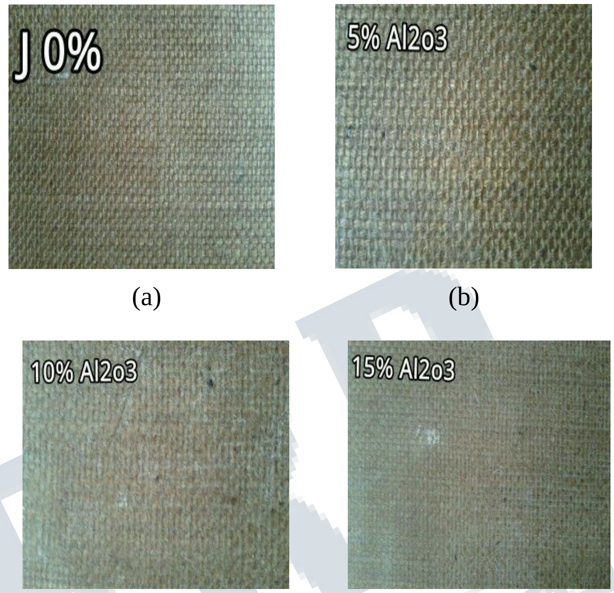
3.5 Fabrication setup

a) Hydraulic Press ***b) Mold***

Figures 3.4 Fabrication setup

Figures 3.4(a) and (b) shows the hydraulic press and mold used for the fabrication of composite laminates. The jute mats of size (280×250) mm are used for fabrication of laminates. The jute mats are laid on the surface of the mold. The resin hardener mixture is applied on both surfaces of the jute mat using brush and with the help of the roller the resin hardener mixture is uniformly distributed throughout the jute mat and the procedure is continued for all the layers of jute mat and the mold is then closed and placed under the hydraulic press and is pressed at 30bar pressure for about 24 hrs for curing.

Figure 3.5 shows the unfilled and filled jute laminates.



(a) (b) (c) (d)

Figure 3.5 Unfilled and filled jute laminates

The weight fraction of fiber and filler in the finished laminate is calculated using the equations 3.1 and 3.2.

$$W_{fiber} = \frac{W_t}{W_{fl}} \quad (3.1)$$

$$W_{filler} = \frac{W_{ffl}}{W_{fl}} \quad (3.2)$$

Table 3.2 Details of jute-epoxy laminates

Sl No	Laminate Code	Jute Fiber wt. Fraction, %	Filler wt. Fraction (based on wt of the resin), %
1	Unfilled	50.37	-------
2	5A%	50.40	5
3	10A%	49.74	10
4	15A%	49.09	15

ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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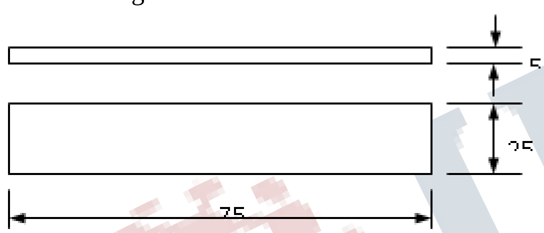
Table 3.2 shows the details of jute-epoxy laminates. For impact test specimen 16 layers and for water absorption, Young's and shear test specimens 6 layers of jute mats were used.

4. WATER ABSORPTION BEHAVIOR

Water absorption of cellulosic fiber composite is an important physical property that determines their end use applications.

4.1 Water Absorption Test Specimen

Water absorption test is conducted according to ASTM D 570. The specimen is cut into required dimension (75×25×5) mm using diamond wheel saw and is finished using emery paper. The geometry of the test specimen is shown in figure 4.1. The jute composite specimen prepared is shown in Figure 4.2.



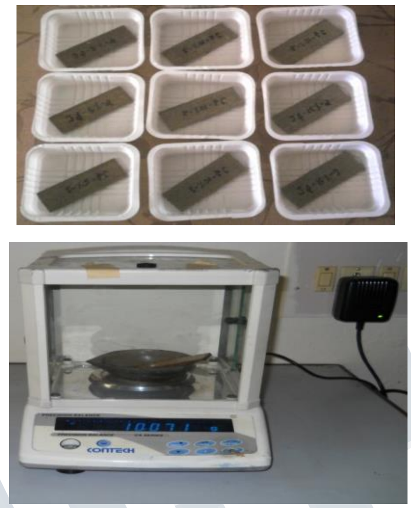
All dimensions are in mm

Figure 4.1 Geometry of Water Absorption Test Specimens

Figure 4.2 Water Absorption Test Specimens

4.2 Water Absorption test

The dried jute samples in groups of three for each case were first weighed and then immersed in distilled water at room temperature as shown in figure 4.3 (a). Samples were periodically (every 24 hours) taken out of water, surface water was wiped off with soft cloth or tissue paper and weighed to the nearest 0.001 gm using the digital balance (figure 4.3 (b)). The procedure is repeated until the saturation level is reached.



a) Samples immersed in water b) Digital balance
Figure 4.3 Water Absorption Testing

The percentage of water gain was determined using equation 4.1.

$$M(\%) = \frac{W_w - W_d}{W_d} \qquad (4.1)$$

The diffusion co-efficient is calculated using the equation 4.2.

$$D_Z = \pi\left[\frac{h}{4M_m}\right]^2\left[\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}}\right]^2 \qquad (4.2)$$

Where,

$\left[\frac{M_2 - M_1}{\sqrt{t_2} - \sqrt{t_1}}\right]^2$ = slope of moisture gain v/s $\sqrt{t}$ curve.

5. IMPACT TEST

5.1 Impact Test Specimen

Charpy impact test was conducted according to ASTM D256. The geometry of the test specimen is shown in figure 5.4. The jute composite specimen prepared is shown in Fig 5.5.

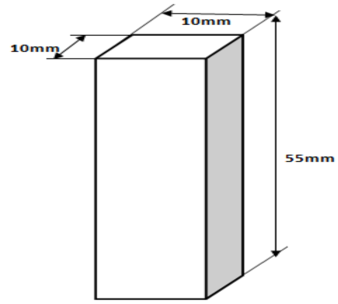


Figure 5.1 Geometry of Impact Test Specimen

Figure 5.2 Impact test specimen

5.2 Charpy Impact test

Charpy Impact test was conducted on computer interfaced impact testing machine. The data acquisition system used is instron dynatup 930-4. The unnotched specimen is kept in anvil perpendicular to the pendulum as shown in figure 5.7. In charpy test energy absorbed is noted.

Figure 5.3 Impact Test Setup

Impact strength is calculated by eq. 5.1

$$\sigma_I = \frac{E_I}{A} \qquad (5.1)$$

6. RESULTS AND DISCUSSION

In this section results obtained for the water absorption test, elastic and impact properties for alumina filled jute-epoxy composites are discussed. The elastic properties were determined analytically and validated by experimental results.

6.1 Water Absorption Test Results

The results presented in table reveal that 15% Alumina filled jute composites exhibit the minimum moisture absorption. Higher resistance to the moisture absorption in filled composite can be explained by the building of chemical bonds as well as hydrogen bonds leads to stronger adhesion between fiber, filler and matrix which reduces the water uptake. It is difficult to entirely eliminate the absorption of moisture in the jute-epoxy composite.

The water absorption behaviour of alumina filled jute-epoxy, shown in fig 6.1, where % of moisture gain is plotted against square root of time. Each data points represent the average of three specimens. It was clearly observed that unfilled specimen has the highest saturated moisture content and 15% filled specimen has lowest value. The water absorption by the composite was found dependence on its filler weight fraction. As filler content increases resistance to moisture absorption also increases. This may be due to the effect of the functional group polarity. Cellulose molecule in raw jute fiber contains hydroxyl group which is polar in nature and absorbs more moisture. Whereas alumina filled jute-epoxy composites has a less polar than hydroxyl group. As a result the filled jute-epoxy composites absorbed less water which might improve the dimensional stability of the composites.

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ISSN (Online) 2456-1290
International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
Vol 2, Issue 5, May 2017

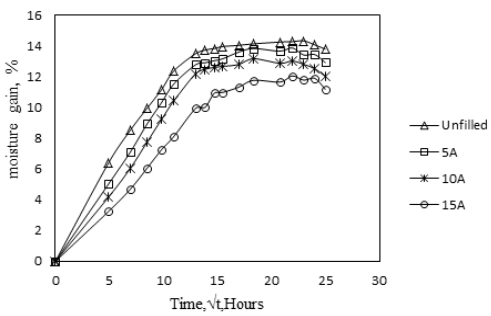

Fig 6.1 Moisture gain v/s time graph for alumina filled composites

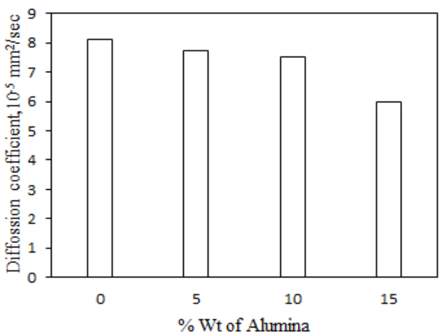

Fig 6.2 Diffusion coefficient v/s percentage of filler content

The water diffusion coefficient of composite was calculated using the equation 4.2. Figure 6.2 shows variation of diffusion co-efficient versus percentage of filler content. As filler content increases diffusion co-efficient decreases for alumina filled jute-epoxy composite. This is because the filler content leads to a composite with decreased permeability.

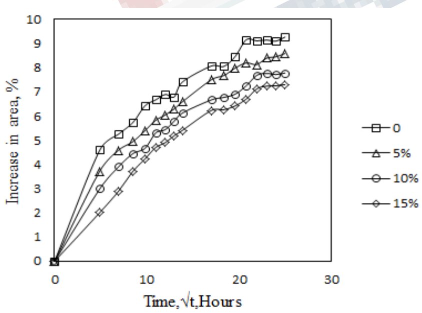

Fig 6.3 Increase in area v/s time graph for alumina filled composites

Figure 6.3 shows variation of percentage increase in area v/s time for different proportions of alumina filled composites.

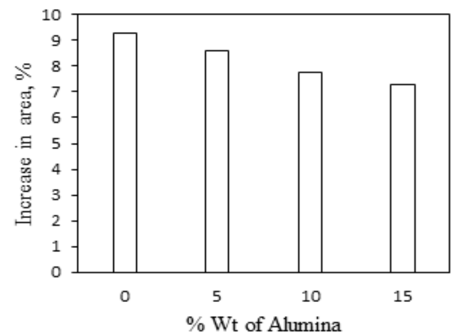

Fig 6.4 Increase in area v/s time graph for alumina filled composites

Figure 6.4 shows % increase in area with respect to percentage of filler content for both unfilled and alumina filled composites. As filler content increases area decreases. The increase in the area is due to absorption of moisture which results in swelling of the laminates. The moisture build up in the cell wall could result in fiber swelling and affect the dimensional stability. In jute-epoxy composites, the extent of increase in the percentage area reduces with the increase in the filler content. This indicates that filled composites have better dimensional stability compared to unfilled composites. The combined filler-epoxy matrix may penetrate deep into the pores of the jute and may form a chemical bond with the lignocellulose present within and as well as on the surface of the jute. The interaction of the filler-resin matrix and lignocellulosic fibre shall reduce the swelling of composite.

6.3 Impact test results

Impact strength exemplifies the toughness of materials under high strain rate deformation. Variation of charpy impact strength with unfilled and alumina filled jute-epoxy shown in table 6.5. Impact strength of the jute-epoxy composite is increased by increasing the wt% of alumina filler. The impact strength of the composite was calculated using the equation 5.8.

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International Journal of Engineering Research in Mechanical and Civil Engineering (IJERMCE)
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Table 6.5 Impact strength

Sl No	Specimen Code	Impact Strength KJ/m^2
1	Unfilled	35.2204
2	5%A	39.2099
3	10%A	47.4396
4	15%A	38.1531

Figure 6.5 shows comparison of impact strength of experimental results for alumina filled composites. Impact strength was found to increase with the increase in the filler content up to 10 wt%. However there was a decrement in impact strength for above 15% alumina content in jute-epoxy composites. The low impact strength of a jute-epoxy composite of above 15 wt% filler content occurs by factors like matrix fracture, fiber/matrix debonding and fiber pull out. The decrease in impact strength for above 15% filler content in composite may be attributed to a change from ductile to brittle fracture behaviour with increasing filler content. Besides, the probability for fiber agglomeration also increases at higher fibre content, creating regions of stress concentration that require less energy to initiate or propagate a crack. This may be decrease impact strength of jute-epoxy composite by addition of filler above 15 wt%.

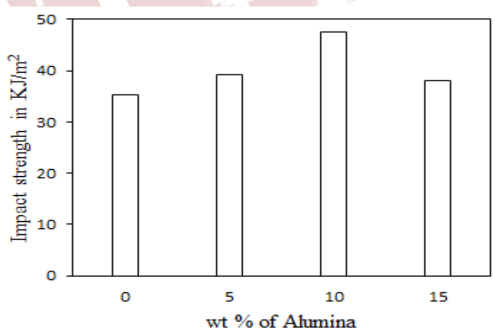

Fig 6.5 Impact strength v/s percentage of filler content

7. CONCLUSION

In this work, the effect of incorporation of alumina filler on water absorption behavior, impact properties of jute fiber reinforced epoxy composites has been investigated. Based on the results, the following conclusions are drawn.

The resistance to water absorption of jute-epoxy composites can be significantly improved with the incorporation of alumina fillers.

The impact strength of the composite is increases with increase in the filler content up to 10 wt%, beyond which the impact strength showed decreasing trend.

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