Study the Impact Property of Laminated Bamboo-Fibre Composite Filled with Cenosphere

Hemalata Jena, Mihir Ku. Pandit, and Arun Ku. Pradhan

***Abstract*—Cenosphere is a ceramic rich industrial waste produced during burning of coal in thermal power plants. The present study deals with the effect of this cenosphere as particulate fillers on impact strength of natural fibre composites. The natural fibre composite consists of bamboo fibre as reinforcement and epoxy as matrix. The bamboo fibre is treated with alkali to improve its surface properties. The conventional hand layup technique is used to prepare different composite specimens. 20 numbers of different composite specimens are prepared with varying number of laminae and filler content. The samples are analysed for their impact property to establish the effect of varying filler content and the number of laminae. It is found that the strength properties are greatly influenced by addition of this waste based ceramic filler.**

***Index Terms*—Bamboo fibre, cenosphere, epoxy resin, impact strength.**

I. Introduction

The physical and mechanical characteristics of composites can be modified by adding a filler phase to the matrix body during the composite preparation. The incorporation of filler in composite is to improve its mechanical properties and to reduce its cost [1]. Therefore, the use of inorganic filler in the composite is gaining popularity in the composite world. There are many investigations on filler in the polymer [2]-[5] and in the fibre reinforced composite [6]-[8]. Ceramic rich industrial by-product, which consists of oxides of metals, can also be potential filler [10]. Cenosphere is the one of the industrial waste produced during burning of coal in thermal power plant [9]. There are several instances of investigation of mechanical properties of the cenosphere filled composites [10]-[15], but no attempt in the literature is found for critically analysing the mechanical characterisation of cenosphere filled bio-fibre composite. The bio-fibres have gained popularity as reinforcements in polymer composites due to their eco-friendly nature and good mechanical properties. They offer a potential alternative to glass, carbon, and other synthetic fibres used for the manufacturing of composites [16]. The potential of natural fibres such as jute, sisal, pineapple, flax and coir as reinforcement in composites has been studied extensively [17]-[21]. Among all Natural fibre, bamboo has many advantages, such as ample availability, faster growth rate, lightweight, low cost, low energy consumption in the processing and their bio-degradability [22]. So bamboo fibre appears to be most promising candidate in polymer composites. It is known to be one of the fastest growing plants in the world. But the problem in these bio fibres is their hydrophilic nature, heterogeneity, low impact property, non-uniformity and low processing temperature. In application of bio-composite as part of structural unit, the major obstacle is their low impact properties, which can be improved by incorporation of discrete layers of tough resin. As thermoplastic resins need a processing temperature which is higher than natural fibre, they cannot be used for natural fibre composites. Whereas thermosetting resins can cure in room temperature and they are used widely in natural fibre composites. Epoxy can present better properties as a matrix [23], but being a thermoset material, its brittle behaviour decreases the amount of energy absorption. Therefore, it is essential to improve their plasticity for better impact damping by incorporating filler in the matrix. For that the spherical glass particles are incorporated in the composite to modify the fracture energies of brittle epoxies and PVC, which has been the subject of a number of studies [24]-[25]. Fracture propagation energies are found to increase significantly as a result of incorporation of the fillers. Cenosphere which is also a micro-sphere ceramic particle may effectively influence the impact energy of the composite and can also make the composite material cost effective.

With the above back ground, the present piece of research aims at a new class of hybrid composite using bamboo-epoxy and cenosphere, as particulate microsphere filler in preparation of the composite and investigates the impact property of this hybrid composite. The effect of adding cenosphere to matrix phase aims at improving their plasticity for better impact damping. The effects of different number of laminae and different weight percent of cenosphere have also been studied for this purpose.

II. Experimental Details

A. Materials

In the present work, the hybrid composite consists of bamboo fibre and cenosphere as filler reinforcement in the epoxy matrix. The properties of these constituents are given in Table I.

B. Fabrication of Composite

Initial step of fabricating the composite is alkali treatment of bamboo mats to improve their mechanical property [26].

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TABLE I: DATA OF RAW MATERIALS AND THEIR CHARACTERISTICS

Raw materials	Grade	Characteristics
Cenosphere	CS 300	Particle density = 0.45–0.80 g/ml, Particle size = 60-94 micrometer, Light grey powder, Non-soluble in water, Melting Temperature = 1300–1500 ^{0}C
Epoxy	LAPOX L-12	Viscosity = 9000-12000 mPa.s, Density = 1.1gm/cc
Hardener	K-6	Refractive index at 25^{0}C = 1.4940-1.5000
Bamboo fibre		Weave type, Density = .95 gm/cc, Width = 4.5 mm, Thickness = 1.5 mm

For this, the bamboo mats are cleaned and dried before dipping into NaOH solution of 5% concentration for 30 minutes at room temperature (20^{0}C) [27]. These mats are thoroughly washed in distilled water and then neutralized in 2% HCl solution. The neutralized mats are then dried in an oven at 60^{0}C for 24 hours. The fabrication of the composite is done by conventional hand-lay-up technique at room temperature by mixing low temperature cured epoxy resin (L12) and corresponding hardener (K6) are mixed in a ratio of 10:1 by weight as recommended. A number of composite specimens are prepared using different number of laminae and weight percent of cenosphere. For the sake of convenience, the composite specimens with varying number of layers and weight percent of cenosphere are designated as described in Table II.

TABLE II: DESIGNATION OF COMPOSITE SPECIMENS

Designation	Composite with varying laminae	Composite with varying weight % of cenosphere
A0		0
A2		1.5
A4	3 layered bamboo-epoxy composite	3
A6		4.5
A8		6
B0		0
B2		1.5
B4	5 layered bamboo-epoxy composite	3
B6		4.5
B8		6
C0		0
C2		1.5
C4	7 layered bamboo-epoxy composite	3
C6		4.5
C8		6
D0		0
D2		1.5
D4	9 layered bamboo-epoxy composite	3
D6		4.5
D8		6

A. Density

The density of composite materials in terms of weight fraction can easily be obtained as for the following equations.

$$\rho = \frac{1}{\left(W_f / \rho_f\right) + \left(W_m / \rho_m\right)} \quad (1)$$

where, W and ρ represent the weight fraction and density respectively. The suffix *f and m* stand for the fiber and matrix of the composite materials respectively.

In case of hybrid composites, consisting of three components namely matrix, fibre and particulate filler, the modified form of the expression for the density of the composite can be written as

$$\rho = \frac{1}{\left(W_f / \rho_f\right) + \left(W_m / \rho_m\right) + \left(W_p / \rho_p\right)} \quad (2)$$

where, the suffix 'p' indicates the particulate filler materials.

B. Impact Test

Impact test is performed on the pendulum impact testing machine as shown in the Fig. 1 as per ASTM D256. A 'V' notch is created at the centre of the specimen having notch depth of 2.54 mm and notch angle of 45^0, using Impactometer 6545 (Ceast, Italy). The respective values of impact energy of different specimens are recorded directly from the dial indicator. Fig. 2 shows the dimension of the specimen.

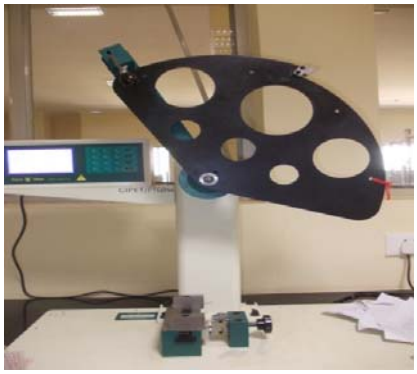

Fig. 1. Impact test machine

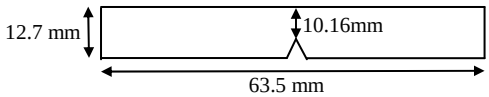

Fig. 2. Dimension of specimen

III. RESULTS AND DISCUSSION

The density values of the composites of different composition are given in table 3. It is found that with the increase in filler content there is decrease in density for all composite type. Density of a composite depends on the relative proportion of matrix and reinforcing materials and this is one of the most important factors determining the properties of the composites.

It is seen from the Figure 3 that impact strength is increased with the increase number of lamina, indicating positive contribution of the number of layers. Increasing the

layers from 3 to 7, the strength of composite is increased. The increased fibre content is improving its capability to absorb more energy. Similar type of work [28]-[30] shows an increase in impact strength with an increase in fibre content. But by further increasing the layers to 9, the impact strength is decreased. From the above investigation, it can be concluded that the optimum number of layers for the composite is 7. Decrease in the mechanical properties is observed at 9 layer composite due to poor interfacial fibre matrix adhesion as a result of poor resin impregnation on the fibre and more voids.

TABLE III: DENSITY OF THE COMPOSITES

Composite type	Density (gm/cc)	Composite type	Density (gm/cc)
A0	1.077	C0	1.051
A2	1.072	C2	1.047
A4	1.067	C4	1.042
A6	1.063	C6	1.038
A8	1.058	C8	1.033
B0	1.060	D0	1.035
B2	1.055	D2	1.030
B4	1.050	D4	1.026
B6	1.046	D6	1.021
B8	1.041	D8	1.017

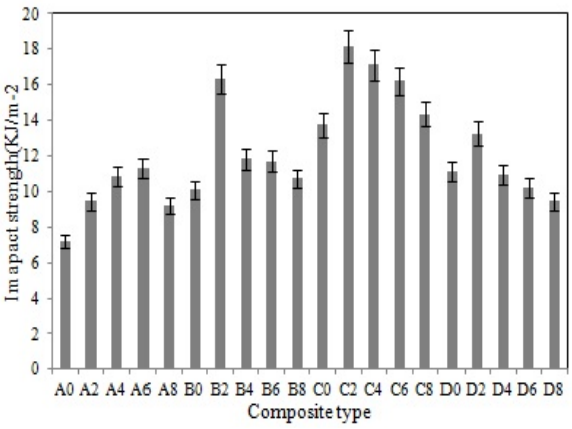

Fig. 3. Impact strength of the laminates

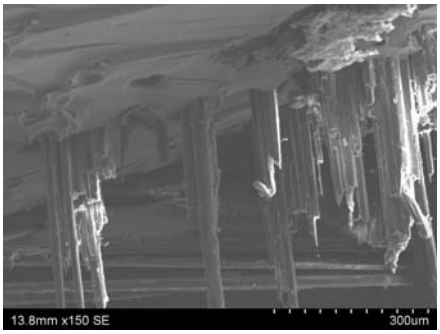

Fig. 4. SEM image of C2 composite

From Fig. 3, it also indicates that with number of laminae remaining same, the addition of cenosphere, improves the impact strength of the composite. This may be due to the reason that cenosphere particles are rigid and have much higher fracture strength as compared to epoxy resin. Additionally, the increase in cenosphere content increases the strength up to certain limit after which the impact strength is decreased on further addition. For 3 layered laminate, the impact strength increases with the increase content of cenosphere and maximum energy is recorded at A6 composite which is 56.82% more as compared to A0. For 5, 7 and 9 layered laminate, the maximum impact strength is recorded for B2, C2 and D2 composite, which increases by 61.49%, 31.7% and 19.35% as compared to B0, C0 and D0, respectively. For higher wt% of cenospher the impact strength is reduced. This may be due to inclusion of more voids and dispersion problem in for larger cenosphere content. Among all composition, type C2 composite has maximum impact strength of 18.132 KJ/m^2.

IV. CONCLUSION

In this paper a study has been carried out to investigate the effect of cenosphere and number of lamina on the impact property of bamboo fibre reinforced epoxy composites. It is concluded that the impact property of bio-fibre reinforced composite is greatly influenced by addition of cenosphere as filler and lamina. For a given laminated composite, the impact strength is increased with addition of filler up to a certain limit and after which it is decreased on further addition. The results reveal the sensitivity of the impact properties to the concentration of the fillers. And with the increase in lamina from 3 to 7, the impact strength is increased and on further increasing the lamina to 9, the strength is decreased. Among all prepared composites, 7 layers composite with 1.5 wt% of cenosphere has the maximum impact strength of 18.132 KJ/m^2. There is also seen that decrease in density of the composites which are also greatly depended on the content of fillers and fibre.

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