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Natural Fibres in Enhancing Toughness and Hardness of Epoxy-based Polymer Composites

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ABSTRACT:

To meet global needs, the production of auto bodies is increasing day by day. This is also growing the CO_2 emission proportionately and challenging the existence of humanity. Replacement of high-density metallic components, as much as possible, by lightweight materials might reduce the overall vehicle weight leading to lower fuel consumption and CO_2 emission. The use of high-strength and high-toughness plastic-based materials in auto bodies might help us in this regard. Unfortunately, all plastic-based products are not biodegradable or environmentally friendly. For the development of biodegradable polymer composites, the role of natural fibers is very vital. This article reports the experimental results on the effects of different types of natural fibers (chopped jute fiber and wood saw dust particles) on the impact toughness of the epoxy-based thermosetting polymer. For this study, at first, pure epoxy was cast into circular disc. In the next stage, 5% chopped jute fiber and saw dust particles were added separately in the pure epoxy resin, and they were cast. Then, the toughness values and fracture morphologies of the pure epoxy samples and the developed composites were characterized by drop ball impact tests. Thus, the experimental results suggest that both the chopped jute fiber and wood saw dust enhance the toughness of the epoxy-based polymer composites. In this context, jute fibers have been found to be more potent.

Keywords: Jute fiber, Wood saw dust, Polymer composite, Drop ball tester, Toughness.

1. Introduction

An advantage of using composites is the wide variety of property values that may be achieved with them, as well as the capacity to adjust those qualities. Additionally, composite materials' strength and modulus-to-weight ratios are typically superior to those of conventional engineering materials. Because of these properties, the overall weight of a system can be cut up to 20 to 30 percent. Weight reduction might lead to cost savings in energy or improved functionality. [1-4].

Throughout the course of a typical workday, vehicles are regularly hit by other vehicles or experience repeated impacts. Impact forces can occur when an object falls from a height onto a moving vehicle or when two moving vehicles collide accidentally. As opposed to this, brittle materials like polymers are more susceptible to impact forces. Consequently, composite materials are being employed to solve this problem. [5-7].

When it comes to biodegradable polymer composites, natural fibers are preferred over synthetic or metallic fillers. Natural fibers are thought to be completely biodegradable. They are also known for a variety of characteristics such as low cost, availability, greenness, and environmental friendliness. As a result, several automotive manufacturers use natural fibers to create environmentally beneficial products. Wood saw dust and jute fibers are Bangladesh's most readily available natural fibers. As a result of this, we made use of them in our research as filler materials. [8-11].

The drop ball impact test is an effective technique for evaluating the toughness of polymer plates. Potential energy is converted into kinetic energy when a ball is allowed to fall from a specific height. We may calculate the impact resistance of polymeric composites by measuring their height and applying a simple equation. Potential energy = $m \times g \times h$, where m is the ball's mass and h are its height. In this technique, the crack generally originates from the weakest point of the sample and propagates throughout the samples. [12-14].

2. Experimental Procedure

2.1 Materials Preparation for Compounding and Molding:

To develop epoxy-based polymer composites, epoxy resin was purchased from the local market and wood saw dusts were collected from local source and then screened to get about~2 mm size particles (Fig.1a). Long jute fibers were also collected from local market and cut into ~2 mm size particles (Fig.1b).

(a) (b)

Figure 1: (a) Wood saw dusts and (b) chopped

2.2 Molding of pure epoxy:

To cure epoxy resin at room temperature, methyl-tetrahydro-phthalic anhydride was utilized as a hardener. The hardener and epoxy resin were mixed in a 1: 10 volume ratios. The mixture was properly mixed after the hardener was added to the resin to ensure consistent mixing. In most cases, dissolved gases are present in the resin and hardener mixture. These can cause flaws in the composites, such as microcracks and voids, which can degrade the mechanical properties of the composites. As a result, the degassing took roughly 10 minutes. The liquid was then poured into a casting mold of the desired shape. The epoxy resin takes around 5 to 6 hours to cure properly after casting.

2.3 Molding of wood saw dust composites:

To eliminate moisture from the saw dusts, they were heated at 100º C for roughly an hour before being added to the epoxy resin. Then, in a beaker, 5wt% saw dusts were mixed adequately with epoxy resin to achieve uniform mixing, and hardener (10 vol percent of the resin) was added to the mixture. The mixture was cast into the mold after a 10-minute vacuum processing.

2.4 Molding of chopped jute fiber composites:

For the development of chopped jute fiber composites, the same procedures as for the wood saw dust composites were used.

2.5 Preparation of the sample for the toughness tests:

About 25 cast samples of pure epoxy resin, epoxy-based 5wt % wood saw dust composites, and epoxy-based 5wt % chopped jute fiber composites of circular shaped samples (Fig.2) were made to determine the effect of natural fiber on the toughness property of epoxy-based composites. Drop ball impact tests were performed using these cast samples.

2.6 Drop Ball Impact Test:

Samples (thickness 7mm) from each group for a certain height were tested by falling ball impact tester (ASTM D1709). A steel ball was used for this test. Different heights were selected to determine the required energy for breaking the circular shaped disk. Two samples have been tested for each height to confirm the accuracy of the results. Tables 1, 2, and 3 present the results of the study.

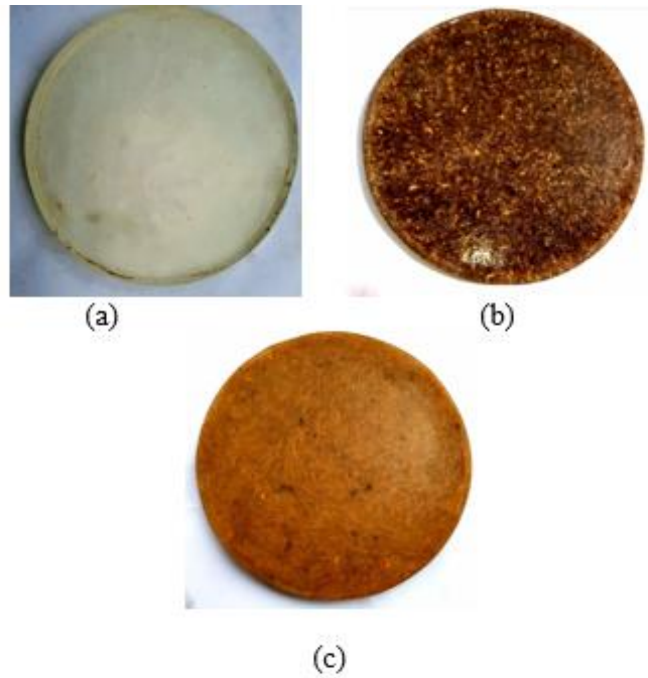


Figure 2: toughness test samples. (a) pure epoxy resin, (b) epoxy-based saw dust composite (c) epoxy based chopped jute fiber composite

3. Calculation

3.1 Calculation of impact energy:

We know, the potential energy= m×g×h … (1)

Here, m= ball mass, g=9.8 and h= height from which the ball was dropped.

For this experiment, the mass of the ball = 0.11kg was used. To determine the potential energy by which the samples were broken, the height of the ball dropping point was gradually increased.

Following this process, the average energy for epoxy-based wood saw dust composites and epoxy-based jute fiber composites were calculated (Table 2 and 3).

4. Result and Discussion

When the ball was dropped from a significant height, the potential energy was transformed to kinetic energy, which assisted in breaking the atomic bond of the polymeric materials and causing cracking. The composite materials failed due to crack propagation along the grain. To measure the impact resistance of the samples, we employed four samples for each height in our study. According to tables 1,2 and 3, the possibilities of the epoxy resin and its composites failing increased as the height increased due to an increase in potential energy.

Table 1: Impact resistance data for the pure epoxy resin

Height (mm)	Energy (J)	Comments	Average Energy (J)
1100	1.18	Not Broken	1.27
1120	1.20	Not Broken	
1140	1.23	Partially Broken	
1160	1.25	Partially Broken	
1180	1.27	Completely Broken	

Table 2: Impact resistance data for the epoxy-based wood saw dust composites

Height (mm)	Energy (J)	Comments	Average Energy (J)
1170	1.26	Not Broken	1.38
1200	1.29	Not Broken	
1240	1.34	Partially Broken	
1280	1.38	Completely Broken	

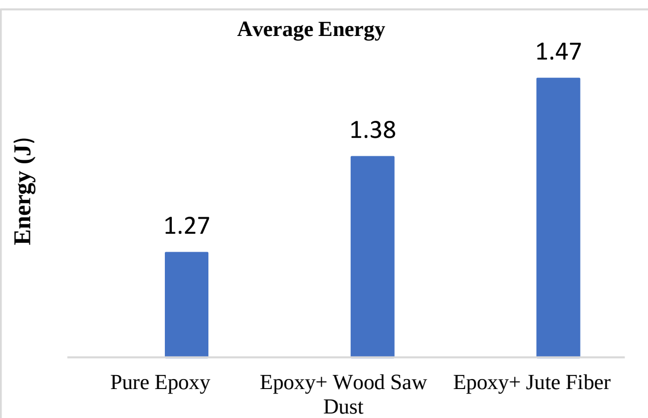
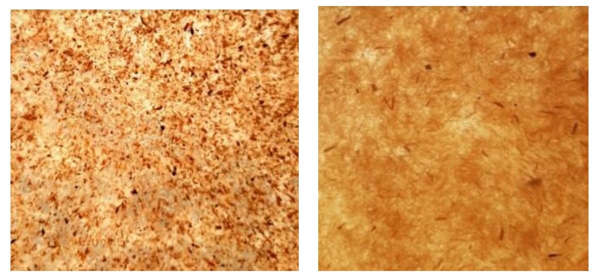


Figure 3: Average energy of the samples absorbed during fracture

Table 3: Impact resistance data for the epoxy-based jute fiber composites

Height (mm)	Energy (J)	Comments	Average Energy (J)
1260	1.36	Not Broken	1.47
1300	1.40	Not Broken	
1330	1.44	Partially Broken	
1360	1.47	Completely Broken	

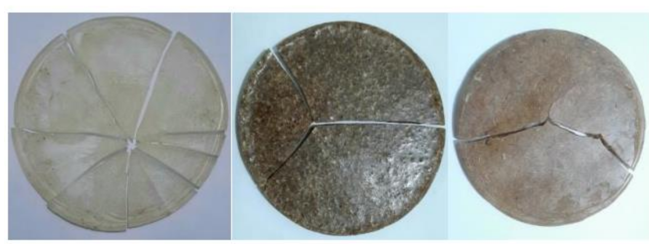
It is obvious that adding 5% wood sawdust and 5% chopped jute fibers to the epoxy resin has improved its impact resistance (Fig 3). Wood saw dust enhanced the toughness resistance by around 10%, whereas jute fiber increased the toughness value of the pure epoxy resin by about 16%. The fact that both wood saw dusts and chopped jute fibers were uniformly dispersed through the epoxy matrix (Fig.4) and the bond formation between the matrix and fibers was perfect could be the explanation for the improved toughness performance. Besides, fibers are known as load bearing components [17]. Thus, most of the applied energy were carried out by the fibers along with the matrix. This aided in the enhancement of the toughness property. Many researchers have also stated that incorporating fibers into polymeric materials improves toughness [18]. Jute fibers are also said to be stronger than wood sawdust. [19-20]. As a result, it was able to absorb more energy than wood saw-dusts. That's why chopped jute fibers performed better than wood saw dusts.



(a) (b)

Figure 4: distribution of fibers in the epoxy matrix (a) wood saw dust composites (b) chopped jute fibers composite

According to Fig. 5, pure epoxy resin and epoxy-based composites are brittle in nature. Because they fragmented like shattered glass when energy was applied [21]. The number of fragments in pure epoxy resin is larger (Fig. 5a) than in epoxy-based composites. (Fig. 5b,5c). Because the fibers assisted in carrying the load along the epoxy matrix and dissipating the energy. This slowed the formation of cracks and the failure of the samples. As a result, natural fibers are thought to have enhanced the failure mechanism of epoxy-based composites. The test results also showed that both types of fibers improved the composites' toughness.



(a) (b) (c)

Figure 5: Failure samples (a) Pure epoxy resin, (b) Epoxy based- wood saw dust composites and (c) Epoxy-based-chopped jute fibers composites

4.1 Hardness:

In addition, a hardness test was performed to verify the accuracy of the evaluation of the impact toughness test. To determine the hardness of epoxy composites, a shore durometer with ASTM D2240 type D scales was used. The information is presented in table 5. The pure epoxy resin has a hardness of 69.7shore D, according to the data table. However, the addition of jute fibers and wood saw dusts substantially increased the hardness of both types of composites. This occurred because the two varieties of fibers shielded and protected the epoxy matrix (Fig. 4). But jute fiber took in more shock and hold up better against localized plastic deformation. Based on this, it is feasible to say that jute fiber is tougher than wood sawdust.

Table 4: Hardness test data for the composites

Sample Id	Hardness Values (Shore D)										Average	Standard Deviation
Epoxy	68.5	69.1	68.3	72.7	71.5	68.2	69.7	67.2	71.4	70.4	69.7	1.6
Epoxy+ Saw dust	76.2	77.6	73.7	74.9	75.8	74.6	73.9	73.1	74.7	72.9	74.74	1.3
Epoxy+ Jute Fiber	83.2	84.6	85.9	84.9	87.4	83.9	83.2	82.8	87.7	86.4	85.1	1.7

5. Conclusion

In this research, the effects of the same weight percentage of wood sawdust and jute fibers of similar sizes on the Impact toughness and fracture behaviors of epoxy-based polymer composites were investigated.

- The impact toughness of an epoxy polymer can be improved by adding wood saw dust of about 5 wt.% and 2 mm in size. Moreover, impact toughness the of the base polymer is increased remarkably by around 16% when chopped jute fibers of size 2mm are added (5 wt.%).
- Toughness was improved due to fiber's ability to shield and absorb impact energy during testing.
- Jute fiber shows better performance than wood saw dusts in both hardness and impact toughness measurements. Additionally, jute fiber helps to improve the fracture morphology of epoxy resin, which causes the material to shatter into a smaller number of pieces when it breaks.

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