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Enhancement of Mechanical Properties of Luffa Fiber/Epoxy Composite Using B_4C

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In current scenario, the natural fibers are widely used in many engineering applications because of its low density compared to metal matrix composites. Regarding the mechanical properties of the natural fibers, it remains low. But the advancement of composite technology, the mechanical strength is improved with suitable hardener and reinforcements. This paper aims to study the enhancement of mechanical properties by the ceramic B_4C addition to the recent innovative Luffa fiber/epoxy composite. The fibers are collected from local sources and extracted by means of water retting process. The Luffa Acutangula is made into short fibers and chemically treated to remove the moisture and the composite is manufactured by hand lay-up method. The mechanical properties are evaluated for the Luffa/Epoxy Composite and Luffa/Epoxy/B_4C Composite. The results show that the tensile strength and compressive strength of Luffa/Epoxy/B_4C Composite are improved about 8.55% and 67% respectively by B_4C addition and achieved the hardness of 91HR_C. The fractrography analysis is carried out for the ruptured impact strength test samples and it concludes the improved energy storage and distribution over the lattice of ceramic is the reason for improved strength.

Keywords: Luffa Acutangula, Boron Carbide, Epoxy, Composites, Fiber.

RESEARCH ARTICLE

1. INTRODUCTION

The fiber composites attracted many researchers in the modern era because of its eco-friendly nature and it can be turned into engineering material.[1] The addition of smart ceramic materials with the fiber composites, it exhibits enormous strength at low density. The use of natural fiber composites is an effective way of improving the performances of even load bearing materials. The most interesting aspect about natural fibers is their positive environmental impact. They are CO_2 neutral, i.e., they do not return excess CO_2 into the atmosphere when they are composted.[2]

In recent research, the Luffa fibers are very attractive material for many weight lifting applications. Patel and Anil[3] studied the mechanical properties of Luffa cylindrica/polyester composites and stated that the addition of microfillers has influenced the physico-mechanical properties of Luffa-fibre based polyester composites. The increase in the amount of ceramic B_4C particles in the metal matrix composite leads to decrease in the distance between the particles, causing an increase in the stress required for the dislocation movement between the B_4C particles, resulting in improved material strength.[4] The surface morphology study is the best way to reveal the exact consequence of the grain size and grain boundary effects.[5] The fractrography analysis using Scanning Electron Microscope (SEM) images of the tension experienced have explained the interfacial linkage between the fibers and reinforcements.[6]

From the literature, it is inferred that the addition of ceramic phase to the fiber composite could improve the strength of the composite. This paper aims to study the enhancement of mechanical properties by the ceramic B_4C addition to the recent innovative Luffa fiber/epoxy composite.

2. MATERIALS AND METHODS

2.1. Natural Fiber-Luffa Acutangular

Luffa is a fruit classified in the cucumber (Cucurbitaceae) family. Luffa acutangula is commercially grown for its unripe fruits as a vegetable. Mature fruits are used as natural sponges for cleaning. It ranges from central and eastern Asia to southeastern Asia. The vegetable is popular in China and Vietnam. The mature fruits are harvested, dried and processed to obtain the fruit Fiber, the fiber obtained can then be used as a sponge and Fiber for making hats. The chemical composition of luffa contains cellulose content varies from 55 to 90%, the lignin content is within the range from 10 to 23%, the hemicelluloses

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content 8 to 22%. The density of luffa is around 0.82 to 0.92 g/cm^3. The luffa sponge material exhibits remarkable stiffness, strength, and energy absorption capacities that are comparable to those of some commonly used metallic cellular materials with a similar density range.

2.2. Fabrication and Sample Preparation

The composite laminates are manufactured using the hand layup technique.[7] At first, the Fibers are kept under direct sunlight for removing the moisture present in it. Then it is alkali treated for removing the cellulose content. The epoxy LY556 resin and hardener HY951 are mixed completely in the ratio of 10:1 by weight with Fiber for good binding. And for Luffa/epoxy/B_4C composite, the B_4C powders are mixed for 10 wt.% with the mixture. Then Fiber and the resin-hardener mixture are applied over the die. After setting and drying the releasing agent the roller is rolled evenly to spread the resin-hardener mixture according to the dimensions required. Finally, a uniform weight is placed over the composite to get the perfect shape and thickness. The thickness of the lamina is limited to 3 mm and the size is 30×30 mm^2. After dried, the edges of the specimen are neatly trimmed by using saw as per the dimensions needed.

2.3. Mechanical Testing Methods

The Rockwell hardness tester is used to measure the hardness of composite specimens as per ASTM E92 standards.

The tensile tests are conducted on computerized Universal Testing Machine HEICO (HL-590) with a crosshead speed of 10 mm/min. The tensile test samples are prepared according to ASTM: D303 standard. The compression tests are conducted on the same equipment as per ASTM D638 standards.[8]

The impact test specimens are dimensioned according to ASTM: E23 to measure the impact strength. The specimens are prepared with the dimension of $55 \times 10 \times 10$ mm^3 and the depth of the notch is 3.33 mm (t/3 mm) with 45° angle. The samples are fractured in Charpy impact testing machine and the energy (joule) absorbed while being broken is recorded.

3. RESULTS AND DISCUSSION

3.1. Hardness

The hardness test is conducted as per the ASTM standard and the results are plotted in Figure 1. The hardness of the Luffa/epoxy/B_4C is increased from 83 and 91HR_C. The enhanced resistance is offered by B_4C reinforced composite at the beginning, which is due to the higher energy storage capacity of the hard ceramic phase in the material.[9]

3.2. Tensile Strength

The tensile test is conducted as per the ASTM standard and the results are tabulated in Table I and graphically represented in Figure 2. The tensile strength of the Luffa/Epoxy/B_4C has increased about 8.55% compared to Luffa/Epoxy Composite.

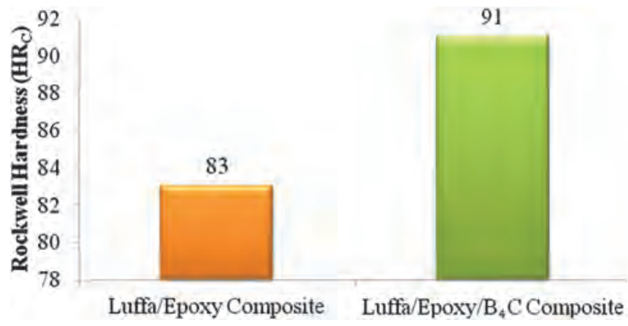

Fig. 1. Results of hardness test.

Table I. Results of tensile test.

Sample	Tensile strength (MPa)	Modulus (MPa)
Luffa/Epoxy composite	12.40	23.14
Luffa/Epoxy/B_4C composite	13.56	73.29

3.3. Compression Strength

The compression test is conducted as per the ASTM standard and the results are plotted in Figure 3. The compression strength of the Luffa/epoxy/B_4C is increased about 67% compared to Luffa/Epoxy Composite.

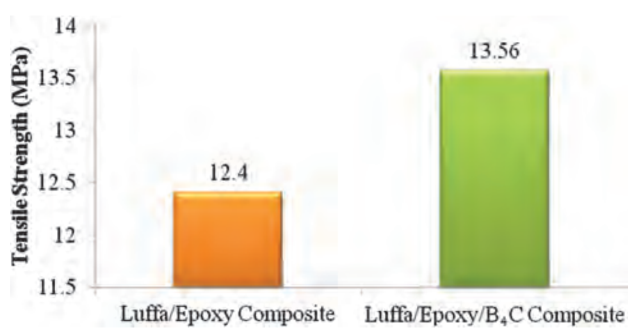

Fig. 2. Results of tensile test.

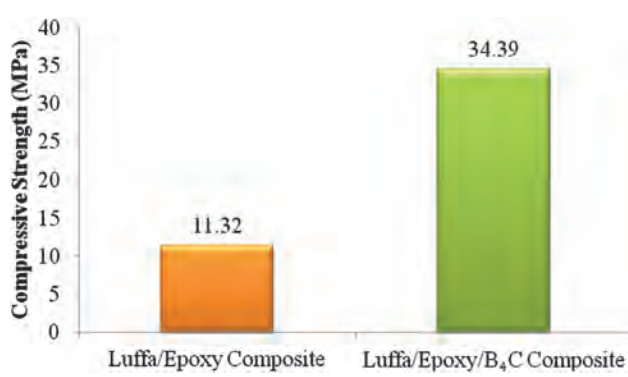

Fig. 3. Results of compression test.

Table II. Results of impact test.

Sample	Impact energy (J)	Impact strength (J/m^2)
Luffa/Epoxy composite	8000	18400
Luffa/Epoxy/B_4C composite	18000	40100

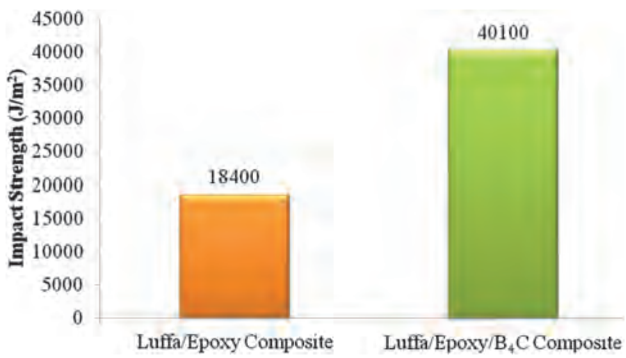

Fig. 4. Results of impact test.

3.4. Impact Strength

The impact test is conducted as per the ASTM standard and the results are tabulated in Table II and graphically represented in Figure 4. The impact strength of the Luffa/epoxy/B_4C is increased about 54.1% compared to Luffa/Epoxy Composite.

3.5. Fractrography Analysis

Scanning Electron Microscope (SEM) is used for analyzing the morphology of the fracture composites samples under tensile test. The SEM image of Luffa/Epoxy Composite is shown in Figure 5. This figure shows a flake-like structure, which was magnified (1 K X) and shown in the green box. This flake-like structured Luffa has the tendency to absorb the tensile load and makes the composite to withstand upto 12.4 MPa. The Luffa fibre with epoxy acts as a rope of wire and increase the strength of the composite. It fails when the load crosses the ultimate strength of the Luffa rope.

The SEM image of Luffa/Epoxy/B_4C Composite is shown in Figure 6. This figure shows a flake-like structure with some hard spherical powders, which was magnified (1 K X) and shown in the red box. This figure shows the ceramic particles of boron in the Luffa/Epoxy/B_4C composite. The fractured surface of the Luffa/Epoxy/B_4C composite has a hard ceramic phase of B_4C in flakes like structured Luffa, which has the ability to storage higher energy and to evenly distribute the load applied on the surface over the lattice of ceramic phase.[10] This phenomenon tends to increase the load bearing capacity to 13.56 MPa for the Luffa/Epoxy/B_4C composite.

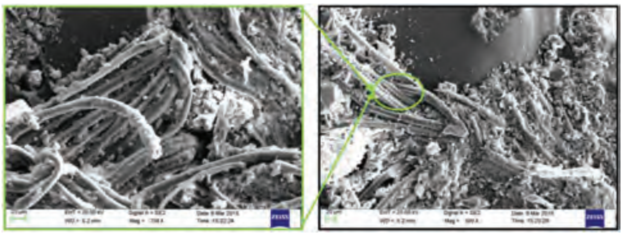

Fig. 5. SEM image of Luffa/Epoxy composite.

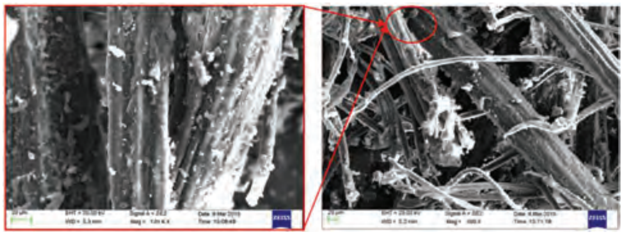

Fig. 6. SEM image of Luffa/Epoxy/B_4C composite.

4. CONCLUSION

- The Luffa/Epoxy/B_4C Composite is successfully manufactured using the cost effective hand lay-up method.
- Luffa/Epoxy/B_4C Composite has the greater mechanical properties compared to Luffa/Epoxy Composite.
- The impact test result shows that the addition of B_4C increases the impact strength of luffa fiber.
- Surface morphology evidences the presence of B_4C in Luffa/Epoxy/B_4C composite and its fractured surface shows a hard ceramic phase of B_4C in flakes like structured Luffa, which has the ability to storage higher energy and to evenly distribute the load on the the lattice of composite.
- In further, this work can be extended to study the physical and tribo properties of the Luffa/Epoxy/B_4C composite.

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