Mechanical Properties of Polymer Matrix Composites Reinforced by azadirachta indica and Glass Fibers

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Abstract

In the current scenario, non-decomposable fibres are the major problem in every field. The present work deals in studying the mechanical properties of azadirachta indica and glass fibre reinforced with epoxy resin hybrid natural fibre composites. The composites are fabricated by compression moulding method by varying the azadirachta indica fibre by 0, 2, 4 and 6% by weight (wt) fraction and the glass fibre with 8, 16 and 24% by weight fraction. The fabricated composites are tested for its mechanical properties such as hardness, impact strength and tensile strength as per ASTM standards. From the results, it is observed that the increase in azadirachta indica and glass fibre with 6 and 24 wt % increases in all the mechanical properties of the composites.

Keywords: Azadirachta Indica, Glass Fibre, Impact Strength, Hardness, Tensile Strength.

INTRODUCTION

Generally, any material containing two or more constituents with dissimilar properties and distinct boundaries between the constituents can be referred to as a composite material. Moreover, the idea of joining several components to create a material with possessions that are not attainable with the individual components has been used by man for thousands of years. Correspondingly, most natural constituents that have emerged as a result of the prolonged evolution process can be treated as composite materials [1]. The demands for advanced materials with improved properties have been increasing. This expansion has significantly contributed to the advent of new polymer matrix composite material, so that facilitate improvement of properties of a material that could use in various engineering applications, including automobile, aircraft and structural composites, biomedical & sporting materials etc. Recently, growing environmental care and sustainability needs throughout the world have increased the attention of researchers to search for better alternatives to synthetic fibres (such as glass, carbon and aramids). Referring to environmental aspects in fact, these synthetic fibres have some disadvantages, but fortunately nature always comes in handy for providing several good alternative materials. These difficulties are overcome by good fibres yielding plants which are cost-effective without compromising mechanical properties. The applications of natural fibres are growing in many sectors such as aerospace, automotive, construction, and packaging industries. This is mainly due to their excellent features compared to synthetic fibres, i.e., low cost, low density, cost effectiveness, high toughness, non-toxic, renewable, recyclable, non-abrasive and biodegradable properties. The chemical constituents of bark fibres are strongly dependent on the age, local environmental conditions of the plants. Natural fibres can be extracted from different parts of plants such as stems, leaves, roots, fruits, and seeds. Azadirachta Indica, well known as Neem tree is pertaining to the mahogany family Meliaceae. It is native in India and it typically grows in tropical and semi-tropical regions. Numerous products made from Azadirachta Indica have been used in India over two millennia because of its inherent medicinal properties. The inter-node length, width, and thickness of average untreated AIF were found to be around 120 mm, 1.27 mm and 1.84 mm, respectively. Acacia Arabica plant was brought to India in 1860 as fuel wood, as the native trees in India in arid and semiarid regions could not fulfil the demands for fuel. It had the capacity to grow in all climatic conditions except in the frost zones of the Himalayan region. It could survive where the annual rainfall was between 150 and 750 mm and maximal temperature 40-45°C and also, they can survive without water for several months [2]. These fibres can be used for making green composites which will be helpful in the applications like light weight sports goods, roofing sheets, door panels, furniture panels, storage tanks, bath units, chairs, partitions, trays, tables

The idea of sustainable materials has now become of paramount importance because of the need to guarantee our condition. Natural fibres such as coconut fibre, bamboo, jute, hemp and Calotropis gigantea are currently discovering applications in a large number of companies. Many research studies have been spread over different basic biological characteristic filaments and their compounds, and the present study has aimed to present another regular bio-based basic fibre as one of the natural products and fortification channels in the assembly of a new composite material for lightweight structures. [3] experimented that, neem fibers and kenaf fibers are cellulose-based plant fibers which are good capable of acting as a reinforcement with glass fiber polymer. Resin and hardener are used as a medium for fabrication of natural fiber composites. Vijaya Ramnath et al. [4] inferred that the main concept of combining two fibers is to compensate the poor property of one fiber by the other and making it as superior when combined together. The surface modification of natural fibers is done by alkali treatment to improve the adhesion between fiber matrix interfaces. But, the mechanical properties of the natural fiber are affected by the hydrophilic nature which is the major disadvantage of the natural fiber. Srinivasan et al. [6] studied that modulus of elasticity is better for dry fibers, and wet fibers showed good adhesion between matrix and fiber. The flexural strength, impact strength and tensile strength for the polymeric composites are found to be better when the kenaf fibers are alkalized. Vijayakumar et al. [6] studied that the neem tree (Azadirachta Indica) is a major source of fibers for various marine applications. The strength of the neem fiber depends on many factors such as harvesting time, growing conditions of the plant and extraction methods which influences the chemical composition and structure of the fiber. Natural fibers which are extracted manually have 20% higher strength than mechanically extracted ones. Vijaya Ramnath et al. [6, 7] investigated that neem fiber reinforced polyester composites are prepared by extracting neem tree fibers and incorporating them in polyester resin matrix to study the tensile strength and impact strength of the resultant composites. Subasinghe et al. [8] studied that in natural fiber composite (NFC), there has been a rapid growth in R&D and innovation sectors. This interest is created because of the superiority in the advantages, which includes low environmental impact, low cost and support wide range of applications when compared to other fibers such as synthetic fiber composites. Vijaya Ramnath et al. [9, 10] inferred that, aeronautical and defense application sectors demand precision engineering, weight saving, finite tolerances, simplifies production and operations uses natural fiber reinforced composites, whereas synthetic fiber composites are limited to these applications because of high cost of material and fabrication methods. Structural members are strengthened by fiber reinforcement polymers even after they have been severely damaged because of its low density and high stiffness. This is because of the increased toughness, impact resistance and the energy absorption provided by the fiber to the composite. The modulus of elasticity is directly proportional to the volume of the fiber, and the ultimate strength is inversely proportional to the volume of the fiber in the composite. The usage of natural fibers in curved pipes has resulted in reduction of cost and weight of about 20% and 23%, respectively. Pickering et al. [11] investigated that, Africa is the origin of kenaf crop (Hibiscus cannabinus). It is widely cultivated around the world for use as fiber, paper or biofuel. It acts as a binder less thermal insulator. Subasinghe et al. [8] inferred that, kenaf fiber because of its rapid growth can be used as reinforcement in natural fiber composites. Developments of kenaf-based industries have been encouraged by the government. Kenaf degrades earlier because of the presence of lignin and hemicellulose. After 300°C, the char content formed from lignin present in the kenaf fibers causes a slow rate of degradation. The kenaf fibers have high lignin content so the thermal resistance can be increased by the incorporations of lingo cellulosic kenaf fibers into a polypropylene matrix. Subasinghe et al. [12] studied that, the photosynthesis rate is three times than that of the usual plants. It can filter carbon dioxide at 14 times its own weight which is higher than others. Tharazi et al. [13] investigated that, the unidirectional long kenaf fiber which is reinforced with polylactic acid were fabricated into biodegradable composites by hot pressing method. To optimize the tensile strength and to determine the significance of the factors influencing it, analysis of variance (ANOVA) and response surface methodology (RSM) were used. For optimum tensile strength, the combination of hot-pressing parameters was 200 °C temperature, 3 MPa pressure and heating time at 8 min. Confirmation test run yields error which is less than 7% verified the validity of the model. Tharazi et al. [13] studied that kenaf fibers are more sustainable that concrete reinforced. The properties are studied based on nano-indentation principle and effect of water absorbing fibers are noted. The result shows that there is not much significant difference in the structure but it has some variations based on relative volume fractions. Experimented that, the ability of a material to withstand applied stress or shock load is called impact resistance. The factors influence the impact strength are strength of the material, elastic modulus of the fiber material, orientation and length of the fibers, interfacial bond strength of fiber matrix, and finally, the method of impact testing. Several applications include interior and exterior components of automobiles, aircraft, constructions and building materials which are used as engineering materials of high impact strength[14]. Vijaya Ramnath et al. [15] inferred that, the low viscous liquids are more absorbed by natural composite materials than high viscous liquids. Infinite material permutation including fiber and resin types, architecture quantities, production methods used and interfaces influences the impact behaviour of composites. Rajesh et al. [16] experimentally investigated the mechanical characteristics of various natural fiber composites and result shows that there is a significant improvement in the mechanical properties. Also, scanning electron microscopy is done to observe the internal structure of the composite specimen. Bajuria et al. [17] investigated flexural and compressive properties of kenaf with the combination of silica nano-particles in the epoxy medium by using vacuum infusion process and found the above properties are mostly significant.

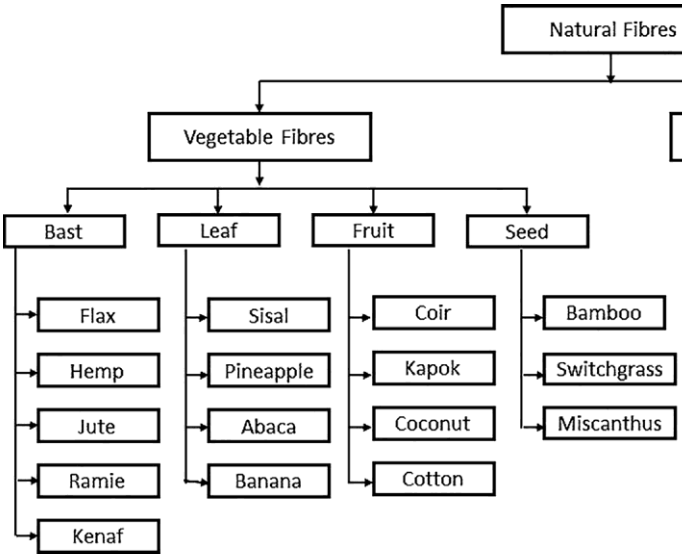

Figure 1: Classification of Natural Fibres

MATERIALS AND METHODS

Neem Fiber (azadirachta indica)

Neem leaves and stem as shown in Figure. 2 is one of the natural fibers which meet a wide range of applications as composites reinforced with polymer matrix, resin and suitable hardener. The strength of the neem fiber depends on many factors such as harvesting time methods of extraction of neem fibers.

Figure 2: Azadirachta indica fiber

Rice Husk

The Rice Husk as shown in Figure. 3 can be used as biochar, extracted silica, or husk itself. In general, Rice Husk is a hull to protect seeds or grains. It is formed from rigid materials, is water-insoluble, and is abrasive, with a high level of cellulose–silica structures. The exterior of the hulls consists of silica covered with a cuticle, with a small amount of silica content at the innermost epidermis. Recently, several attempts have been made to utilize these waste materials in composite structures. Furthermore, it discusses the potential of Rice Husk composites to be used in photonics, construction materials, and automotive and furniture applications, based on their strength and thermal characteristics.

Figure 3: Rice Husk

Glass Fiber

Figure 4 shows the glass fiber. It is the most commonly used polymer which is made up of many strands of silica glass fiber. It is extremely strong and robust material. The strength to weight ratio of glass fiber is high and can be easily manufactured by extruding and molding processes. It has very good bulk and weight properties when compared to metals. The erosive wear rate of the composite is increased by the glass polymer.

Figure 4: Glass Fiber

Epoxy Resin and Hardener

Materials Epoxy has been the major matrix material of polymer matrix composites for aerospace and automotive applications for many years. This is attributable to ease of processing, and low cost. HV953 hardener has good mechanical, chemical properties and low cost. AW106 epoxy resin has good bonding strength. The resin-hardener severs the purpose of binder between various layers of fiber. The mixing ratio between resin and hardener is 10.1. AW106 epoxy resin and HV953 hardener are shown in Figure. 5 give the best binding property in room temperature of 28–30 °C.

Figure 5: Epoxy and Hardener

Compression Moulding Technique

The fabrication part was done on compression moulding. The compression moulding machine is shown in Figure. 6. First die was cleaned properly. The surface to the die was made free of moisture and cleaned properly. Then, release gel was applied on the surface of the die so as to create a non- sticky surface. Then, the epoxy was applied layer by layer with jute and Calotropis gigantea by considering safety and precautions. Ratio was calculated according to weight fraction where jute fibre kept as constant for all the three specimens. The die was covered with OHP sheet to avoid sticking on top die. Fibres were compressed at a set pressure and temperature of 50 bar and 40 °C, respectively, for 3 h. The fabrication was completed, and specimen has been taken out. The composition of the specimens is shown in Table 1.

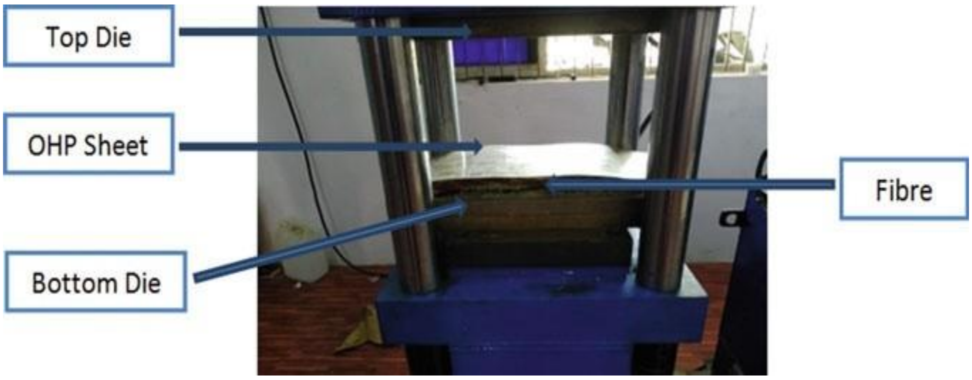

Figure 6: compression moulding machine

Table 1. Detailed composition of the specimen

	Matrix Epoxy	Filler Material (Rice Husk)	Neem	Glass
Specimen 1	90	10	-	-
Specimen 2	80	10	2	8
Specimen 3	70	10	4	16
Specimen 4	60	10	6	24

TESTING OF COMPOSITES

Tensile Strength Test

The tensile strength test for specimens were prepared according to the ASTM (D-638) at room temperature [17]. The dimension of tensile strength is shown in figure 7.

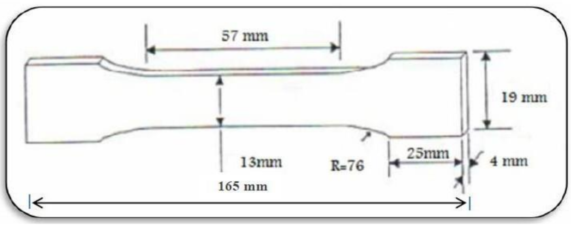

Figure 7: Standard specimens for tensile strength test

Impact Test

In this test, the amount of energy absorbed by the specimen during the breakage is the impact strength of the material. A pendulum is setup to drop on specimen to fracture. Charpy impact test is employed in this case. The specimen is prepared as per ASTM: D256 standards, which are shown in Figure 8.

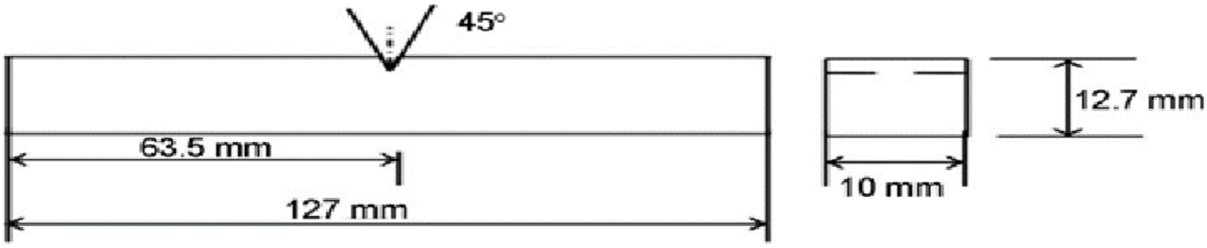

Figure 8: Standard specimens for impact strength test

Hardness Test

The hardness of the composites was measured using a Rockwell hardness testing machine according to ASTM D785-98. The hardness value of a composite corresponds to the amount of indentation occurred when the steel ball is made to indent on the composite specimen.

RESULT AND DISCUSSION

Results of Impact test

The impact test results obtained from the Charpy impact test is shown in figure 9 impact strength values corresponding to three trials of each sample are noted. The average energy absorbed is calculated in joules and noted. The total energy absorbed is 5.9 J for Sample 4 due to the presence of azadirachta indica and glass fibre in the composite laminate which resists the fibers to break at maximum load. This increases the contact area between the laminate which in turn increases the contact area against impact load.

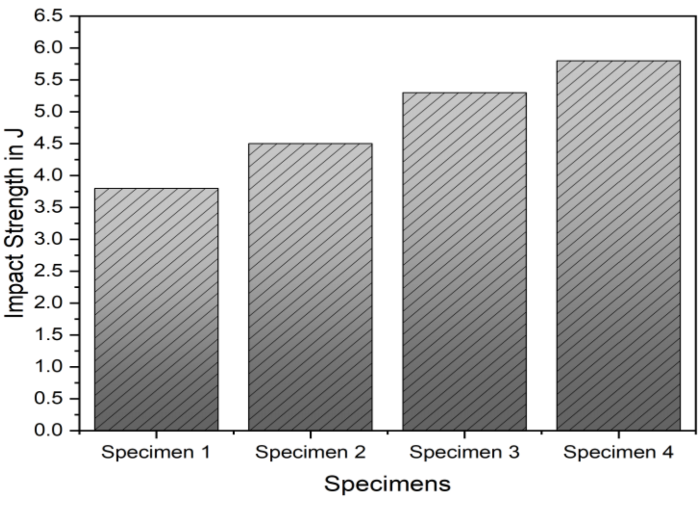

Figure 9: Impact strength of specimen

Results of Hardness Test

The experimental results of the value of indentation obtained during the hardness test carried out using Rockwell hardness machine are furnished in figure 10. Three trials are carried out for each sample and the hardness number is noted. The maximum indentation occurs for Sample 4 with average 76.4 Rockwell number. The results are plotted as graphics as shown in Figure 10. Sample 4 has high hardness as the fibers weight percentage is incresed, which resist the indentation. This is the result of high bonding between fibers and increased contact area due to orientation. The graph shows the result of Hardness test for the four samples.

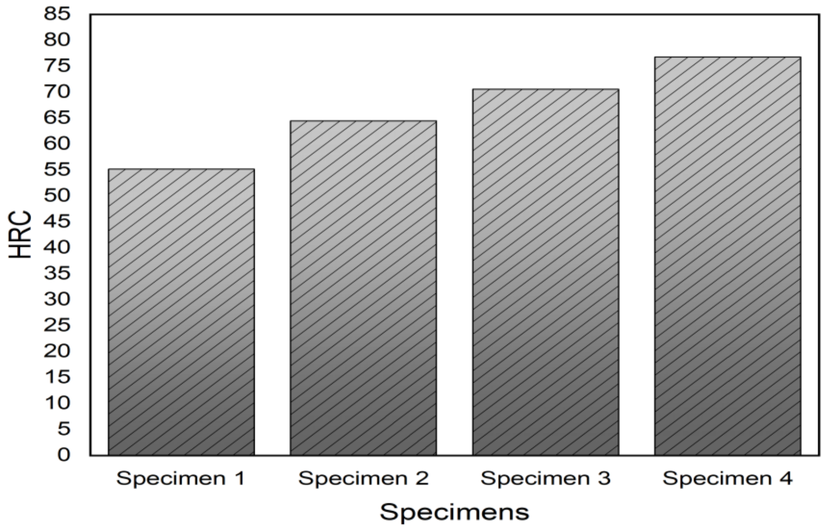

Figure 10: Hardness strength of specimen

Results of Tensile Strength

The experimental results obtained during the tensile test carried out using Universal Tensile Machine are furnished in figure 11. Three trials are carried out for each sample and the values is noted. The maximum stress occurs for Sample 4 with average of 88 Mpa. The results are plotted as graphics as shown in Figure 11. Sample 4 has high tensile strength as the fibers weight percentage is increased, which resist the elongation. This is the result of high bonding between fibers and increased contact area due to orientation. The graph shows the result of tensile test for the four samples

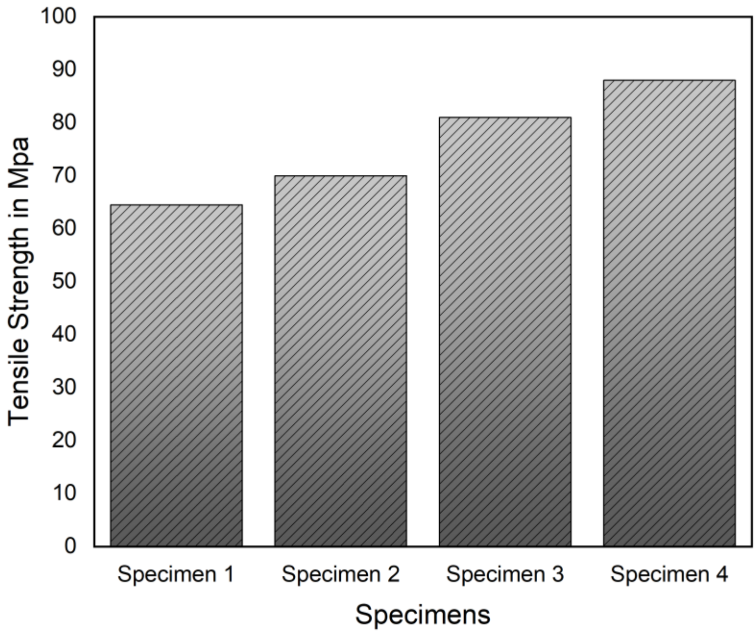

Figure 11: Tensile strength of specimen

Conclusion

Based on impact, hardness and tensile strength experimental results, the following conclusions have been made. For impact, the maximum amount of energy absorbed is recorded as 5.9 J. This is due to the presence of azadirachta indica and glass fibre which resist the force to minimum, thereby reduce the damage of the composite specimen. For hardness test, the value of indentation is 76.4 Rockwell hardness number. The indentation on the specimen is restricted due to the presence of strong adhesion between the fibers and the matrix which does not allow the penetration due to load into the composite specimen. For tensile strength, the value of maximum stress is 88 Mpa. The load on the specimen is restricted due to the presence of strong adhesion between the fibers and the matrix which does not allow the penetration due to load into the composite specimen. Hence, due to high value of impact, hardness and tensile properties, this hybrid composite can be implemented in various engineering applications where high impact is in demand.

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