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Processing and Characterization of *Strychnos nux-vomica* Fiber Reinforced Epoxy based Composite Material

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Abstract

Polymer Matrix Composites (PMC) consist of thermoset or thermoplastic matrix resins reinforced by fibers which can be used in various sectors like aircraft, aerospace, automobile, marine, bio-medical, industrial, electrical, safety equipment, sports goods, and structural application. Because PMC exhibit lightweight, high stiffness and their high strength along the direction of their reinforcements. The synthetic fiber material is used in polymer composite which causes environmental pollution, and its material cost is high. In this study, natural fiber is identified and *Strychnos nux-vomica* fiber reinforced composite is fabricated using compression molding process. It can also be used as alternative reinforcement for FRP (Fiber Reinforced Polymer) composite material. The composition of epoxy and nux-vomica fiber in wt% are varied as 70:30, 60:40, and 50:50. The mechanical properties, namely tensile strength, flexural load, and impact energy are measured for nux-vomica fiber reinforced composite. From the results, it is found that the maximum mechanical properties such as tensile strength (14.93 MPa), flexural load (1.76 kN), and impact energy of 4 J are obtained at composition of 50:50 in wt%.

Keywords

Strychnos nux-vomica fiber, Compression molding process, Tensile strength, Flexural load, Impact energy

Introduction

Due to the increasing population, urbanization expansion, and expeditious industrialization our world has ended up with serious man-made environmental issue namely, solid waste management. Currently, the generation of municipal solid waste is about two billion tons annually, which can potentially rise up to three billion tons per year by the year 2025 across the globe. This municipal solid waste comprises of organic and inorganic wastes. The organic wastes are food wastes, wastes from fruits, and vegetables. The inorganic wastes are from plastics, glasses, and pieces of metals. In this, plastic wastes are the ones which contribute a larger part of inorganic municipal solid waste [1-2]. Thus, the superfluous usage of plastics and its inappropriate maintenance and disposal have ended up with harmful effects on the environment and has crafted serious problems for the entire global ecological community [3]. This enlightens many engineers, researchers, and scientists to undergo research in order to discover an alternative for plastics. According to their wide research studies, the natural fibers reinforced composites can be used as an alternate for the plastics in variety of applications such as aircraft, automobiles, wind turbines, sport goods, structural products and so on [4]. Also, the natural fibers are amply available, ecofriendly, easily bio-degradable, and low-cost [5]. Natural fiber reinforced composite also possesses excellent mechanical properties which makes the state-of-the-art industrial sectors namely aerospace, construction, and automobile. These sectors also make an effort to use natural green fibers in a variety of applications in order to promote sustainable technology [6-7]. This natural green fiber may be mainly categorized into three, namely animal fibers, plant fibers, and mineral fibers. And these fibers are further classified in such a way that discussed further. Horse hair, goat hair, lamb's wool, chicken or a bird feather are grouped into animal fibers. Coir, cotton, jute, sisal, hemp, kenaf, pineapple, and banana fibers are grouped into plant fibers. Ceramic, asbestos, and metal fibers are grouped into mineral fibers [8]. In this, the plant fibers are the ones abundantly available, biodegradable, recyclable, has excellent strength, characteristics, and also low cost, which makes most of the industry and research people desirable about it [9]. Generally, the plant's cell membrane is made of cellulose, hemicellulose, lignin, pectin, and wax. Particularly, cellulose is the one which does not get dissolved in water, has high crystallinity, molecular weight, and it also possesses excellent tensile properties and increased thermal stability [10]. In order to use this plant based cellulosic natural fiber, we must extract it from the source. This extraction can be achieved in different ways such as mechanical extraction, chemical extraction, and water retting process. The water retting process is widely preferred because it does not cause any affects to the cellulosic fiber characteristics [11]. Further, this extracted cellulosic fiber might be treated with alkali solution in order to eliminate the other wastes such as lignin, pectin, and wax. These wastes affect the bond strength characteristic between the reinforcement and matrix during the composite production process [12]. The other such chemical treatment can be employed in order to enhance the adhesion, physical, and mechanical strength of the fibers. Such chemical treatments are as follows: Silane treatment, acetylation treatment also known as esterification method, benzoylation treatment, permanganate, and peroxide treatment [13-14]. Next, the fabrication of composites materials, which can be achieved by any one of the following composite fabrication methods: hand lay-up process, compression molding process, resin-transfer molding, injection molding, pultrusion, and filament-winding process. Each of these processes has its own merits and demerits, which also has a significant effect on composite mechanical performances [15]. Once the fabrication of composite material is completed, it is very important to undergo the characterization process of the fabricated composite specimen. The characterization of the composite materials helps researchers to know better about the material and how it will behave when it gets used in technological applications. The composite material characterization can be achieved by investigating the mechanical strength namely tensile, compression, flexural, and impact energy [16]. In this article, processing and characterization of *Strychnos nux-vomica* fiber reinforced composite are discussed. The *Strychnos nux-vomica* also known to be the Strychnine tree, which can be found in the tropical forest of India, also in Sri Lanka and Australia. Strychnine consists of alkaloid which is extreme poison to human which affects the central nervous system and also causes death. And also, other 84 compounds such as flavonoids, steroids, organic acids and so on have been also identified from this *Strychnos nux-vomica* which can be used for medicinal purpose too [17]. The idea of this research is to determine whether it can be a potential candidate for composite materials using natural fiber, which is an alternative to synthetic fiber usage.

Materials and Methods

Materials

Strychnos nux-vomica or Strychnine tree is a medium sized tree, which grows in the tropical forest of India. For our research, this Strychnine tree is found in Yercaud forest near Salem, Tamil Nadu, India. The *Strychnos nux-vomica* fibers are drawn out from the bark of Strychnine tree with help of water retting process. To undergo the water retting process, the bark of the Strychnine tree is immersed in tub of water for two weeks. After two weeks, the bark is removed from the immersed water and combed using a metal comb in order to extract the fiber out of it. This extracted *Strychnos nux-vomica* fiber is employed as the reinforcement. Then, for the matrix, Epoxy LY556 and Hardener HY951 are used in 10:1 proportion [18] for better results.

Composite fabrication

The *Strychnos nux-vomica* fiber reinforced composite material is manufactured using compression molding process. This compression molding is a hydraulically operated press which has two plates, in that the lower plate acts as a stationary plate and upper plate as the movable one. The mixture of reinforcement and matrix as mentioned in table 1 are placed between these preheated plates.

The die with the cavity specification 200 x 125 x 20 mm was used for the fabrication of *Strychnos nux-vomica* fiber reinforced composite material. The fabricated composite material specimen is shown in figure 1.

Table 1: Composition of material for the fabrication of composite specimen.

Specimen	Epoxy		*Strychnos nux-vomica* fiber	
	Wt%	Gms	Wt%	Gms
1	70	350	30	150
2	60	300	40	200
3	50	250	50	250

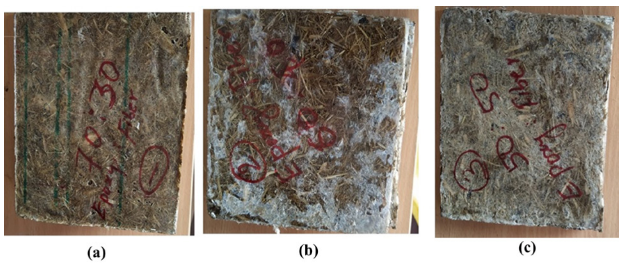

Figure 1: (a) Composite Specimen-1, **(b)** Composite Specimen-2, and **(c)** Composite Specimen-3.

Mechanical testing

Strychnos nux-vomica fiber epoxy composites were fabricated by compression molding process according to the ASTM standards. According to ASTM standards D368, tensile, flexural, and impact tests would be carried out using a universal testing machine. Although ambient laboratory settings are the most typical setting for doing mechanical testing on PMCs. The results that were obtained were tested for three separate specimens with regard to each weight percentage.

(a) (b)

Figure 2: The specimen **(a)** before the tensile test and **(b)** after the fracture.

Results and Discussion

Tensile properties

The weight percentage of the material highly influences the mechanical strength of the fabricated composite, which is due to the fiber properties which provides greater strength and stiffness [19]. For manufacturing a quality composite material, it is very important that an optimum percentage of fiber for the reinforcement must be determined [20]. In order to optimize the strength of the composite, it must be fabricated by varying the reinforcement weight percentage i.e., from 30% to 50%. Due to the matrix's ability to transmit and distribute the maximum applied stress to fibers, the weight % would raise the tensile stress. Figure 3 shows the specimen-1 with 30 wt% of fiber showed 8.58 MPa tensile strength, specimen-2 with 40 wt% of fiber showed 13.90 MPa tensile strength and

(a) (b)

Figure 4: Shows the specimen **(a)** before the flexural test and **(b)** after the flexural test.

specimen-3 with 50 wt% of fiber showed 14.93 MPa tensile stress. A significant raise in the fiber's weight percentage has increased the tensile strength. The optimum tensile strength was noted for the composite which consists of 50 wt% of fiber.

Flexural properties

The material's ability to bear an applied bending load is indicated by its flexural strength. Flexural strength of the material enables its application in the structural field. Due to the homogeneous distribution of the *Strychnos-nux vomica* fiber and its enhanced fiber matrix bonding, the compressive stress which created on the across of the composite material during the bending was increased significantly for 50:50 wt% of fiber/matrix. Also, the flexural strength of the composites increased notably of 1.76 KN at 50 wt%. Flexural strength of *Strychnos nux-vomica* fiber epoxy composites for varying weight percentages (from 30% to 50%). Figure 5 shows specimen-1 with 30 wt% of fiber results 1.21 KN, specimen-2 with 40 wt% of fiber results that 1.15 KN flexural strength, and specimen-3 with 50 wt% of fiber results that 1.76 KN flexural strength. Specimen-1 and specimen-2 were impotent to give higher flexural strength when compared to the specimen-3.

Impact testing

By using the specimens which are un-notched and of various fiber wt%, the loading in the Izod impact test, the toughness characteristics of the composite was assessed.

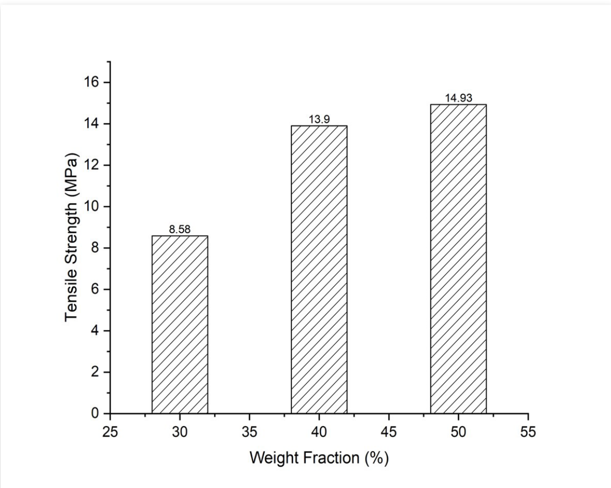

Figure 3: Shows the effect of varying fiber weight percentages with respect to tensile strength.

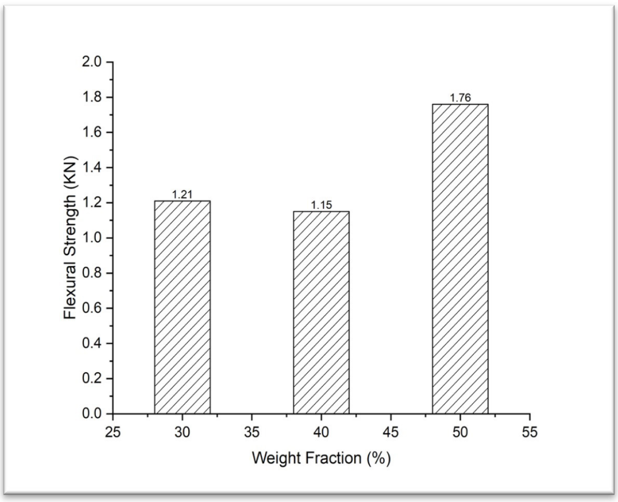

Figure 5: Shows the effect of varying fiber weight percentages with respect to flexural strength.

Up until the impact samples shattered, the impact test was conducted. Figure 6 displays the impact strength findings for different weight percentages of fiber and epoxy before and after. As the proportion of fiber grew from 30 to 50 wt%, the impact strength produced by the various specimens increased by 4 to 6 J. As a result of the effective stress transference between the fiber and matrix and the superior fiber distribution, the test results show that the impact strength grew linearly up to 40% in reinforcement as shown in figure 7. Over 40% fiber loading results in a significant rise in fiber-to-fiber contact, which reduces impact strength and causes fiber breaking within the composite. *Strychnos nux-vomica* has a toughening effect and a maximum impact strength of 6 J at a fiber loading of 40%. This finding demonstrates improved interfacial bond strength between the matrix material and the *Strychnos nux-vomica* fiber, which is supported by the composite's ability to absorb more energy during impact fracture.

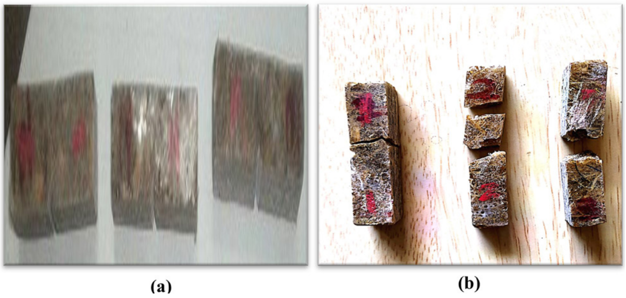

Figure 6: Izod test specimen **(a)** before testing and **(b)** after the testing.

Conclusion

In this present work, fabrication of *Strychnos nux-vomica* fiber and epoxy matrix of hybrid composite materials were prepared with three various specimens (i.e., 30:70, 40: 60, and 50:50 fiber/matrix weight ratio). From the above three specimens, it was found that better mechanical properties results were obtained for the third specimen 50:50. The mechanical properties of specimen 3 have the highest tensile strength of 14.93 MPa, flexural load of 1.76 KN, and impact energy of 4 J, respectively. These prepared composite materials can be used in automotive applications.

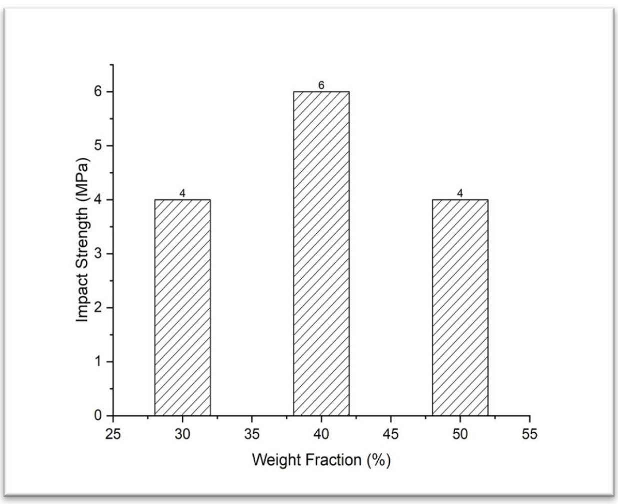

Figure 7: Shows the effect of varying fiber weight percentages with respect to impact strength.

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Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Credit Author Statement

Sasi Kumar M: Conceptualization, Methodology; Makeshkumar M: Project administration, Supervision, Writing - original draft preparation; Surender S R: Resources, Investigation, Writing - original draft preparation; Suganya Priyadharshini G: Visualization, Software; Vembarasan E: Formal analysis, Validation; Hari Prasath V: Data curation. All the authors read and approved the manuscript.

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