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Mechanical Properties of Luffa Fiber and Ground nut Reinforced Epoxy Polymer Hybrid Composites

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Abstract

This paper presents the study of the tensile, compressive, flexural, impact energy and water absorption characteristics of the luffa fiber and Ground nut reinforced epoxy polymer hybrid composites. Luffa fiber and Ground nut reinforced epoxy resin matrix composites have been developed by hand lay-up technique with luffa fiber treated conditions and Ground nut with different volume fraction of fibers as in 1:1 ratio (10%, 20%, 30%, 40% and 50%). Effects of volume fraction on the Tensile, Compressive, Flexural, Impact strength were studied. SEM analysis on the composite materials was performed. Tensile strength varies from 10.35 MPa to 19.31 MPa, compressive strength varies from 26.66 MPa to 52.22 MPa, flexural strength varies from 35.75 MPa to 58.95 MPa and impact energy varies from 0.6 Joules to 1.3 Joules, as a function of fiber volume fraction. The optimum mechanical properties were obtained at 40% of fiber volume fraction of treated fiber composites. Fractures surface of the composite shows the pull out and de-bonding of fiber is occurred.

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Keywords: Mechanical properties; volume of fraction; Luffa/Ground nut fiber; SEM Analysis

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1. Introduction

In today's scenario, there is an increasing need for eco-friendly materials with relatively high strength to weight ratio. FRPs reinforced with synthetic fibres are of high strength to weight ratios and become excellent substitutes for conventionally used high strength materials. The poor biodegradability of synthetic FRPs is a serious issue, as of today. Natural fibre reinforced FRPs can solve both the performance and environment related issues. Murali et al. [1] carried out a research to study the possibilities of introducing new natural fibers as fillers in a polymeric matrix, to develop economic and light weight structural materials. Later, techniques for extraction of fibres from plants like vakka (Roystonea regia), date and bamboo fibers were developed by researchers. The density and tensile properties of these fibers were almost as good as those of established fibers like sisal, banana, coconut and palm. Mechanical properties of coconut spathe and coconut spathe-fiber reinforced epoxy composites were studied by Sapuan et al. [2] and their potential to become successful materials in engineering applications was quantified. Tensile strength and flexural strength for the coconut spathe-fiber-reinforced composite laminates ranged from 7.9 MPa to 11.6 MPa and 25.6 MPa to 67.2 MPa respectively. These values were lesser compared to that of composites made from cotton fibre, coconut coir and banana fiber. The coconut spathe-fiber-reinforced composite laminates with chemically treated fibres showed good fibre marix adhesion and hence better mechanical properties.

Many researchers developed composites containing both natural and synthetic fillers and these materials were termed as hybrid composites. The hybrid composites showed better impact and compressive properties than mono-filler FRPs [3-4]. The mechanical properties of short random oil palm fiber reinforced epoxy (OPF/epoxy) composites were studied by Mohd zuhri et al [5]. In their study, composite plates with different volume fractions (5, 10, 15 and 20 vol%) of oil palm fiber were fabricated by hand-layup technique. The tensile and flexural properties showed inverse variation with fibre loading. The maximum tensile strength values were obtained for the sample with 5 vol% fraction of fibres and beyond that there was no significant change. From this research, it is obvious that oil palm fibre is not suitable for structural applications. Mansour Rokbi et al. [6] analysed the influence of alkaline treatments on the flexural properties of Alfa fibre to determine the optimum conditions for alkaline treatment. The experimental results obtained from a treatment with 10% NaOH in 24h, showed improvement in the flexural strength and flexural modulus, from 23 MPa to 57 MPa and from 1.16 GPa to 3.04 GPa respectively.

Naga prasad Naidu et al. [7] presented the tensile and flexural strengths of Glass-sisal polyester hybrid composites. Tensile strength and flexural strength for the composite laminates were about 12.35 MPa and 53.46 MPa. Lassaad Ghali et al. [8] found that the luffa fiber weight fraction influenced the flexural properties of polyester composites. The maximum values of strength and strain were reported at 10% weight fraction of fiber. Boyand et al. [9] studied an effect of alkali treatment of sponge gourd (luffa cylindrica) fibers on the flexural properties of polyester matrix composites. Experiment results showed an increase of flexural strength by 14%. Girisha et al. [10] fabricated composites consisting of reinforcement in the hybrid combination such as sisal-coconut spathe, sisal-ridge gourd and coconut spathe-ridge gourd with fibers varying from 5% to 30 Wt%. The tensile strength reached a maximum value of 22 MPa at 25% weight fraction of fibers. This result explained that the incorporation of different natural fibres (instead of a synthetic and a natural fibre) as reinforcements is also a very practical approach. The tensile and compressive properties such as strength and modulus of fibrous composites decreased with increase in angle of fibres from 0° to 90° [11]. Raju et al. [12] prepared the composite with different weight % of randomly distributed groundnut shell in polymer matrix. The addition of the ground nut shell to the polymer composites results reduced thermal conductivity and increases the glass transition temperature of the composites. The scarcity of literature on morphologically different natural reinforced composites directs us towards the development of luffa-ground nut shell–epoxy hybrid composite. In this work, epoxy based polymer composites were prepared with single luffa fiber and ground nut fibre as the reinforcing materials. The tensile, compressive, impact and flexural tests and SEM analysis of fractured surfaces of the composite were performed and are discussed in detail.

2. Experimental

2.1. Materials

The raw materials involved in the fabrication were Epoxy resin LY 556, Luffa Fiber, Ground nut shell, Hardener HY951, and Mansion Wax. Luffa fiber and ground nut are randomly oriented in polymer matrix. Samples are to be prepared with alkali treated fibers. Luff and ground nut shell were alkali-treated in 2% NaOH solution for 30 min to remove any greasy material and hemi cellulose, and then dried in sun light. The single fiber was used in making the luffa fiber and ground nut epoxy composite.

2.2. Material Preparation

Luffa cylindrica (LC) is a tropical plant belonging to the family of Cucurbitacea, The fruit of this plant has a vascular system with a fibrous arrangement [9]. Raw luffa fibers were cut lengthwise and the middle part was removed. Finally the fiber was cut to 10mm to 20mm long segments as shown in figure 1. The Botanical name of the groundnut is Arachis hypogeal which belongs to Leguminosae family, as shown in fig. 2(a) and 2(b). Groundnut shell is protecting cover of the pod is also known as a seed, former one having higher mechanical properties. The reported average length, thickness and density of the groundnut shell were 38 mm, 0.25 mm and 1.06g/cm^3 respectively [12].

Fig. 1 The rectangular portion of Luffa fiber

Fig 2 (a) Ground nut fiber

Fig 2 (b) Ground nut cylindrical shell

2.3. Volume fraction of fiber and Orientation of fibers

The composites were fabricated with 10%, 20%, 30%, 40% and 50% fiber and ground nut shell in the ratio of 1:1 as in volume fractions. The treated fibers were taken with required volume fractions laid into the mold of same size 300 mm x 300 mm x 5 mm and care is taken to ensure that the fibers are pressed to form the size of the mold. Then the top mold is closed and bolts are tightened. Then the mold is transferred to a compression press and placed under pressure for about an hour such that it compresses and forms a thin laminate shape. Orientation is termed as the alignment of fiber in the mould along with the resin mix. This also defines the properties of composites to be fabricated. In this work, the discontinuous fiber mat has oriented in longitudinal axis and discontinuous single fiber materials are in random orientation.

3. Fabrication process

Considering factors such as type of reinforcement and matrix materials, size, shape, quantity and cost, there are many specialized processes available. The most commonly used process is the hand layup method. The set-up for hand lay-up technique is shown in figure 3. The mould used for the composite is made of mild steel with stainless sheet placed in the inner surface. A de-bonding agent (mansion wax) is applied before curing of resin on the stainless sheet and the composite specimen is casted in the mould. The inner cavity dimension of the mould is 300mm x 300mm x 5mm. The hand lay-up method is a simple and the most widely used for FRP fabrication process. This process comprises of applying resin on the either side of natural fibre knitted pad with usage simple tools brush and roller. The fiber is arranged in discontinuous method in the steel plate and it is compressed by the help of bolt. After 15 minutes the bolt are released and the mat form fiber is taken out carefully without any damage. The fiber are arranged in such a way that there is no gap in-between the fiber, If there is any gap in the fiber arrangement the resin is filled by the gap so as to manage the strength. Measure the weight of the fiber using weighing scale. Then 1:5 of resin and hardener is added and mixed using the jar. Then the steel plate was cleaned with acetone and wax is applied in the inner side of the plate finally resin is poured and steel plate was compressed by tighten the bolt and nut. After 24 hrs the bolt was released and the laminates are taken carefully without any damage. Specimens are cut for testing as per ASTM standards.

Fig. 3 Preparation of the composite

4. Characterizations of composite materials

4.1. Determination of Water Absorption behaviour of Composite

The water absorption characteristics of luffa fibre and Ground nut reinforced polymer composite were studied by immersion in distilled water at room temperature for 12, 24, 48, 72 hours. The test specimen size (5 mm x 5 mm) is prepared as per ASTM D-570 for water absorption test. Edges of the sample were sealed with polyester resin. Samples were dried for 24 hours at 50^{O}C. After 24 hours samples were weighed accurately. Sealed samples were then immersed in distilled water at room temperature for 12, 24, 48, 72 hours. Samples were taken out of water after appropriate time and wiped with a tissue paper to remove surface water. The moisture absorption in the composite was measured by weighing the material in periodic intervals [13-14]. The ratio of increase in mass of the specimen to the initial mass gives as the percentage moisture absorption.

4.2. Tensile and compressive test

The tensile tests were conducted according to ASTM D 3039-76 standard on a computerized Universal Testing Machine. The loading arrangement for the specimen and the photograph of the machine used are shown in figure 4. The specimens with dimensions of length 300mm and width 25 mm were used. The test was conducted at a crosshead speed of 5 mm/min using 10 kg load cell. In each case, 3 samples were used and the average values were reported. The compressive strength is usually obtained experimentally by means of a compressive test with using UTM.

Fig. 4 UTM machine Sample loaded condition for tensile testing

Fig. 5 UTM machine Sample loaded condition for Flexural testing.

4.3. Flexural and Impact Test

Flexural strength of the composites was determined from the three point bend technique. It can be carried out in the modified UTM machine in accordance with ASTM D790-03. The loading arrangement for the specimen and the photograph of the machine used are shown in figure 5. All the composite specimens were of rectangular shape having length 80mm x 15mm x 5mm. Experiments were conducted at a cross head speed of 0.5 mm/min. Then flexural strength was calculated using simple bending moment diagram of simply supported beam at central point load. The impact strength values were calculated by charpy impact test using specimens of dimension

65mm x 12mm x 5mm.

4.4. Scanning electron microscopy (SEM)

The morphological characterization of the composite fracture surface was carried out using SEM. The samples were gold sputter coated to improve electrical conductivity.

5. Results and discussion

5.1. Water Absorption behaviour of Composite

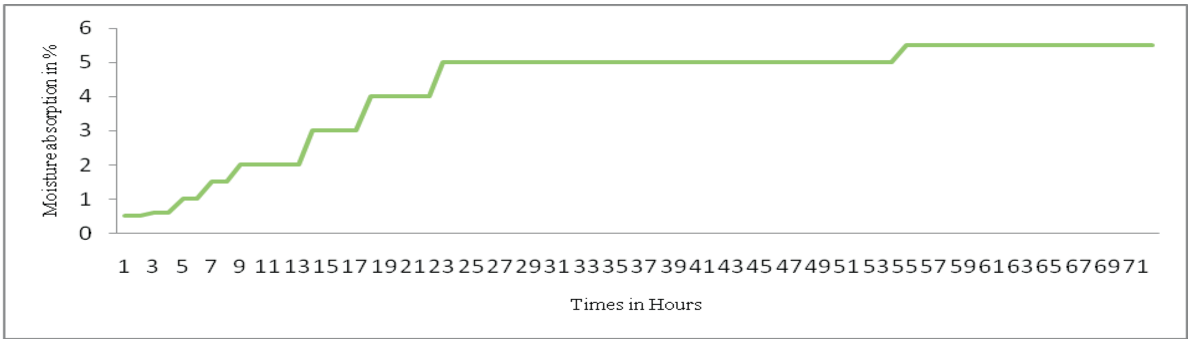

Fig.6 Water Absorption behaviour of Luffa with groundnut Composite

Water absorption is one of the major concerns in using natural fibre composites in many applications. The water absorption in hybrid composites in 24 hours, maximum and minimum water uptake was shown in the fig. 6. Water absorption after 10 hrs increases at the rate of 1% - 5.5%.

5.2. Impact strength

The variation of impact strength with the fibre content, in case of ground nut fiber composite is presented in figure 7. In this case, the ground nut fiber-luffa composites exhibited better impact properties. The impact strength increases with increasing volume fraction of fibres, reaching a maximum value at 30%. Beyond 30%, the impact strength shows a decreasing trend. The maximum impact strength of the composites varies between 0.6 Joules to 1.3 Joules. Alkali treated luffa fibers and groundnut shells showed improved impact strength. This result was in line with the findings of Varada Rajulu et al [15] and Ramachandra reddy et al [16]. They have carried out the research on characterization of bamboo composites.

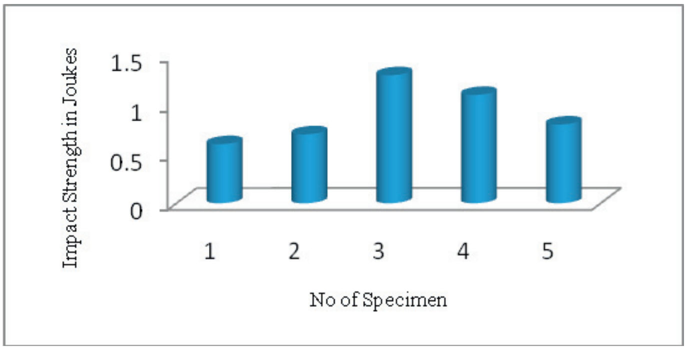

Fig. 7 Impact Strength

5.3. Compressive strength

The variation of compressive strength with the fiber content on the alkali treated composites is shown in figure 8. The luffa-ground nut fiber composite material was tested and the compressive strength was calculated. Three specimens were tested, with different fiber volume fractions and average compressive strength was reported. The compressive strength was increasing steadily upto 30% and beyond that the change was very marginal. The compressive strength of the luffa with ground nut fiber varies from 26.66 MPa to 52.22 MPa.

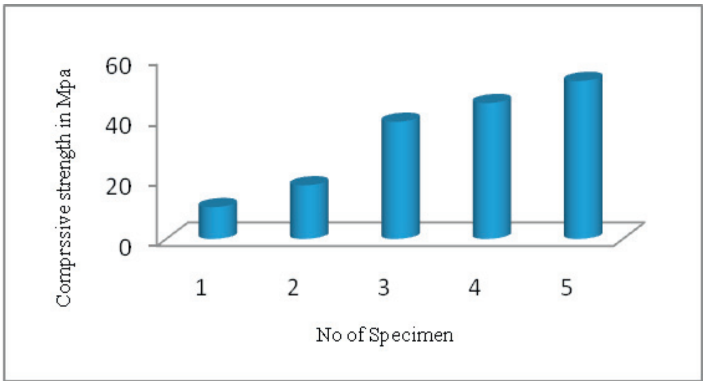

Fig. 8 Compressive Strength

5.4. Tensile and Flexural strength

Fiber content and fiber strength are influencing parameters for the strength related properties of the composite. Hence the strength variation with different volume fractions of fibre loading showed differently. This variation in tensile and flexural strength of the composites with 10%, 20%, 30%, 40% and 50% of fibre content are shown in figures 9 and 10 respectively. These figures clearly indicate the gradual increase in both tensile strength and flexural strength for 30% and 40% fibre content. However there is a decrease in both tensile and flexural strength of the composite with 50% fibre content. Similar observations were reported by Noorunisa Khanam et al. [17]. They have experimented with Sisal/Silk reinforced hybrid poly-ether-ketone composite.

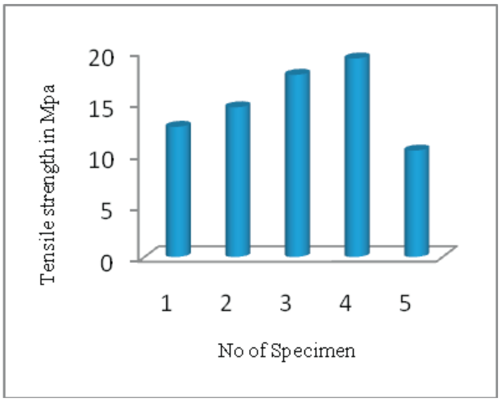

Fig. 9 Tensile Strength

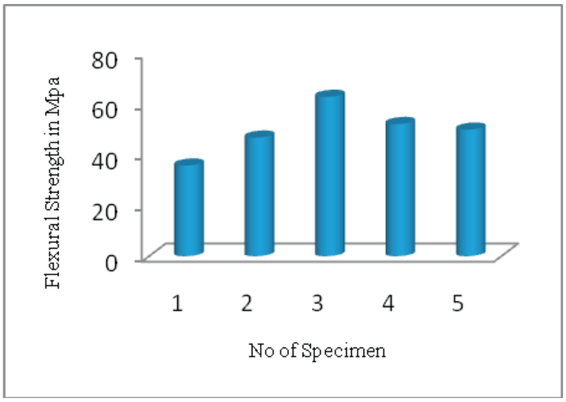

Fig. 10 Flexural Strength

5.5. Morphology Test on Cross Sections of Fractured Surface

The analysis of the micrographs of the composites prepared under the fractography of alkali treated luffa fiber and groundnut reinforced polymer composites are presented in figure 11. These fractography were recorded at two different regions at x35 and x300 magnifications. From these micrographs, it is clearly evident that the surface of the fibers becomes rough after alkali treatment. The elimination of hemi-cellulose from the surface of the luffa fiber may be responsible for the roughening of the surface. As a result of improvement in fibre matrix adhesion, fiber pull out is reduced.

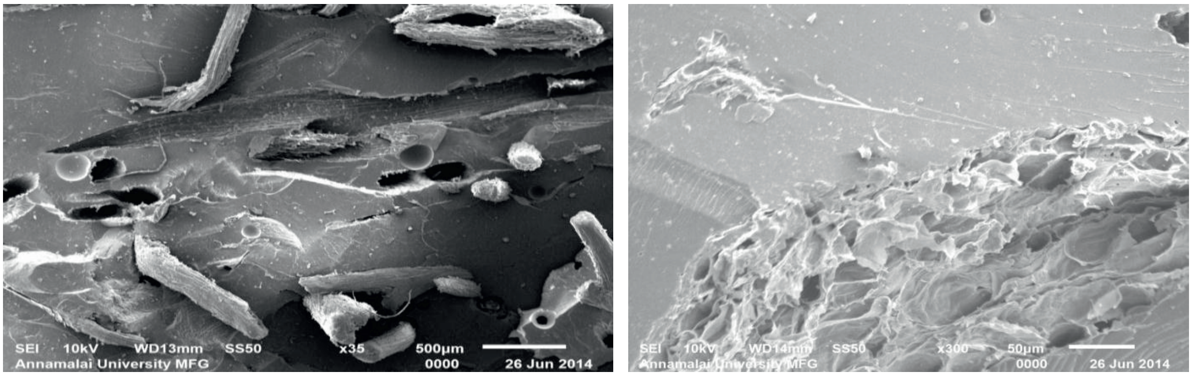

Fig. 11 SEM image of impact fractured surface of Luffa and Ground nut composites

5.6. Comparison for mono poly with hybrid polymer composites

It clearly shows that luffa with groundnut polymer exhibited higher mechanical properties when compared to luffa polymer composites. These figures clearly indicate that there is a marginal increase in tensile, flexural, compressive and impact strength of 30% and 40% volume fractions of fibers.

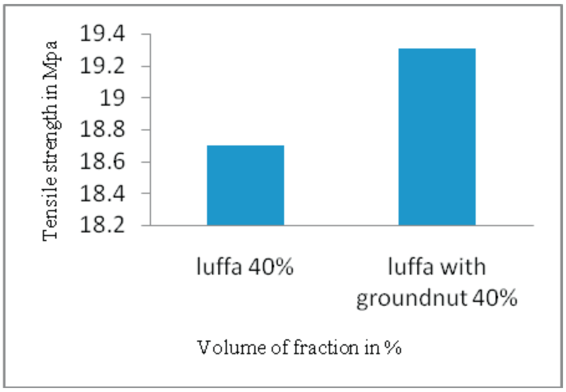

Fig. 12 Tensile strength for luffa

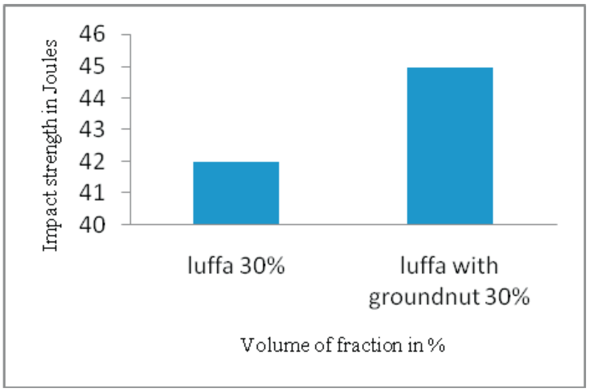

Fig. 13 Impact strength for luffa

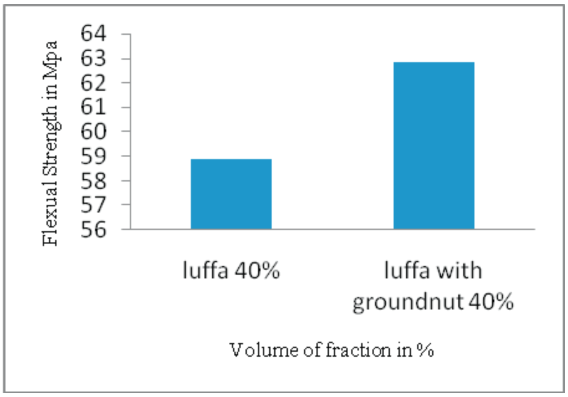

Fig. 14 Flexural strength for luffa

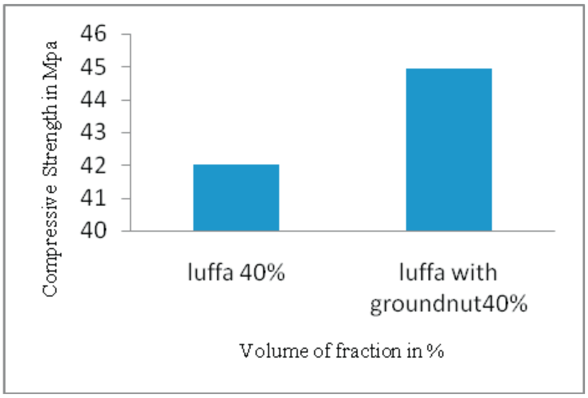

Fig. 15 Compressive strength for luffa

6. Conclusion

The variation of compressive, impact, tensile and flexural properties of the luffa fiber and groundnut reinforced epoxy polymer hybrid composites for 10%, 20%, 30%, 40%, and 50% fibers content were studied as a function of alkali treatment. It is reported that composites having 40% treated fiber content exhibited higher values for the fore mentioned properties than luffa groundnut fiber polymer composites with 30% and 50% fibre contents. The mechanical property values of luffa – groundnut reinforced composite were slightly higher than that of luffa fibre reinforced composite. After the alkali treatment, it was found that, treated composites possessed higher values of aforementioned mechanical properties because the alkali treatment improves the adhesive characteristics of the surface of the luffa fibers and groundnut by removal of hemicelluloses, waxes, impurities and lignin from the fibers.

In the present work, it was found that optimum values and significant improvements were at 40% treated fiber reinforced composites. The morphology of fractured surface observed by SEM suggests that the networking of structure restricts the pull out of fiber, which is responsible for higher mechanical properties for 40 % fiber content. The decrease in strength at 50% fiber content is due to insufficient wetting of fiber with the matrix.

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