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Research paper

Studies on mechanical properties of luffa acutangula/lignite fly ash reinforced composites

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Abstract

The demand of using natural fibers in various applications were increasing day by day due to its eco friendly nature over the artificial fiber based polymer matrix composites. This paper describes the fabrication and evaluation of mechanical and thermal properties of Luffa Acutangula fiber with and without Lignite Fly Ash. The lignite fly ash was added as a filler material in the ratio of 0, 0.5, 1, 1.5, percent of weight along with the matrix and fiber. The laminates were fabricated using hand layup technique and the samples were prepared based on ASTM standards for testings.The tensile test was performed using universal testing machine. The addition of filler lignite fly ash has shown the improvement in mechanical and thermal properties of laminated composites. The Tensile, flexural, and compression test was conducted for the fabricated samples and it was observed that the influence of lignite fly ash on natural fiber leads to the increase in tensile strength and compressive strength but the flexural strength was reduced for the fabricated laminates with the filler material lignite fly ash. The morphological analysis was carried out for finding the fractured surface and material failures using scanning electron microscope (SEM).

***Keywords**: Luffa acutangula, lignite Fly Ash (LFA), scanning electron micro scope, mechanical properties.*

1. Introduction

Now a days the natural fiber composites were widely used in many applications due to its specific properties like lowcost, lowdensity, biodegradable, ecofriendly and easy availability of natural fibers.The natural fibres, like coir,sisal, jute,banana,flax and bamboo was widely used as reinforcement materials in polymer matrix composites.[2].Due to its specific properties like low density to weight ratio and low cost it can be used as potentional reinforcements instead of synthetic fibers in polymer matrix composites. Luffa Acutangula (Brazilian sponge gourds) is from curcubitacea family, and is commonly found in Asian, Central and South America Luffa Acutangula fiber presents some advantages when compared to others tropical fibers like sisal, banana fibers etc.The ripe fruit is in the form of 3D mat like structure and the fibers were arranged multidirectionally as array like structure which represents in the form of an inner fibre core and an outer mat core[1].The hydrophilic nature of fiber and hydrophobic nature of matrix affects the bonding between the fiber and the matrix. The weak fiber/matrix interface reduces the reinforcing efficiency of the fiber and also it reduces the stress transfer from the matrix to load bearing fibers. The mechanical properties of natural fiber-reinforced composites mainly depends on the degree of bonding between the natural fiber and the matrix.[6].Chemical treatments on natural fiber composites was the mostly used method for improving the mechanical properties of the natural fiber laminates. Other methods employed for improving the strength of natural fiber composites was the addition of filler materials along with the fiber and matrix. In this work we used lignite fly ash as a filler material for improving the strength of polymer matrix composites. The addition of fillers with polymers is to improve the processing properties like stiffness and strength of polymer matrix composites. To overcome the limitations of polymers like low stiffness and low strength, the inorganic fillers such as Al_2O_3, SiO_2,TiO_2, clay, fly ash, graphite and short glass fiber were often used along with matrix and fibers to make polymer matrix composites **[**16]. Ashik K.P.et al have reported that filler makes changes in hardness, tensile and flexural strength of laminates. The tensile modulus increased with increase in the fiber and filler but the inter laminar shear strength increased only by increasing the fiber content and the inter laminar shear strength decreases with the addition of filler in polymer matrix composites.[10].Luffa Acutangula is having similar cellulose content with that of sisal and ramie fiber but lower than that of cotton fiber. The lignin and hemicellulose content of luffa fiber is higher than that of sisal, ramie and cotton fiber[7].The chemical composition of luffa Acutangula fibre mainly depends on several factors such as plant origin, weather condition and soil nature. The cellulose content varies from 55 to 90 wt%, the lignin content varies from 10 to 23 wt %, the hemicellulose content is around 8 to 22 wt%, extractives nearly 3.2 wt%, and ash 0.4 wt% [8]. The density of luffa fiber is around 0.82 to 0.92 g/cm^3 which is lower than the density of some common natural fibres like sisal (1.26 to 1.45 g/cm3), hemp (1.48 g/cm3) , coir (1.25 g/cm3), ramie (1.5g/cm3), and cotton (1.51 to 1.6 g/cm3) [9]. In this study we have developed a novel polymer matrix composite material and the effect of filler lignite fly ash with different proportions on Mechanical properties of luffa Acutangula fiber reinforced with epoxy polymer matrix composites was investigated.

2. Luffa acutangula

Luffa acutangula belongs to the family Cucurbitaceae and it is commercially used as vegetables in the form of unripe condition. Mature fruits are used as cleaning sponges. The cellulose content of luffa fiber varies from 55 to 90 wt%, the lignin content varies from 10 to 23wt%, hemi cellulose content varies from 8 to 22 wt% ,extractives nearly 3.2wt%, and ash 0.4 wt%, The density of luffa is around 0.82 to 0.92 g/cm^3.The luffa fiber was chopped to the length of 2mm with the help of diamond cutter.

Lignite fly ash

Fly ash is one of the residues formed after the combustion of coal.The particles of fly ash are generally spherical in shape and r size of the particle is in the range of 0.5 µm to 300 µm.Fly ash contains the chemical compositions like silicon dioxide and calcium oxide.The fly ash produced from thermal power plants were disposed in lands and ash ponds. Since it contains SiO_2 and CaO as chemical compositions so it is used as an filler in polymer matrix composites.

Epoxy resin and HY951 hardener

Epoxy resin has excellent adhesion with different materials it has high resistance to chemical attacks and also it has excellent mechanical and electrical properties.The hardner HY951 gives the best binding property with epoxy resin.

3. Fabrication process

The laminates were fabricated with the help of hand layup technique.First the fibres were chopped to the length of 2mm with diamond cutter and the chopped fibers were chemically treated with sodium hydroxide and acetic acid and dried in sunlight to remove the moisture present in it. The mould of size 300mm x 300 mm x 3mm dimension were used for the fabrication of laminates.At first the releasing agent was spread over the die for easy removal of laminates from the mould. The epoxy resin and the hardener mixture was completely mixed along with the filler and fibre for an effective binding. The resin hardener mixture luffa acutangula fiber, lignite fly ash is taken in the ratio of 90:10:0 for sample 1. For sample 2 the resin hardener mixture, luffa acutangula fiber and lignite fly ash is taken in the ratio of 90:9.5:0.5. For sample 3 the resin hardener mixture, the fiber and fly ash is taken in the ratio of 90:9:1.For sample 4 the resin hardener mixture, the fiber and the fly ah is taken in the ratio of 90:8.5:1.5. The roller is rolled over the laminates for the removal of air bubbles and also to spread the resin-hardener mixture with the fiber for the required dimension. Finally a uniform dead weight of 25 kg is placed over the die for 24h, to get the perfect shape and thickness. The specimens were exposed in sunlight for 24h after removing from the mould. After drying, the edges of the specimen were neatly cutted by using cutter as per the required dimensions.

Testing of composites

Tensile test

The specimens for tensile test was prepared based on ASTM standard D638-14. A universal testing machine is used to conduct the tensile test. The five samples from each laminates were tested. For each case the specimen is held between the grips and adjusted manually to apply force on the specimen. The initial load of 10KN was applied with the cross head speed of 5mm/min until the specimen breaks and breaking load and ultimate tensile strength were noted.

Compression test

The universal testing machine were used to conduct the Compression test on the fabricated samples. The specimen for Compression test was prepared with required dimensions based on ASTM: D695-15 standard. Five samples from each laminates were tested The compressive force was applied on the specimen with the cross speed of 3mm/Min .The breaking load and compressive strength was noted for all prepared samples.

Flexural test

The specimens were cut with required dimensions based on ASTM standard D790-15. This test was carried out with the help of universal testing machine. The three point bending test was followed and load was applied at the middle of the specimen.five samples from each laminates were tested. The load was increased until the specimen fails. The breaking load was noted for all the fabricated laminates.

Hardness test

The specimens for Hardness test was cut with required dimensions based on ASTM standard D785-08 and it was performed with Rockwell hardness testing machine. The load was applied on the specimen and then the load was removed after intentation.Five samples from each laminates were tested and the corresponding hardness values were noted for all laminated samples.

4.5 Morphological analysis

Fracture surfaces of fabricated laminates were studied using scanning electron microscope. All the specimens were coated with gold prior to testing.

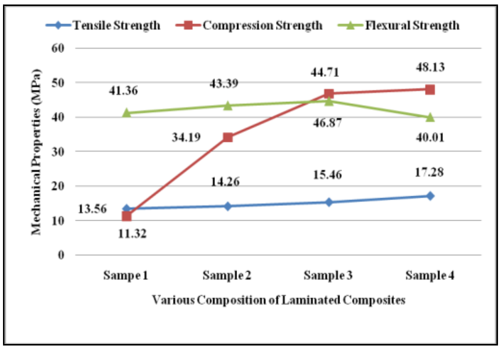
4. Results and discussions

Tensile strength

The table 1 shows the tensile strength of laminated composites from the above results, it is clear that tensile strength of sample 4 was increased due to the addition of lignite fly ash as compared with sample1 without the addition of lignite fly ash. The addition of fly ash along with luffa fiber increases the interfacial bonding between the matrix and fiber and their by increases the tensile strength of the laminated composites.

Table 1: Tensile and Compressive Strength of Composites

Specimen	Tensile Strength (Mpa)	Compression strength (Mpa)
Sample 1	13.56	11.32
Sample 2	14.26	34.19
Sample 3	15.46	46.87
Sample 4	1728	48.13



Graph 1: Mechanical properties of various laminated samples

Compression test

The table 1 shows the results of compressive strength of fabricated laminates.From the above results, it is clear that compressive strength of the composite 2 and 4 were increased with addition of lignite fly ash as compared with the sample without lignite fly ash. It is also found that sample 4 fibers with lignite fly ash are having highest compressive strength when compared to all laminated samples it may due to increase in interfacial bonding between the matrix and fibers.

Flexural properties

Flexural test was done on 4 different laminates and results were shown in table 2.

Table 2: Flexural Strength of Composites

Specimen	Flexural Strength (Mpa)
Sample 1	41.36
Sample 2	43.39
Sample 3	44.71
Sample 4	46.01

The flexural strength was increased to 41.36,43.39,44.71 and 46.01 Mpa during the addition of fly ash 0,0.5,1,1.5 wt%.the increase in flexural strength is mainly due to the addition of flyash and it may due to increase in chemical bonding between the fiber and matrix.

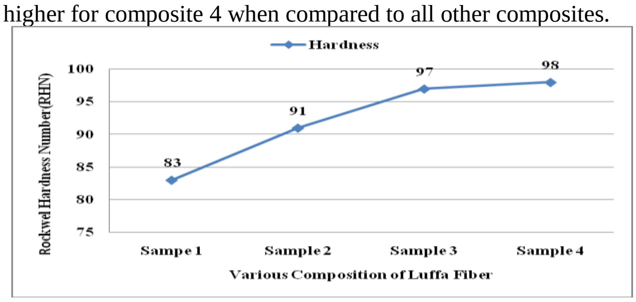
Hardness test

Hardness test is done in Rockwell hardness testing machine for 4 different composites and results are tabulated is shown in the table 3

Table 3: Hardness Value of the Composites

Specimen	Rockwell Hardness (RHN)
Sample 1	83
Sample 2	91
Sample 3	97
Sample 4	98

From the above results it is to be found that hardness value is higher for composite 4 when compared to all other composites.



Graph 2: Rockwell hardness values of various laminated samples

5. Morphological analysis using scanning electron microscope (SEM)

The morphological analysis of the tested composites was done by means of scanning electron microscope. The samples from tensile tests are studied using SEM. Each composite samples were coated with a layer of gold with thickness 15-20nm using an ion sputter device. The gold coated samples were analyzed using SEM.

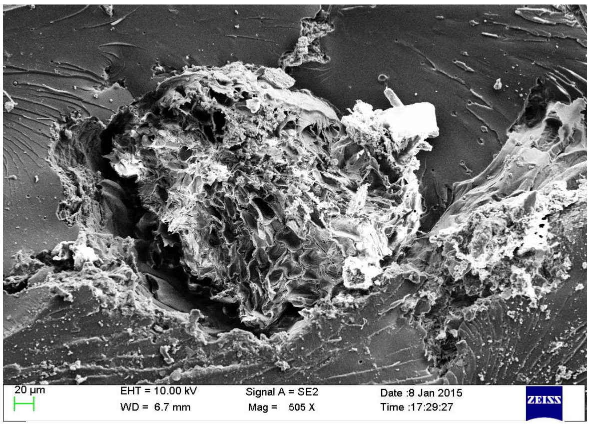


Fig. 1: SEM micrograph of tensile fracture surface of sample 1

Micrograph of fractured surface of sample 1 shows the fiber pulls out from the matrix due to failure.

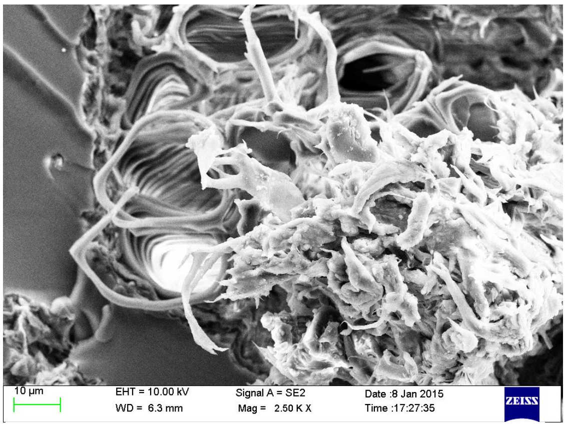


Fig. 2: SEM micrograph of tensile fracture surface of sample 2

Microstructure image of sample 2 is shown in figure 2.and the failure of samples is due to presence of voids in the fabricated laminates.

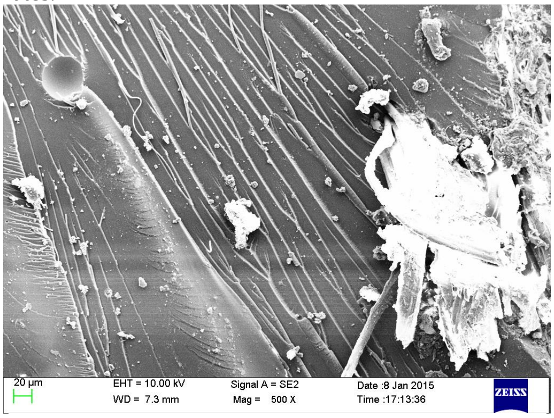


Fig. 3: SEM micrograph of tensile fracture surface of sample 3

Micrograph of sample 3 shown in figure 3.The failure is mainly due to improper bonding between the fibre and the matrix.

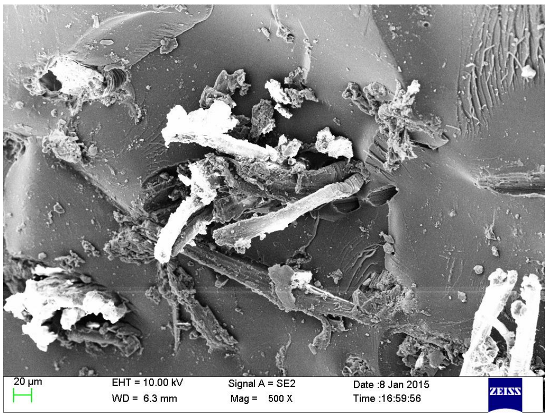


Fig. 4: SEM micrograph of tensile fracture surface of sample 4

Micrograph of sample 4 shown in figure 4 .The failure of sample 4 is mainly due to the presence of voids and improper mixing of fiber and fly ash.

6. Conclusion

The samples were prepared by adding with and without lignite fly ash along with fiber. Results showed that the addition of filler lignite fly ash increases the tensile strength of fabricated samples. Compressive strength of sample 4 is found be highest and the value is 48.13 Mpa compared to all other samples. Flexural strength of sample 4 is found to be highest and the value is 46.01 Mpa. Hardness value was found to be highest for sample 4 and the value is 98 RHN. The addition of fly ash increases the adhesion between the matrix and the reinforcement there by increases the stiffness of the fabricated laminates and there by increases the mechanical properties of the fabricated samples. Microstructure images taken at the breakage specimen shows that failure is due to the presence of voids and improper mixing of fibre and the matrix in the composite.

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