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Research Article

EXPERIMENTAL INVESTIGATION ON THE MECHANICAL PROPERTIES OF NATURAL FIBER REINFORCED POLYMER COMPOSITES

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ABSTRACT

The effect of fiber length on the mechanical properties of sisal fibre reinforced unsaturated polyester composite has been investigated. Sisal fiber was extracted from sisal leaves by water retting method. The fibers are chemically treated in 5% NaOH solution for 1 hour at room temperature. The composites are prepared by hand lay-up technique with random fiber orientations of different length (20mm, 35mm & 50mm) and constant volume fractions (10wt%). Computerized universal testing machine was used to test the tensile and flexural test, while izod impact testing machine was used for the impact test. Experimental results show that the tensile strength, flexural strength and impact strength are increased with increasing fiber length. The 50mm fiber length composite exhibited the maximum tensile strength, flexural strength and impact strength compared to the other fiber length used in the composites.

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INTRODUCTION

In recent years, natural fibers are used as reinforcement in thermoplastic and thermoset composite has increased due to their abundantly available, bio degradable, cheap, easy processing, eco-friendly, higher strength to weight ratio, light weight and no skin irritation (Asheesh Kumar *et al*, 2017; & Avinash R. Pai *et al*, 2015). Natural fibers can be classified according to their origin into three categories. They are plant fibers, animal fibers and mineral fibers. The plants, which produce cellulose fibers can be classified into bast or stem fibers (flax, hemp, isora, jute, kenaf, kudzu, mesta, nettle, okra, ramie, rattan, roselle, urena and wisteria), seed fibers (cotton, kapok, loofah and milkweed), leaf fibers (abaca, agave, banana, cantala, caroa, curaua, date palm, fique, henequen, istle, piassava, pineapple, raphia and sisal), fruit fibers (coir, oil palm and tamarind), stalk fibers (barley, maize, oat, rice, rye and wheat), grass and reed fibers (bagasse, bamboo, canary, corn, esparto, rape and sabai) and wood (soft wood and hard wood) (Mohd Nurazzi. N *et al*, 2017; Avinash R. Pai *et al*, 2015). The most used natural fibers are coir, flax, hemp, jute, kenaf and sisal. The native of sisal fiber was north and south america. The largest producers of sisal are antiqua, east africa, kenya, tanzania and india. The sisal fiber was extracted from the leaf using water retting method. This method is simple and economical, also this method produced high quality of fibers.

Chemical compositions such as cellulose, hemicellulose, lignin, ash, wax and moisture content vary with various natural fibers. Chemical composition of some natural fiber is shown in Table-1 (TP Sathishkumar *et al*, 2014). The chemical composition of natural fibers depends on various factors such as type of soil used, age of the plants, weather conditions, etc. The mechanical properties of the natural fibers mostly depend on the percentage of cellulose content present in chemical composition. The rich content of cellulose tends to improve the mechanical properties of the fibers. The low hemicellulose content tends to reduce the moisture absorption capacity of the fiber. The presence of lignin content acts as a bonding agent between the cell wall structures to improve the rigidity and strength of the fiber. The bonding strength of the fiber in matrix determines the wax content and ash content of the fibers. The low wax and ash content improves the properties of the composite materials. The main drawback of using natural fiber is their high level of moisture absorption, insufficient adhesion between untreated fibers and the polymer matrix (Asheesh Kumar *et al*, 2017; Layth Mohammed *et al*, 2015)

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Table 1 Chemical composition of some natural fibers

Name of the fiber	Cellulose (%)	Hemi cellulose (%)	Lignin (%)	Ash (%)	Wax (%)	Moisture (%)
coir	37	-	42	-	-	11.36
flax	64.1-71.9	16.7	2.0-2.2	-	1.7	8-12
hemp	70.2-74.4	17.9-22.4	3.7-5.7	0.8	0.8	6.2-12
jute	61-71.5	17.9-22.4	11.8-13	0.5-2	0.5	12.5-13.7
sisal	78	10	8	1	2.0	11

Chemical treatment of the natural fibers can clean the fiber surface, chemically modify the surface, decrease the moisture absorption process, increase the surface roughness and improve the bonding between matrix and fiber. The different kinds of chemical treatments used on natural fibers include acrylation, alkali, benzoylation, silane, peroxide, maleated coupling agents, permanganate, acrylonitrile and acetylation grafting, stearic acid, isocyanate, triazine, fatty acid derivate, sodium chloride and fungal (LaythMohammed *et al*, 2015). The most popular treatments are alkali, acetyl and silane. The alkali treatment is the most common method that is used for the treatment of natural fibre because this method is easy, inexpensive (low cost) and effective. The alkali treatment process has some critical parameters like types of alkali used (NaOH, KOH & LiOH), concentration of the solution, treatment duration and temperature. The types of alkali used, concentration of solution and treatment duration plays major role.

Polymer matrices are most commonly used because of cost efficiency, ease of fabricating complex parts with less tooling cost and also have excellent room temperature properties when compared to other matrices (SaravanaBavan. D *et al*, 2013). The important functions of polymer matrices are to bond fibers together and to transfer loads to the fibers. The polymer matrices can also provide a good surface finish to the composites and protect the fibers against chemical attack. Normally the polymers are divided into two groups depending on how it reacts to heat. Those are thermoplastics and thermo settings. Thermoplastics can be repeatedly softened by heating and hardened by cooling. Thermosetting plastics, however, harden permanently after being heated once. The most commonly used thermoplastics are polyamide (PA), polycarbonate (PC), polyethylene (PE), poly methyl methacrylate (PMMA), polypropylene (PP), polystyrene (PS), poly vinyl chloride (PVC), while epoxy, phenolic resin, polyester, polyurethane resin, polyvinyl ester, unsaturated polyester and urea formaldehyde are the commonly used thermo settings. Unsaturated polyester resins can be utilized in a wide range of manufacturing processes such as compression moulding, filament winding, hand lay-up process, injection moulding, pultrusion and resin transfer moulding. The advantages of unsaturated polyester are its dimensional stability, low cost, good range of mechanical properties, corrosion resistance and low weight (MohdNurazzi. N *et al*, 2017). The mechanical properties of natural fiber reinforced composite materials depend on many factors, such as percentage of fibre volume/loading, fiber length, size, shape, composition, orientation and distribution, as well as manufacturing process.

The natural fiber composites are used in various applications such as aircraft(e.g. pilot's cabin door, door shutters, flooring etc), automobiles (e.g. dash boards, door panels, head liners, seat backs, truck liners etc), railway coaches, marine field(e.g.

boat hulls, fishing rods etc.) military applications, sports(e.g. tennis rackets, bicycles frames, snowboards, sports helmets etc.), building and construction industry (e.g. walls, floor, ceiling, partition boards, roof tiles, window and doorframes etc), packaging, storage devices(e.g. bio-gas container, postboxes etc.), furniture(e.g. chair, table, shower, bath units etc.), electronic devices, toys, consumer products etc.

MATERIALS AND METHODS

Material

Sisal fibers are used as reinforcement in this experimental work. The unsaturated polyester resin is selected as the matrix. Methyl ethyl ketone peroxide (MEKP) and Cobalt naphthalene were used as catalyst and accelerator, respectively. Catalyst and accelerator were used to cure unsaturated polyester resin. The catalyst initiates the polymerization process and the accelerator speeds up this process. The resin, accelerator and catalyst were purchased from Covai Seenu & Co, Coimbatore, Tamil Nadu, India.

Extraction of Natural Fiber

Natural fibers are extracted by the following methods.

1. Water retting
2. Enzymatic retting
3. Dew retting
4. Mechanical retting
5. Chemical retting.

Water retting

The sisal leaves are cut from sisal plants (figure-1). After harvesting, sisal leaves are grouped in bundles. These bundles was immersed in water (river, pond or tank) until it becomes decay. This method required 2 to 3 weeks to degrade the hemicellulose, lignin etc. The period of retting depending upon the maturity of the crop at the time of harvesting and the temperature of water. The retted leafs were cleaned in running water and dried under sun light for one day.



Figure 1 Sisal leaf cut from sisal plant

Chemical Treatment

Alkaline treatment or mercerization is one of the most commonly used chemical treatments of natural fibers. Modifying natural fibers with alkali has greatly improved the mechanical properties of composites. 5% NaOH solution was prepared using sodium hydroxide pellets and distilled water. First of all sisal fibers were treated with 5% NaOH solution in a glass beaker for soaking time of 1 hour, at room temperature. After 1 hour sisal fibers were washed with distilled water to

remove the excess of NaOH sticking to the fibers. Treated sisal fibers were dried in sun light for two days. Then fibers were chopped to different fiber length (20mm, 35mm & 50mm).

Fabrication of Composite

Hand lay-up technique is the simplest method of fabrication of composite. A steel mold is used for preparing the test specimen and having dimension of 300mm x 300mm x 3mm. The wax was coated on the mould for easy removing and good surface finishing of the laminates. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. The unsaturated polyester resin is taken along with 2% each of catalyst-Methyl Ethyl Ketone Peroxide (MEKP) and accelerator- cobalt naphthenate. First the catalyst is added with resin and then the accelerator. Initial layer of the mould was filled with unsaturated polyester resin mixture and then sisal fibers were randomly spread over the resin mixture and rolled with hand roller. Again, resin mixture is poured on the sisal fibers and then pressed heavily for 5 hours before removal. Then, the top plastic sheet was removed from the mould and cured at ambient temperature for one day. After the curing process, test samples were cut according to the sizes of ASTM standards.

Mechanical Testing

The main objective is to determine three important mechanical properties of composite by conducting the following test. All tests were performed at room temperature. In each case, three samples were tested and average value tabulated. Mechanical testing was carried out at LMP R&D Laboratory, Near jeeva shed, Pallipalayam, Erode, Tamilnadu.

Tensile test

The tensile strength were determined according to ASTM D3039 standard. The test specimens were cut to a rectangle shape (250mm X 25mm X 3mm), and gauge length was 150 mm. Tensile tests were conducted using computerized universal testing machine. The speed of the crosshead was 2 mm/min. The tensile strength was reported in MPa.

Flexural test

Flexural strength was carried out at room temperature through three-point bend testing using computerized universal testing machine. The specimens were prepared according to ASTM D790 with dimension 127mm × 13mm × 3mm. The speed of the crosshead was 2 mm/min. The specimen was freely supported by a beam and the point load was applied in the middle of the specimen. The flexural strength was reported in MPa.

Impact test

Izod impact test unnotched specimens are prepared and the dimensions are (66mm x 13mm x 3mm) based on the ASTM D256 standards. The specimen was fixed on the slot and load is applied suddenly by swinging pendulum. The impact strength was reported in J/m.

RESULTS AND DISCUSSION

Tensile Test

The tensile strength is defined as the maximum tensile load that a body can withstand before failure, divided by its cross

sectional area. This property is also sometime referred to ultimate tensile stress. Figure-2 shows the effect of varying fiber length (20mm, 35mm & 50mm) on the tensile strength of the sisal fiber polymer composite. This is the result obtained whereby the tensile strength increased with increased fiber length from 20mm to 50mm. The tensile strength of 50mm length of fiber composite were found maximum value of 14.63MPa as compared to other composites. The longer fiber would generate greater bonding capacity between the fiber matrixes. Generally, the thermoset composites show that the trend of the mechanical properties of their increases depending on the length of fiber. AhmetÇağrıKılınç *et al* (2016), whose work was on Production and Characterization of Althea Officinalis L. Fiber Reinforced Polyester Composites reported similar behaviour. Nine althea fiber reinforced unsaturated polyester composite samples with different combinations of fibre length (10, 30 and 50 mm) and fibre weight fractions (5, 10and 20 wt%) were prepared. The maximum tensile strength was observed from 50mm fiber length composite samples for all fiber weights. Similarly, Maya M.G *et al* (2017) investigated the Mechanical Properties of Short Sisal Fibre Reinforced Phenol Formaldehyde Eco-Friendly Composites. The sisal fibre Phenol Formaldehyde resin composites were prepared with different fiber length (10,20,30,40& 50mm). The tensile strength of short sisal fiber composites is increasing with increase of fiber length up to 50mm. Effect of Fiber Length and Fiber Weight Ratio on Tensile Properties of Sun hemp and Palmyra Fiber Reinforced Polyester Composites were studied by B. M. Dabade *et al* (2006). These composites are prepared with varied fiber lengths and varied fiber weight ratios. Various fiber lengths used here are 10, 20, 30, 40, 50, and 70 mm. Fiber weight ratios range from 1 to 70%. The tensile strength of Palmyra reinforced composites is increasing with increase of fiber length up to 50mm after which it is decreasing.

Table 2 Mechanical test results

S.No	Fiber length(mm)	Tensile strength(MPa)	Flexural strength(MPa)	Impact strength(J/m)
1	20	11.41	26.74	50.00
2	35	13.78	34.14	58.33
3	50	14.63	43.02	75.00

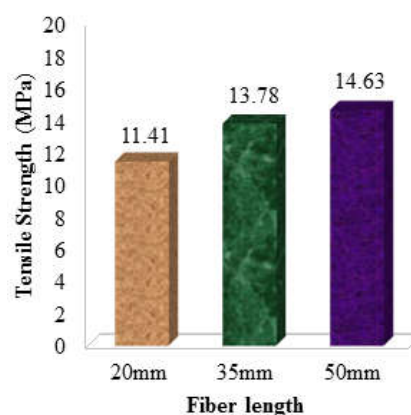


Figure 2 Tensile Strength

Flexural test

Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. Table-2 and figure-3 presents the effect of varying fiber length

on the flexural strength of the sisal fiber composite. The result of the test showed that the 50mm fiber length composite has the highest flexural strength value of 43.02MPa as compared to other composites. The longest fiber needs the highest force to release the bond of matrix and fiber. Flexural strength of the fiber with 20mm, 35mm and 50mm are 26.74MPa, 34.11MPa and 43.02MPa respectively. This is similar to the findings of Lourdh *et al* (2014) that have conducted a study on Mechanical Behavior of Surroundings Friendly Compression Wrought Random and Woven natural Fiber Polyester Composite. The composite preparation is done using polyester resin mixed with random orientation of the fibre of lengths 20,30,40 and 50mm to a weight of 21,28,31,35,42 and 45 grams. The flexural strength is increasing from 20mm length of fibre up to 50mm for almost all the fibre weights. In another research done by S.Velumani *et al* (2013) Optimization of mechanical properties of non-woven short sisal fibre-reinforced vinyl ester composite using factorial design and GA method were studied. Untreated short sisal fibre reinforced vinyl ester polymer composites were prepared with fiber lengths of 10, 30 and 50 mm and fibre content of 15, 30 and 45 wt%. The maximum flexural strength was found at 50 mm in fiber length for all the fiber content. Moreover, AhmetÇağrıKılınç *et al* (2016) reinforced althea fiber in unsaturated polyester resin to make composites and investigated. It was found that 50mm althea fiber reinforced polyester composite exhibited the highest flexural strength than 10mm and 30mm length of fiber composites.

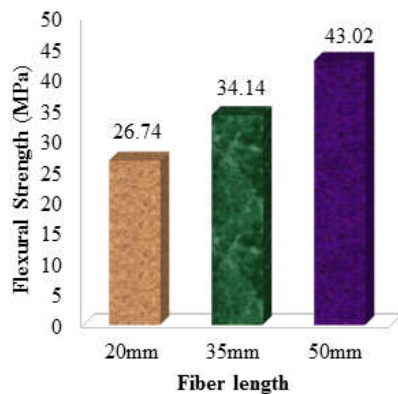


Figure 3 Flexural Strength

Impact test

The impact properties of the material are directly related to the overall toughness which is defined as the ability to absorb applied energy. The impact strength values of different composites recorded during the impact tests are given in Table-2. Figure-4 shows chart of impact strength of composites against the fiber length. It can be seen from figure-4, impact strength increases with increasing length. The impact strength of 50mm length of fiber were found maximum compare to other all the composites. Similar result was reported by ImranMusanif *et al.* (2018) on Effect of Fiber Length Against Hardness And Composite Impact Coconut Fiber - Polyester Resin. The composites are prepared with random fiber orientations of different length(10, 20, 30, 40 & 50mm)and volume fractions(30, 40 & 50%). He reported the impact strength of composites is increasing with increase of fiber length up to 50mm. Maya M.G *et al* (2017) tested the Mechanical Properties of Short Sisal Fibre Reinforced Phenol Formaldehyde Eco-Friendly Composites at different length (10, 20, 30,40 & 50mm) of fiber. Increasing the length in the

composite materials will increase the impact strength. The greatest impact strength was achieved on fiber length composition of 50 mm. S.Velumani *et al* (2013) study the Optimization of mechanical properties of non-woven short sisal fibre-reinforced vinyl ester composite using factorial design and GA method. Composites with different fibre length (10, 30 & 50mm) and loading (15, 30 & 45 wt%) were prepared and properties were evaluated. The maximum impact strength are observed at 50 mm fibre length of composites.

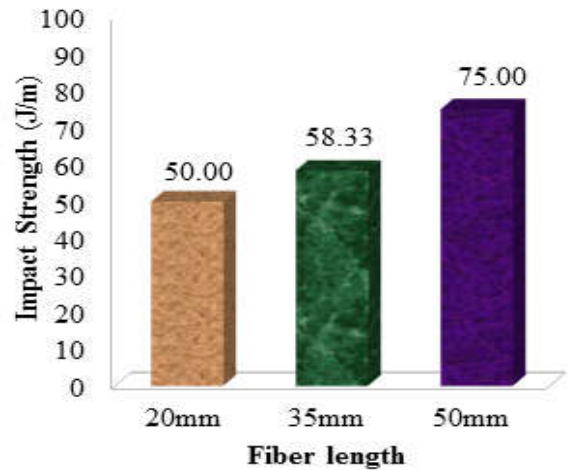


Figure 4 Impact Strength

CONCLUSION

Sisal fiber reinforced unsaturated polyester composites were investigated by tensile, flexural and impact tests. It was concluded that tensile, flexural and impact strengths were increased with increasing fiber lengths.

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