International Journal of Scientific Research in Science, Engineering and Technology
Print ISSN: 2395-1990 | Online ISSN : 2394-4099 (www.ijsrset.com)
doi : https://doi.org/10.32628/IJSRSET229272

The Effect of Fiber Length on Mechanical Properties of Unsaturated Polyester Composites Reinforced by the Fibers of Sisal

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Article Info
Volume 9, Issue 3
Page Number : 14-20
Publication Issue :
May-June-2022
Article History
Accepted : 01 May 2022
Published: 05 May 2022

ABSTRACT

In this research work, sisal fiber with random oriented reinforced unsaturated polyester resin composite was developed by hand lay-up technique with four different fiber lengths (20, 30, 40 & 50mm). The tensile strength, flexural strength and impact strength of the composites were determined as per ASTM standards. 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.

Keywords : Sisal fiber, unsaturated polyester, fiber length, sisal fiber polymer composite, mechanical properties.

I. INTRODUCTION

Composites are combination of two materials in which one of the material is called as the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other material called the matrix. Matrix surrounds the fibers, acting as load transferring medium and thus protecting those fibers against chemical and environmental attack. Today's, the development of polymer composites by reinforcing natural fibers has attracted attention of researchers, engineers and scientists. The various advantages of natural fibers are absence of health hazards, biodegradability, easy availability, easy collection, good thermal properties, high strength to weight ratio, low density per unit volume, low cost, less abrasion to processing equipment, non-corrosive nature, non-irritation to the skin and renewability [1]. 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) [2]. Nowadays, the most commonly used natural fibers as reinforcing agents in polymer composites are banana, coir, flax, hemp, jute, kenaf, sisal and roselle fibers. The main concept of reinforcing the polymer with natural fibers is to enhance the properties of the polymers. The detail information of fibers and the countries of origin are given in Table-1.

Table-1: Fibers and countries of origin

Fibers	*Countries of origin*
Abaca	*Philippines, Bolivia, Malaysia, Uganda*
Coir	*India, Sri Lanka, Philippines, Malaysia*
Jute	*India, Egypt, Guyana, Jamaica, Ghana, Malawi, Sudan, Tanzania*
Kenaf	*Iraq, Tanzania, Jamaica, South Africa, Cuba, Togo*
Roselle	*Borneo, Guyana, Malaysia, Sri Lanka, Togo, Indonesia, Tanzania*
Sisal	*East Africa, Bahamas, Antiqua, Kenya, Tanzania, India*
Sun Hemp	*Nigeria, Guyana, Siera Leone, India*

Polymer matrix composites can consist of either a thermoplastic or thermoset matrix, which is used to bind the reinforcing fibers together, as well as to transfer applied stresses from the composite to the fibers. Thermosets are plastics that cannot be melted once cured, and include resins such as epoxy, phenolic resin, polyurethane resin, polyvinyl ester and unsaturated polyester. Thermoplastics, on the other hand, are plastics that can be repeatedly melted, thus enabling them to be recycled. Commonly used thermoplastics include polypropylene, polyethylene and polyvinyl chloride. 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 density. Mechanical properties of natural fiber based polymer composites are influenced by many factors such as fibers volume fraction, fiber length, fiber aspect ratio, fiber-matrix adhesion, fiber orientation, etc.

The natural fiber composites can be very cost effective material for following applications:

- Building and construction industry: panels for partition and false ceiling, partition boards, wall, floor, window and door frames, etc
- Storage devices: post-boxes, grain storage silos, bio-gas containers, etc.
- Furniture: chair, table, shower, bath units, etc.
- Electric devices: electrical appliances, pipes, etc.
- Everyday applications: lampshades, suitcases, helmets, etc.
- Transportation: automobile and railway coach interior, boat, etc.

II. LITERATURE REVIEW

P. Kongkaew et al [3] investigated the effects of fiber length on mechanical properties of epoxy composites reinforced by the fibers of vetiver. Five different specimens were made by varying the length of the fiber 3, 5, 7, 9 and 13 mm at 12% wt. fiber loading using the hand lay-up method. The tensile strength, tensile modulus, flexural strength, flexural modulus and impact strength of the composite were investigated. Experimental results show that the tensile strength, tensile modulus and impact strength increased with increase fiber length.

Y.Sesha Rao et al [4]conducted experimental study on mechanical properties of carbon fiber–epoxy composites with different fiber lengths. Carbon fiber is took in the 3, 5, 7 % weight in order to suspend on epoxy resin with different fiber lengths such as 10, 20 and 30mm.The results are to be compared whether the fiber content in weight percentage and the length of fiber are influenced on the improvement of tensile, flexural, and micro structural properties.

B. Vinod et al [5] study the effect of fiber length on the mechanical properties of coir and wild date palm reinforced epoxy composites. The composite prepared by hand lay-up method by using the various fiber lengths (3, 6, 9, 12 and 15mm). From this experimental study, it was observed that the fiber length greatly influences the tensile properties of reinforced composites.

The effect of fiber length on tensile properties of sansevieria trifasciata fiber reinforced polyester composites were studied by Palla Hari Sankar et al [6]. The composite sample was fabricated with five different fiber lengths of STF (2, 4, 6, 8 and 10 mm). The fabrication was made by hand lay-up technique. Tensile properties were determined using tensile testing. The study reveals that the tensile strength increased with fiber length without effecting the elongation at break of the composite.

Himanshu Bisaria et al [7] investigated the effect of fibre length on mechanical properties of randomly oriented short jute fibre reinforced epoxy composite. The composite was prepared using Hand lay-up method with 30 wt. % of jute fibre in the various lengths of 5, 10, 15 and 20 mm into epoxy matrix. The results show that the tensile and flexural properties were found maximum for the composite with 15 mm length of fibre whereas the impact properties were found maximum for the composite with 20 mm length of fiber.

Ramesh G et al [8] studied the mechanical behavior of calotropis gigantean fiber epoxy composites. Using compression molding, samples of different fiber lengths (25, 50, 75, 100, 125,and 150 mm) with different fiber weight proportions (10%, 20%, 30%, 40%, and 50%) were made and subjected to tensile, fractural and impact tests. The author concluded that the maximum values of tensile, flexural and impact strength of 60.53 MPa, 121.09 MPa and 43.54 KJ/m^2 were observed for the specimen with a fiber length of 100 mm and fiber weight proportion 40%.

P.Senthilkumar et al [9] investigated the effect of chemical treatment on the tensile properties of sisal fiber reinforced epoxy composites. The fiber was treated with 3%, 6% and 9%NaOH solutions. Sisal fiber composites were fabricated by compression molding technique using both the untreated and treated fiber with constant length and volume of fiber. The experimental results show that the tensile properties of composites made from alkali treated fibers are better compared to the untreated fiber composite.

III. MATERIALS AND METHOD

Materials

The materials selected for preparation of polymer composites are unsaturated polyester resin as the matrix and sisal fiber as reinforcement. Catalyst and accelerator were used to cure unsaturated polyester resin. The catalyst initiates the polymerization process and the accelerator speeds up this process.

Chemical Treatment of Sisal Fiber

Alkaline treatment is one of the most commonly used chemical treatments of natural fibers. The chemical treatments are used to increase the mechanical properties of natural fibers. 6% NaOH solution was prepared using sodium hydroxide pellets and distilled water. First of all sisal fibers were treated with 6% 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. The washed fibers were dried at sun light for 7 hours.

Fabrication of Composites

A wood mould with size dimension 300mm×300mm×4mm was used to prepare the composites. The mould was cleaned to remove the dust particles and a thin layer of wax was applied by using a brush. This layer prevents the sticking of the composite to the mould during curing; hence the composite can be removed easily from the mould. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the composite. The polyester resin was cured by incorporating 1 % volume of the methyl ethyl ketone peroxide (MEKP) catalyst. 1 % volume of Cobalt Napthenate (accelerator) was also added to perform effective reaction. A stirrer was used to homogenous the mixture and then, the resin mixture was used to fabricate the sisal fiber polymer composite. Initial layer of the mould was filled with unsaturated polyester resin mixture and then fibers were randomly spread over the resin mixture and rolled with hand roller. Again, resin mixture is poured on the glass fibers and then pressed heavily for 7 hours before removal. Then, the top plastic sheet was removed from the mould and cured at room temperature for one day.

Tests conducted

The tensile, flexural and impact tests were conducted on the prepared sisal fiber reinforced unsaturated polyester composites.

Tensile strength

A material can withstand the maximum stress while being stretched or pulled before necking. This test was done with computerized universal testing machine according to ASTM standards (D3039). The tensile strength was reported in MPa.

Flexural strength.

The flexure test method measures behavior of materials subjected to simple beam loading. Flexural test is conducted on computerized universal testing machine. The specimens were prepared according to ASTM D790. The flexural strength was reported in MPa.

Impact strength.

Impact test is used to determine the amount of impact energy that was required to break the specimen. An un-notched izod impact test is conducted to study the impact energy according to ASTM D256. The impact strength was reported in J/m.

IV. RESULTS AND DISCUSSIONS

After fabrication the test specimens were subjected to various mechanical tests as per ASTM standards. The mechanical properties of the composites with different fiber length under this investigation are presented in Table -2.

Table -2: Mechanical properties of the composites

Fiber length (mm)	Tensile strength (MPa)	Flexural strength (MPa)	Impact strength (J/m)
20	12.03	29.72	37.5
30	13.29	36.16	50.0
40	15.61	40.83	75.0
50	16.42	48.07	87.5

Tensile strength

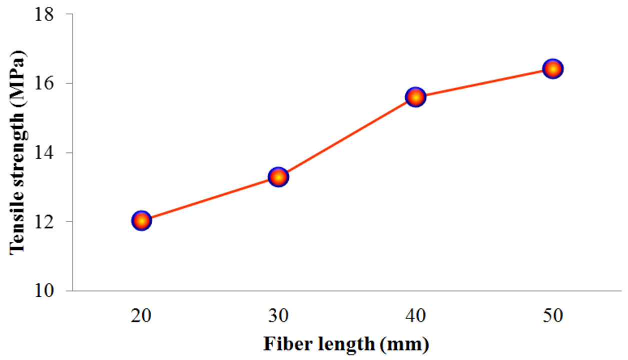

Figure-1: Tensile strength of composites

Figure-1 shows the effect of varying fiber length (20mm, 30mm, 40mm & 50mm) on the tensile strength of the sisal fiber polymer composite. It can be seen that the tensile strength of sisal fiber reinforced unsaturated polyester composites is increasing gradually with the fiber length. The tensile strength of 50mm length of fiber composite was found maximum value of 16.42MPa as compared to other composites. The longer fiber would generate greater bonding capacity between the fiber matrixes. Vatti Chandra Sekhar et al [10] investigated the mechanical properties of teak fiber reinforced epoxy composites. Teak fiber reinforced epoxy composites were prepared with fiber lengths of 10, 30 and 50 mm and fibre content of 2, 3 and 4wt%. Results concluded that the maximum tensile strength was found at 50 mm in fiber length for all the fiber content.

Flexural strength

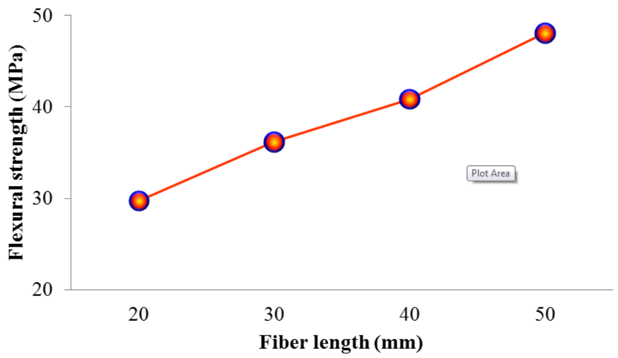

Figure-2: Flexural strength of composites

Figure-2 presents the effect of fiber length on flexural strength of different composites. It is observed that the flexural strength increases with the increase in fiber length up to 50mm. The flexural strength of 50mm fiber length of kenaf fiber composites is increased by a factor of 1.61 compared with 20mm fiber length composite. The longest fiber needs the highest force to release the bond of matrix and fiber. Lourdhet al [11] investigated the 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 author concluded that the flexural strength is increasing from 20mm length of fibre up to 50mm for almost all the fibre weights.

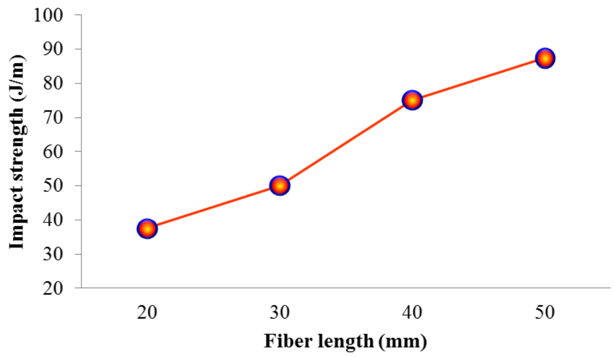

Figure-3: Impact strength of composites

Figure-3 shows chart of impact strength of composites against the fiber length. From the figure it is observed that the impact strength of unsaturated polyester composites increased with increasing fiber length. The fibers play an important role in impact strength as they should resist the crack propagation and act as a load transfer medium. Mechanical properties of short sisal fibre reinforced phenol formaldehyde eco-friendly composites were investigated by Maya M.G et al[12]. The sisal fibre phenol formaldehyde resin composites were prepared with different fiber length (10,20,30,40& 50mm). The results show that the impact strength of short sisal fiber composites is increasing with increase of fiber length up to 50mm.

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V. CONCLUSION

This experimental investigation of mechanical properties of sisal reinforced unsaturated polyester resin composites leads to the following conclusions:

- This work shows that successful fabrication of a sisal fiber reinforced unsaturated polyester resin composites with different fiber lengths is possible by simple hand lay-up technique.
- It has been noticed that the mechanical properties of the composites such as tensile strength, flexural

strength and impact strength of the composites are greatly influenced by the fibre lengths.

- The tensile strength, flexural strength and impact strength of the sisal fiber polymer composite increases with increase in the fiber length.

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Cite this article as :

G. Nallaiya, "The Effect of Fiber Length on Mechanical Properties of Unsaturated Polyester Composites Reinforced by the Fibers of Sisal", International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Online ISSN : 2394-4099, Print ISSN : 2395-1990, Volume 9 Issue 3, pp. 14-20, May-June 2022. Available at doi : https://doi.org/10.32628/IJSRSET229272
Journal URL : https://ijsrset.com/IJSRSET229272