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EVALUATION OF MECHANICAL PROPERTIES OF LADY FINGER-SISAL FIBER REINFORCED HYBRID POLYESTER COMPOSITES

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Abstract —*The term hybrid composite refers to the composite containing more than one type of fiber material as reinforcing fillers. It has become attractive structural material due to the ability of providing better combination of properties with respect to single fiber containing composite. Composites are eco-friendly as well as, light weight and low cost has enhanced the attraction and interest of natural fiber reinforced composite. The objective of present research is to study the mechanical properties of lady finger-sisal fiber reinforced hybrid epoxy resin composite according to filler loading variation. In the present work composites were manufactured by using hot press machine at 3 levels of fiber loading (0.5, 1.5, 2.5 wt. %). Lady finger and sisal fibers were utilized at a ratio of (1:1) during composite manufacturing. Mechanical properties such as tensile properties (such as tensile strength, tensile modulus), Flexural properties (such as Flexural Strength, Flexural Modulus), Impact Strength when subjected to varying weights of fiber (0.5, 1.5, 2.5 wt.%) of maximum loading fibered composites are studied and also calculated the percentage of volume of fiber placed in each fabricated composite specimen. It is found that the tensile and flexural strength of hybrid fibered composites (lady finger sisal) is higher than that of individual composites. Similarly, the impact strength of lady finger sisal hybrid composite is better composite. Based on the fiber loading used in this study, 22% fiber reinforced composite resulted the best set of mechanical properties.*

Keywords*-tensile strength, hybrid composite fiber, lady finger, matrices, epoxy*

I. INTRODUCTION

The word “composite” means two or more distinct parts physically bonded together”. Thus, a material having two more distinct constituent materials or phases may be considered as composite material. Fiber-reinforced composite materials consist of fiber of high strength and modulus embedded in or bonded to a matrix with distinct interfaces (boundary) between them. In this form, both fiber and matrix retain their physical and chemical identities, yet they produce a combination of properties that cannot be achieved with either of the constituents acting alone. In general, fiber is the principal load-carrying members, while the surrounding matrix keeps them in the desired location and orientation also acts as a load transfer medium between them, and protects them from environmental damages due to elevated temperatures and humidity etc. The properties that can be improved by forming a composite material include strength, stiffness, corrosion resistance, wear resistance, attractiveness, weight, fatigue life, temperature-dependent behavior, thermal insulation, thermal conductivity, acoustical insulation and electrical insulation. Naturally, neither all of the properties are improved at the same time nor is there usually any requirement to do so. The commonly accepted classifications of composites are

1. Fibrous composites
2. Laminated composites
3. Particulate composites

1.1Fibrous composites

The fibrous composites are formed by embedding and binding together of fibers by a continuous matrix. According to the definition fiber is a material in an elongated form such that it has a minimum length to a maximum average transverse dimension of 10:1, a maximum cross-sectional area of 5.2 x 10^{-4} cm² and a maximum transverse dimension of 0.0254 cm. A fiber is inherently much stiffer and stronger than the same material in bulk form, because of its perfect structure. Commercially available fibers are of glass, boron, Kevlar and graphite etc. The matrix is meant for bonding the fibrous so that they act in concert. The purpose of the matrix is manifold, namely to support, to protect and to transfer stress among the fibers. The matrix is usually of much lower strength, stiffness and density and is tougher than the fibers. It would not withstand itself high stresses. Resins are widely used as matrix materials. The composite, resulting from the combination of fibers and matrix, possesses higher specific stiffness and specific strength, and is lighter than conventional engineering materials.

1.2 Laminated composites

Bonding layers of different materials or same materials makes laminated composites. In this class of composites, discontinuous matrix or mechanical fasteners are used at times to keep the layers together. Depending upon the ways of fabrication, behavior, or constituent materials of laminates, laminated composites are commonly called as bimetal, clad-metals, laminated or safety glass, plastic based laminates, laminated fibrous or hybrid composites and sandwiches.

1.3 Particulate composites

Suspending particles of one or more materials in a matrix of another material produces particulate composites. The particles and matrix can be either metallic or non-metallic. The commonly used particulate composites are concrete, solid rocket propellants, carbides etc.

1.4Natural Fiber Reinforced composites (NFRC)

Fibers are a class of hair-like materials that are continuous filaments or are in discrete elongated pieces, similar to pieces of thread. They can be spun into filaments, thread, or rope. They can be used as a component of composite materials. They can also be matted into sheets to make products such as paper or felt. Fibers are of three types, natural fiber which consists of animal and plant fibers, and manmade fiber which consists of synthetic fibers and regenerated fibers. The interest in natural fiber-reinforced epoxy composite materials is rapidly growing both in terms of their industrial applications and fundamental research. They are renewable, cheap, completely or partially recyclable, and biodegradable. Plants, such as flax, cotton, hemp, jute, sisal, knead, pineapple, ramie, bamboo, banana, etc., as well as wood, used from time immemorial as a source of lignocelluloses fibers, are more and more often applied as the reinforcement of composites. Their availability, renewability, low density, and price as well as satisfactory mechanical properties make them an attractive ecological alternative to glass, carbon and man-made fibers used for the manufacturing of composites. The natural fiber-containing composites are more environmentally friendly and are used in transportation (automobiles, railway coaches, aerospace), military applications, building and construction industries (ceiling paneling, partition boards), packaging, consumer products, etc. Secondly, only food producing plants, fiber-producing plants play a significant role in early and modern civilization. Fiber is an anatomical structure obtained from stems, leaves, roots, fruits, and seeds. It is derived from meristematic tissue of primary or secondary origin depending on the species. Vegetable fibers consist of cellulose, lignocelluloses, pectin, and hemicelluloses depending on the vegetable species. Worldwide, despite of the availability of modern synthetic fibers, vegetable fibers remain in great demand and compete with wool, silk, and synthetics for quality resistance, durability, color, and luster. Due to the intense competition between natural and industrial fibers, a need exists for analysis of the growth and productivity of those fiber crops most important worldwide. Farmers and researchers in the field of fiber crops face varying problems in their thrust to increase fiber productivity, not the least of which are restrictions due to uncontrollable edaphically and agro climatic factors and economic constraints at grassroots levels. In that Calotropis gigantea is one of the natural fiber reinforced composite material. It is a species of Calotropis native to Cambodia, Indonesia, Malaysia, Philippines, Thailand, Sri Lanka, India and China. It is a large shrub growing to 4 m tall. It has clusters of waxy flowers that are either white or lavender in color. Each flower consists of five pointed petals and a small, elegant "crown" rising from the center, which holds the stamens. The plant has oval, light green leaves and milky stem. Calotropis is a genus of flowering plants in the dogbane family, Apocynaceae. They are commonly known as milkweeds because of the sap they produce calotropis species are considered common weeds in some parts of the world. The flowers are fragrant and are often used in making floral tassels in some mainland Southeast Asian cultures. Fibers of these plants are called madar or mader. The plant is known as Arka in Ayurveda and was used in cases of cutaneous diseases, intestinal worms, cough, ascites, asthma, bronchitis, dyspepsia, paralysis, swellings, intermittent fevers, anorexia, inflammations and tumors. In large doses, Arka is known to act as a purgative and an emetic.

Matrices

The matrix resin generally accounts for 30 to 40 percent, by volume, of a composite material. In addition to maintaining the shape of the composite structure, aligning the reinforcements, and acting as a stress transfer medium, the matrix protects the fibers from abrasion and corrosion. More importantly, the limitation of a composite may well be a function of matrix properties. The two basic classes of resins are thermo sets and thermoplastics. The difference between the two arises from their unique behavior when heated. Thermo sets undergo an irreversible chemical change when they are cured. They chemically cross-link and develop a network structure that sets them in shape. If they are heated after they have been cured, they do not melt. They will retain their shape until they begin to thermally decompose at high temperatures. On the other hand, thermoplastics reversibly melt when heated and solidify when cooled. Once they have been initially melted to form the composite, heating above a lower forming temperature can reshape them. Thus, thermoplastic composites have the unique ability to be repaired once they have been placed into service.

Epoxy is a term used to denote both the basic components and the cured end products of epoxy resins as well as a colloquial name for the epoxide functional group. Epoxy resins, also known as **polyepoxides**, are a class of reactiveprepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homopolymerisation, or with a wide range of co-reactants including polyfunctional amines, acids (and acid anhydrides), phenols, alcohols and thiols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with high mechanical properties, temperature and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics / electrical components, high tension electrical insulators, fiber materials and structural adhesives.

II LITERATURE REVIEW

Reghvendraet.al has conducted research on the mechanical properties short banana fiber as the fiber concentrations increases tensile strength also got increased. The bond got weakened when the fiber concentration was low. The combination of fiber and rubber matrix increased the hardness of the composite, in terms of strength and toughness. The close packing of fibers in the compounds increases the density while resilience decreases. The composites made from 15mm length banana fibers shows the maximum tensile strength and good tear strength. Natural rubber can successfully be used as matrix in bio composites. Using different surface modifications of fiber the strength of the composites can be increased **[1].**S.RKatti et.al researched on mechanical behavior of MWCNT filled polypro pane thermoplastic composites. These composites are produced using twin screw extruder and injection modeling. It contains 2.5,5 and 10% by weight of MWCNT as reinforcements. It was identified that the mechanical properties were improved by nearly 50% as the reinforcement percentage increases. Flexural Modulus and strength have improved noticeably due to the special properties of MWCNT. Hence this material can prove to be a promising one in many industrial sectors **[2].**Sudhir et.al done research on Tensile and Flexural Properties of Sisal/Jute Hybrid Natural fiber composites.They have considered five different weight fractions of the materials and observed that It can be observed that jute /sisal (20/20) weight fraction hybrid composite samples possess good tensile strength and can with stand the strength up to 39.93 M Pa. The jute /sisal (20/20) weight fraction hybrid composite samples with maximum flexural strength of 88.33MPa.They have demonstrated the potential of hybrid natural fiber composites can be regarded as material for light weight**[3].**.Santhosh et.al worked on banana fiber for understanding the mechanical properties. In their work, Mechanical properties of untreated/alkali treated banana fiber/epoxy, untreated/alkali treated banana fiber/vinyl ester and treated banana / coconut shell powder/epoxy, treated banana/coconut shell powder/vinyl ester hybrid composites were investigated. It has been observed from the literatures [2 -4,] were compared the resulting mechanical properties. The tensile, flexural and impact properties of the composites as a function of fiber content were analyzed .Mechanical properties of alkali treatment on surface have been improved than untreated fiber. **[4].** Pradeepe et.al analyzed on effect of water absorption on mechanical properties of wood flour and wheat husk poly propylene hybrid composites and observed that Tensile strength are decreased 29% while modulus are decreased 31% at the loading of 30phr and at the loading of 40phr tensile strength are decreased 23% while modulus are decreased 27% in treated hybrid filler polypropylene composites. Flexural strength are decreased 15% while modulus are decreased 28% at the loading of 30phr and at the loading of 40phr tensile strength are decreased 23% while modulus are decreased 39% in treated hybrid filler polypropylene composites. The impact strength are decreased 11% at the 30phr loading and 13% at the 40phr loading with treated hybrid filler and 17% at the 30phr loading and 22% at the 40phr loading with untreated hybrid filler in polypropylene hybrid filler composites**[5]**.Shinji ochi et.al conducted research on tensile properties of bamboo fiber reinforced biodegradable plastics. The unidirectional biodegradable composites were made from bamboo fiber bundles and a starch-based biodegradable resin. The tensile strengths of the composites increased with increasing fiber content up to 70%. The composites possessed extremely high tensile strengths of 265 M Pa. The fabrication with emulsion-type biodegradable resin contributed to reduction in voids and fiber contacts in the composites. Moreover, heat resistance of bamboo fibers and bamboo fiber reinforced plastics was investigated. As results, tensile strength of both bamboo fiber and bamboo fiber reinforced plastics decreased at 160℃**[6]**. M.Deepya has done extensive research on mechanical and thermal properties of typha angustifolia fiber reinforced composites with alkaline

treatment. Five identical specimens are prepared for each fiber content. In this study, mechanical properties of composite such as tensile strength, tensile modulus were measured using universal testing machine. Guarded hot plate apparatus was used to measure the thermal conductivity of natural fiber typha angustifolia reinforced composite. The results showed that mechanical properties were improved as fiber content gets increased. Thermal conductivity of composite is in the range of 0.168 w/m k to 0.187 w/m k and thermal conductivity decreased about 11.3% as fiber content increased. The newly developed composite material has lower thermal conductivity and is used as an insulating material to save energy [7].Sakthive et.al worked on mechanical properties of natural fiber banana ,coir and sisal polymer and composites and they focused on the fabrication of polymer matrix composites by using natural fibers like coir, banana and sisal which are abundant in nature in desired shape by the help of various structures of patterns and calculating its material characteristics(flexural modulus, flexural rigidity, hardness number,% gain of water) by conducting tests like flexural test, hardness test, water absorption test, impact test, density test, and their results are measured on sections of the material and make use of the natural fiber reinforced polymer composite material for automotive seat shell manufacturing. It is found that polymer banana reinforced natural composites is the best natural composites among the various combination [8].

III EXPERIMENT

In this proposed research work is to exploit the advantages of using natural fibers as reinforcement material in composites. The work provides basic understanding of the behavior and response of new natural fibers and lightweight materials. Under the proposed research work the following aspects of natural fibers and composites have been studied.

- Preparation of Hybrid Natural Fiber Reinforced Composite specimens as per ASTM standards by using the injection molding machine.
- Investigate the mechanical properties and Results and discussion.

3.1 Extraction of fiber form ladyfinger and sisal

Okra or Okro known in many English-speaking countries asladies fingers, ochro or gumbo, is a flowering plant in the mallow family. It is valued for its edible green seed pods. The geographical origin of okra is disputed, with supporters of West African, Ethiopian, and South Asian origins. The plant is cultivated in tropical, subtropical and warm temperate regions around the world

Fig.1 Ladies finger

Fig.2 Sisal

Sisal with the botanical name *Agave sisal Ana* is a species of *Agave* native to southern Mexico but widely cultivated and naturalized in many other countries. It yields a stiff fiber used in making various products. The term sisal may refer either to the plant's common name or the fiber, depending on the context. It is sometimes referred to as "sisal hemp", because for centuries hemp was a major source for fiber, and other fiber sources were named after it. The sisal fiber is traditionally used for rope and twine, and has many other uses, including paper, cloth, foot ware, hats, bags ,carpets, and dartboards.

Fiber is extracted by a process known as decortication, where leaves are crushed and beaten by a rotating wheel set with blunt knives, so that only fibers remain. In East Africa, where production is typically on large estates, the leaves are transported to a central decortication plant, where water is used to wash away the waste parts of the leaf. The fiber is then dried, brushed and baled for export. Proper drying is important as fiber quality depends largely on moisture content. Artificial drying has been found to result in generally better grades of fiber than sun drying, but is not always feasible in the developing countries where sisal is produced. In the drier climate of north-east Brazil, sisal is mainly grown by smallholders and the fiber is extracted by teams using portable raspador which do not use water. Fiber is subsequently cleaned by brushing. Dry fibers are machine combed and sorted into various grades, largely on the basis of the previous in-field separation of leaves into size groups.

Fig.3 Lady finger fiber

Fig.4Sisal fiber

3.2 Preparation of specimens

3.2.1Tensile strength specimens

Fig.5 Tensile strength specimens

The standard test method of ASTM D638M-89 is used to prepare specimens as per the dimensions for getting tensile properties of fiber- resin composites. The test specimen has a constant cross section with tabs bonded at the ends The specimen is prepared by hand layup process in the form of a rectangular strip of 160x12.5x3 mm thick and ground to conform to the dimensions. The mold is prepared on smooth ceramic tile with rubber shoe sole to the required dimension. Initially the ceramic tile is cleaned with shellac (NC thinner) a spiritous product to ensure clean surface on the tile. Then mold is prepared keeping the rubber sole on the tile. The gap between the rubber and the tile is filled with mansion hygienic wax. A thin coating of PVA (polyvinyl alcohol) is applied on the contact surface of specimen, using a brush. The resulting mold is cured for one hour. Hand layup method is adopted to fill the prepared mold with general- purpose polyester resin. ECMALON 4411 is an unsaturated polyester resin of orthophthalic acid grade with clear colorless or pale yellow color. Its viscosity is 500-600 CPS (Brookfield Viscometer) and specific gravity is 1.13 grams/c.c. at 250 C. Acid Number (mg KOH/g) is 22 and monomer content is 35%. Cobalt accelerator and MEKP catalyst are added for curing the resin at room conditions. The quantity of each of these materials, added is 1.5% of the volume of resin. The gel time is found to be about 20 min. The accelerator is mixed thoroughly with the resin and the catalyst is added later to avoid explosion. A thin coating of the resin is applied to the mold surface and known weight of the fiber is placed along the longitudinal direction of the specimen so that the fibers are oriented 0deg along the axial direction of the specimen. Then the rest of the mold is filled with the resin making sure that there are no air gaps in the mold. Then, a thin Polyethylene paper of 0.2mm thick is placed on the rubber mold. A flat mild steel plate is placed on the mold and a pressure of 0.05Mpa is applied and left for 24 hours to cure. Later the specimen is removed and filed to obtain the final dimensions. The specimen is cleaned with NC thinner and wiped off to remove dirt particles. The ends of both flat sides of the specimen are roughened enough using a sandpaper, so as to bond the end tabs. Five such identical specimens are prepared each fiber content in the specimens were 0.5,1, 1.5, 2.0, 2.5 grams are incorporated in the specimen. Two of plain polyester is also prepared in order to compare the results of with and without NAOH natural fiber reinforced composites.

3.2.2 Flexural testing specimens

Fig.6 Flexural testing specimens

The standard test method of ASTM D790M-86 is used to prepare specimens as per the dimensions for getting flexural properties of fiber-resin composites. The test specimen has a constant cross section with tabs bonded at the ends The specimen is prepared by hand layup process in the form of a rectangular strip of 100x25x3 mm thick and ground to conform to the dimensions. The mold is prepared on smooth ceramic tile with rubber shoe sole to the required dimension. Initially the ceramic tile is cleaned with shellac (NC thinner) a spirituous product to ensure clean surface on the tile. Then mold is prepared keeping the rubber sole on the tile. The gap between the rubber and the tile is filled with mansion hygienic wax. A thin coating of PVA (polyvinyl alcohol) is applied on the contact surface of specimen, using a brush. The resulting mold is cured for one hour. Hand layup method is adopted to fill the prepared mold with general- purpose polyester resin. ECMALON 4411 is an unsaturated polyester resin of orthophthalic acid grade with clear colorless or pale yellow color.Its viscosity is 500-600 CPS (Brookfield Viscometer) and specific gravity is 1.13 grams/c.c. at 250 C. Acid Number (mg KOH/g) is 22 and monomer content is 35%. Cobalt accelerator and MEKP catalyst are added for curing the resin at room conditions. The quantity of each of these materials, added is 1.5% of the volume of resin. The gel time is found to be about 20 min. The accelerator is mixed thoroughly with the resin and the catalyst is added later to avoid explosion. A thin coating of the resin is applied to the mold surface and known weight of the fiber is placed along the longitudinal direction of the specimen so that the fibers are oriented 0deg along the axial direction of the specimen. Then the rest of the mold is filled with the resin making sure that there are no air gaps in the mold. Then, a thin Polyethylene paper of 0.2mm thick is placed on the rubber mold. A flat mild steel plate is placed on the mold and a pressure of 0.05Mpa is applied and left for 24 hours to cure. Later the specimen is removed and filed to obtain the final dimensions. The specimen is cleaned with NC thinner and wiped off to remove dirt particles. Five such identical specimens are prepared each fiber content in the specimens were 0.5,1.5,2.5 grams are incorporated in the specimen. Two of plain polyester is also prepared in order to compare the results of with and without NAOH natural fiber reinforced composites.

3.2.3 Impact testing specimens

Fig.7 Impact testing specimens

The standard test method of ASTM D256M is used to prepare specimens as per the dimensions for getting impact energy of fiber-resin composites. The test specimen has a constant cross section with tabs bonded at the ends The specimen is prepared by hand layup process in the form of a rectangular strip of 63.5x12.5x10 mm thick and ground to conform to the dimensions. The mold is prepared on smooth ceramic tile with rubber shoe sole to the required dimension. Initially the ceramic tile is cleaned with shellac (NC thinner) a spirituous product to ensure clean surface on the tile. Then mold is prepared keeping the rubber sole on the tile. The gap between the rubber and the tile is filled with mansion hygienic wax. A thin coating of PVA (polyvinyl alcohol) is applied on the contact surface of specimen, using a brush. The resulting mold is cured for one hour. Hand lay-up method is adopted to fill the prepared mold with general- purpose polyester resin. ECMALON 4411 is an unsaturated polyester resin of orthophthalic acid grade with clear colorless or pale yellow color. Its viscosity is 500-600 CPS (Brookfield Viscometer) and specific gravity is 1.13grams/c.c. at 25deg C. Acid Number (mg KOH/g) is 22 and monomer content is 35%. Cobalt accelerator and MEKP catalyst are added for curing the resin at room conditions.

The quantity of each of these materials, added is 1.5% of the volume of resin. The gel time is found to be about 20 min. The accelerator is mixed thoroughly with the resin and the catalyst is added later to avoid explosion. A thin coating of the resin is applied to the mold surface and known weight of the fiber is placed along the longitudinal direction of the specimen so that the fibers are oriented 0deg along the axial direction of the specimen. Then the rest of the mould is filled with the resin making sure that there are no air gaps in the mold. Then, a thin Polyethylene paper of 0.2mm thick is placed on the rubber mold. A flat mild steel plate is placed on the mold and a pressure of 0.05Mpa is applied and left for 24 hours to cure. Later the specimen is removed and filed to obtain the final dimensions (63.5mm*12.5*10mm). The specimen is cleaned with NC thinner and wiped off to remove dirt particles.Five such identical specimens are prepared each fiber content in the specimens were 0.5, 1.5, 2.5 grams are incorporated in the specimen. Two of plain polyester is also prepared in order to compare the results of with and without NAOH natural fiber reinforced composites.

IV. Composite Testing

A 2 ton capacity - Electronic tensometer, METM 2000 ER-I model (Plate II-18), is used to find the tensile strength of composites. Its capacity can be changed by different loads of 20 N, 200 N & 2000 N. A load of 2000 N is used for testing composites. Self-aligned quick grip chuck is used to hold composite specimens. A digital micrometer is used to measure the thickness and width of composites.

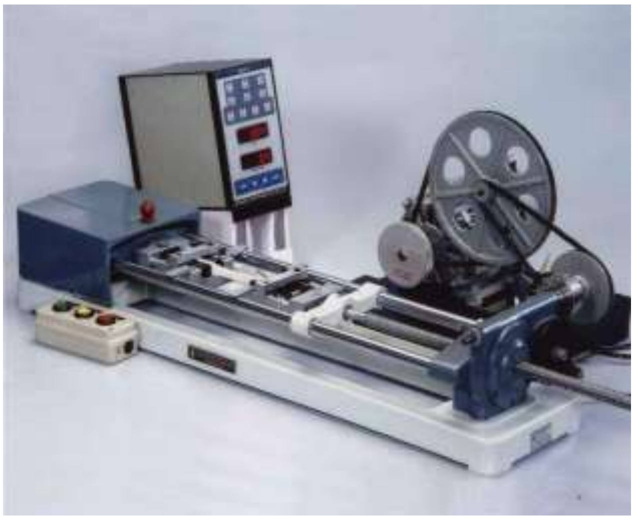


Fig.8 Electronic Tensometer for tensile testing of composites **Fig.9** Electronic Tensometer for flexural testing of composites

The specimen is prepared by injection molding machine process in the form of a rectangular strip of 165x13x3 mm thick and ground to conform to the dimensions. The gauge length, thickness and width are measured with 0.001 mm least count micrometer. The electronic tensometer is fitted with load and extension indicators, which has a least count of 0.01 kg and 0.01 mm, respectively. The tensometer is fitted with a fixed self-aligned quick grip chuck and other movable self-aligned quick grip chuck to accommodate 16 mm wide and 8mm thick specimen.

The specimen was held in fixed grip and the movable grip is manually moved until the specimen is held firmly without slackness. The power supply is switched on to measure the load and extension of the specimen. The movable chuck is further moved such that the load indicator just starts giving indication of loading on the specimen. At that instant the extension meter is adjusted to read zero, when the load on the specimen is zero. The speed reduction pulleys are chosen such that a cross head speed of 2mm/min. is applied on movable grip. Then the electric motor fitted to tensometer is started. Starting from zero, at every 0.2 mm extension the load indicated are noted until the specimen breaks. At the end of the test, the final load and elongation is also noted from the electronic indicator display. It is also confirmed that the specimen failed at a section within the gauge length of all the specimens. For each specimen the type of failure and any other such observations pertaining to failure are noted. The tests are conducted at 28 C and 50 % relative humidity in the laboratory atmosphere. Five identical specimens are tested for samples of Hybrid Fiber Reinforced Epoxy Composite. The rate of loading is selected such that the testing time of each specimen varied between 2 to 5 minutes.

4.1 Flexural testing

Standard test method, ASTM D790M-86 for bending properties of hybrid fiber reinforced epoxy composite has been used to test the unidirectional composite specimens. The standard test method, ASTM D790M-86, for bending properties of plastics and standard method of testing rigid sheet are referred in preparing and testing the specimens. The composite materials used in the current study comprise of hybrid natural fiber reinforced epoxy composite. The standard specimen size required is adopted for the present study. The specimen is prepared injection molding machine process in the form of a rectangular strip of 100x10x4 mm thick and ground to conform to the dimensions. The gauge length, thickness and width are measured with 0.01 mm least count micrometer. The electronic tensometer is fitted with load and extension indicators, which has a least count of 0.01 kg and 0.01 mm, respectively. The tensometer is fitted with a fixed self-aligned quick grip chuck and other movable self-aligned quick grip chuck to accommodate 10mm wide and 4mm thick specimen. The specimen was held in fixed grip and the movable grip is manually moved until the specimen is held firmly without slackness. The power supply is switched on to measure the load and deflection of the specimen. The movable chuck is further moved such that the load indicator just starts giving indication of loading on the specimen. At that instant, the deflection meter is adjusted to read zero, when the load on the specimen is zero. The speed reduction pulleys are chosen such that a crosshead speed of 2mm/min. is applied on movable grip. Then the electric motor fitted to tensometer is started. Starting from zero, at every 0.2 mm extension the load indicated is noted until the specimen breaks. At the end of the test, the final load and deflection are also noted from the electronic indicator display. For each specimen the type of failure and any other such observations pertaining to failure are noted. The tests are conducted at 28°c and 50 % relative humidity in the laboratory atmosphere. Five identical specimens are tested for each of hybrid fibers content in the specimen. The rate of loading is selected such that the testing time of each specimen varied between 2 to 5 minutes.

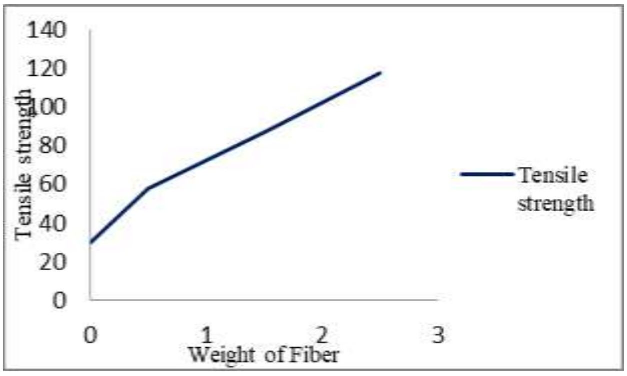
4.2 Impact testing

Fig.10 Composite under impact testing

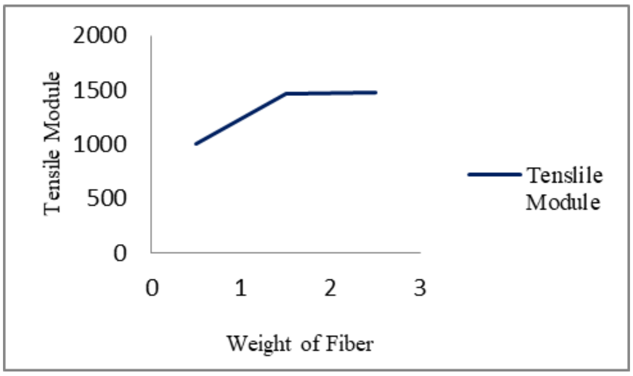
Standard test method, ASTM D256-97, for impact properties of fiber reinforced composites has been used to test the unidirectional composite specimens. The specimens are prepared to dimension of 80*13*10mm thickness. A V-notch is provided in pattern itself at an included angle of 45deg at the center of the specimen, and at 90deg to the sample axis. The depth of the specimen under the notch is 11.16+0.05mm or 11.16-0.05mm. The impact testing equipment compiles with ASTM standards. Depending on the volume fraction of the specimen, one of the four hammers has to be selected to break the sample. The hammer is fixed to the pendulum in such a way that it will make initial contact with the specimen on a line 22mm above the top surface of the clamping vice. The sample is fixed to the vice as a vertical cantilever beam in such a way that the notch faces the striking edge of the hammer and aligned with the surface of the vice. The pendulum hammer is released from its locking position which is at an angle of 150deg with respect to the axis of specimen with a striking velocity of 2.46m/sec. The sample is stripped and energy is indicated in joules by the pointer on the respective scale. The impact energy is calculated as per the ASTM standards. The tests are conducted at 28°c and 50 % relative humidity in the laboratory atmosphere. Five identical specimens are tested for each of hybrid fibers content in the specimen. The rate of loading is selected such that the testing time of each specimen varied between 2 to 5 minutes.

VI. RESULTS AND DISCUSSIONS

Front the Graph 1 it was observed that tensile strength of fabricated composites increases with increase in weight of fiber, when compared with the zero percent fiber composite. The tensile strength of hybrid fiber reinforced epoxy composite with pure epoxy composite is different. The tensile properties of pure epoxy are also determined experimentally. The tensile strength of pure epoxy is 22.65 M pa. The tensile strength of a hybrid natural fiber reinforced epoxy 28.03 M pa (for maximum loading fiber).Graph 2 shows the tensile module V_S weight of fiber

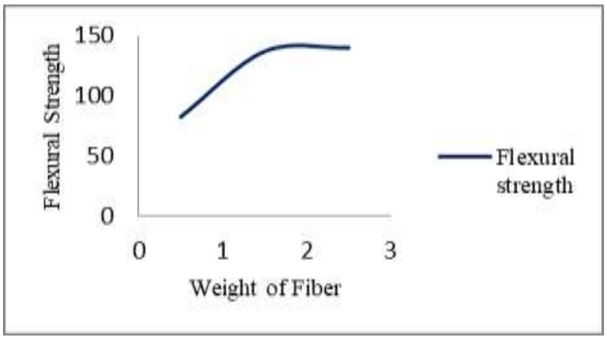


Graph 1 Tensile strength of Hybrid natural fiber epoxy composite by varying fiber weights

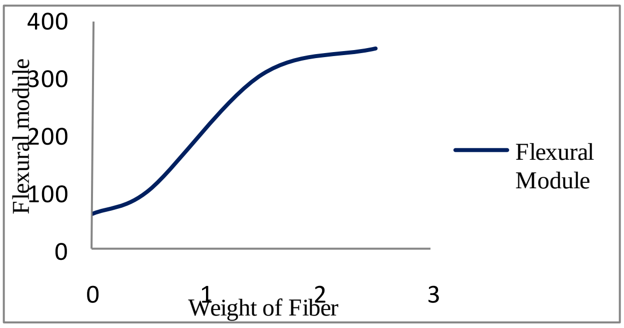


Graph 2 Tensile module of Hybrid Natural fiber epoxy composite by varying fiber weights

as the tensile module of fabricated composites increases with increase in weight of fiber, when compared with pure epoxy composite. The tensile module of pure epoxy is 680.54 M pa. The tensile module of a hybrid natural fiber reinforced epoxy composite is 908.42 M pa (for maximum loading fiber).



Graph 3 Flexural strength of Hybrid Natural fiber epoxy composite by varying fiber weights



Graph 4 Flexural strength of Hybrid Natural fiber epoxy composite by varying fiber weights

Graph 3 shows Flexural strength of fabricated composites increases with increase in weight of fiber, when compared with pure epoxy composite. The Flexural properties of pure epoxy are also determined experimentally. The Flexural strength of pure epoxy is 35.09 M pa. The flexural strength of a hybrid natural fiber reinforced epoxy composite is 42 M pa (for maximum loading fiber). Graph 4 shows that Flexural modulus of fabricated composites increases with increase in weight of fiber, when compared with pure epoxy composite. The Flexural modulus was observed as 350 M Pa.

Graph 5 shows Impact strength of fabricated composites decreases with increase in weight of fiber. When compared with pure epoxy the Impact strength of a hybrid natural fiber reinforced epoxy composite decreases. The Impact strength of pure epoxy is also determined experimentally. The Impact strength of pure epoxy is 22.82 J/m. The Impact strength of a hybrid natural fiber reinforced epoxy composite is 6.54 J/m (for maximum loading fiber).

VII CONCLUSIOINS

After determining the material properties of natural fiber reinforced epoxy hybrid composites with different weight fractions of the materials, the following conclusions can be made.

1. Successful fabrication of the hybrid composite using sisal/Lady finger fiber reinforced epoxy has been done by the hand layup technique.
2. It can be seen that there is an appreciable increase in tensile properties of hybrid natural fiber epoxy composite when compared to pure epoxy composite which can be observed from the results.
3. The tensile strength of pure epoxy is 22.65 M pa and the tensile strength of hybrid natural fiber epoxy composite is 28.03 M pa, which shows almost an improvement of 21%.
4. The tensile modulus of pure epoxy is 680.54 M pa and the tensile modulus of hybrid natural fiber epoxy composite is 908.42 M pa approximately an improvement of 24%.
5. It can also be seen that there is an appreciable change in the flexural properties of hybrid natural fiber propylene composite when compared to pure epoxy composites.
6. The flexural of pure epoxy is 35.09 M pa and the flexural strength of hybrid natural fiber epoxy composite is 42 M pa.

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