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SCOPE OF BANANA FIBER HYBRID COMPOSITE FOR INDUSTRIAL APPLICATIONS: A REVIEW

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ABSTRACT

In recent years, natural fibers are gaining considerable attention due to their properties of low cost and varied applications. The recent developments in the area of fiber technology has led to the realization of the potential of the composites in the near future. One of the most important developments has been in the discovery of uses of banana fibers. Banana fibers obtained from the trunk of the trees of the Musacae species of plant have started to become as a renowned interest for scientist all over the world. Cellulose has been found out to be the main constituent of plant fibers followed by lignin, hemicellulose and pectin. Cellulose serves as the reinforcement for all other constituents. This paper presents a coherent effort of compiling all the research-work done in the scope of hybridization of banana fiber with various natural and synthetic fibers and effects of layering pattern on the properties of the hybrid. The fiber can be used in combination with other fibers as an additive and enhance the properties of the base fibers. Banana fiber due to its varying properties and differing usages is going to serve an important part in the development of the future of fiber industry.

Keywords: ***Banana fiber, Hybridization, Natural fiber***

I. INTRODUCTION

Now a days, research and engineering interests have been shifting from traditional synthetic fiber composite to lingo cellulosic natural fiber composite due to their advantages like high strength to weight ratio, non-carcinogenic and bio degradability. Besides the availability of natural fibers and easy of manufacturing have tempted researchers to try locally available inexpensive fiber and to study their feasibility of reinforcement purpose and to what extent they satisfy the required specifications of good reinforced polymer composite for different applications. The term “natural fiber” covers a broad range of vegetable, animal and mineral fibers.

However in the composite industry, it is usually refers to woods, bones, stones, fiber and agro based bast, leaf, seed, and stem fibers are natural composites, as they are either grown in nature or developed by natural processes. These fibers often contribute greatly to the structural performance of plant and when used in plastic composites, can provide significant reinforcement. Cellulose fibers are flexible but possess high strength. The more closely packed cellulose provides higher density and higher strength. The walls of these hollow elongated cells are the primary load bearing components of trees and plants. Despite the interest and environmental appeal of natural fibers, their use is limited to non-bearing applications due to their lower strength compared with synthetic fiber reinforced polymer composite. The stiffness and strength shortcomings of bio composites can be overcome by structural configurations and better arrangement in a sense of placing the fibers in specific locations for highest strength performance.

Natural fiber composites combine plant-derived fibers such as wood, sisal, hemp, coconut, cotton, kenaf, flax, jute, abaca, banana leaf fibers, bamboo, wheat straw, etc with a plastic binder. These composites are not only light weight, eco-friendly but also involve low production cost. The use of these fiber composites as substitutes reduces the weight by up to 10%, the energy by up to 80% and the production cost by up to 5% compared to glass reinforced components.

Hoi-yan Cheung et. al. studied various natural fibers and reinforced natural fiber composites for bioengineering and environmental engineering applications. They also compared the advantages of natural fibers regarding environmental, i.e., recyclability, renewability, bio-degradability, concerns over the synthetic fibers. Their research showed that the mechanical properties of the neat polymers increased substantially in terms of elastic modulus, stiffness and ductility on making composites with natural fiber matrix [1].

MR Mansor and Balakrishnan et. al. showed that natural fiber polymer composites are most promising candidates for aeronautic applications due to low density and initial cost parameters [2-3].

Banana fiber, or *musa fiber* is one of the world's strongest natural fibers. The biodegradable natural fiber is made from the stem of the banana tree and is greatly durable. The fiber consists of thick-walled cell tissue, bonded together by natural gums and mainly comprises of cellulose, hemicelluloses and lignin. Banana fiber is similar to natural bamboo fiber, but its spin ability, fineness and tensile strength are found to be superior. The outer sheaths produce thicker and sturdier fibers whereas the inner sheaths yield softer fibers.

Banana fiber can be used to make a number of different textiles with different weights and thicknesses, based on the part of the banana stem from which fiber was extracted though the major field of interest is the use of banana fiber for mechanical purposes. The mechanical properties of banana fiber were investigated by Kulkarni et. al. [4]. They reviewed that the failure of banana fiber under tensile load is due to pull-out of microfibrils and the rupturing of the cell walls. The trend of pull-out of fiber decreases with increasing testing speed. At lower strain rates, an increase in strain aids the amorphous to crystalline sharing of load, however, the defects dominate with catastrophic failure at the highest strain rates. Signs of strain hardening are also showed in some stress strain curves [5]. Nilza et. al. conducted various fiber characterization tests to investigate ash and carbon content, water

absorption, moisture content, tensile strength, elemental and chemical properties of banana, coconut coir and bagasse fibers as composite materials and concluded that coconut the highest lignin content, while banana fiber exhibited the highest ash, carbon and cellulose content, hardness and tensile strength [6].

Hybrids are materials constituting two or more chemically distinct components having a distinct interface parting them. A composite consists of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase are usually stronger and harder than the continuous phase and are thus known as reinforcement. The continuous phase is known as matrix. The matrix can be either metallic, polymeric or ceramic, when the matrix is polymeric, the composite is called polymer matrix composite (PMC) [7].

The natural fiber hybridization has not only improved the mechanical strength of the banana fiber but has also reduced its cost and made it an eco-friendly composite [8]. The environment friendly nature makes the materials very popular choice in engineering markets such as the automotive and construction industry [7].

II. METHODS OF FABRICATION OF COMPOSITES

There are various methods used for the purpose of fabrication of composites, the most common ones are indicated below.

- **Hand Lay-up Method**: It is the most common method used for manufacturing composite, it is also one the cheapest. It is a low volume, labour demanding method suited for manufacturing of large components. In this method, the resin is first coated over the mold surface, then, the reinforcing mat is laid manually in the mold and resin is poured, brushed or sprayed over it. The entrapped air is then degassed by the means of squeegees or rollers to complete the laminate structure. The polyesters and epoxies which cure at room temperatures are generally used as matrix in this method. The curing process is initiated by a catalyst which hardens the fiber reinforced resin composite without external heat [9].
- **Resin Transfer Molding process**: It is a closed mold process in which the laminates are between two mold halves. In this method, the dry fiber mats are placed in the mold and the mold is then closed. The resin is then injected to the mold by injection pressure, vacuum pressure or both. The curing temperature depends on the resin used [10].

- **Compression Molding Process**: Compression molding is conventional processing technique generally used to manufacture polymer matrix composite due to its high reproducibility and low cycle time. It is better known for its low fiber attrition and speed. Compression molded composites have high impact strengths. In this process, the fibers and mats are laid in mold and compressed under constant pressure at a constant temperature for a specific period of time [11].
- **Injection molding process**: Injection molding process is a rapid, high volume, low pressure and closed mold process. In this process, the material is forced through machines heated barrel and injected into a closed, heated mold with the help of a ram or a screw type plunger. Heat built up is controlled so as the curing time could be minimised. After curing, the parts need very less finishing and are mostly perfect [12].
- **Vacuum bagging process**: In this process, the composite plates are placed in a vacuum bag and atmospheric pressure is applied on it by removing the air in the bag using a vacuum pump [13].

III. RESULTS AND DISCUSSIONS

M. Boopalan et. al. [7]prepared the composite by hybridising jute fiber having modulus of 55 GPa and density of 1300Kg/m3 with Banana Fiberusing epoxy resin of modulus 3.42 GPa and density of 1100 Kg/m3 as reinforcement in 0:100, 25:75, 50:50, 75:25, 100:0 weight ratios of banana fiber and jute fiber, hardener HY951 was used in 10:1 weight ratio of epoxy resin. Thorough mixing of the mixture was done to disperse the resin and the hardener into the matrix. They made the composite slabs by hand lay-up technique followed by light compression molding technique. Silicon spray was used as releasing agent so that the composite can be cured easily from the mold. The slab of composite thus formed was used for the purpose of mechanical, thermal, Scanning Electronic Microscope (SEM) studies and also water absorption test was carried out.

The test specimen was subjected to various mechanical tests according to ASTM D 638-03 standards for tensile test with test speed of 5mm/min. The flexural strength test was conducted according to ASTM D 790 standard with test speed 1.5 mm/mm. Also Bending and Izod impact test were carried out on the sample. The results of mechanical tests showed that the mechanical properties of the sample increased with increasing weight percentage of banana fiber up to a certain limit, further addition causes poor interfacial bonding between the fiber and the matrix the maximum values of properties was found at 50:50 weight ratio of banana fiber and jute fiber.

The interfacial properties such as fiber-matrix interaction, fracture behaviour and fiber pull out were examined using DXS-10ACKT scanning electron microscope. Thermogravimetric Analysis (TGA) and Heat Deflection Temperature Analysis (HDT) were carried out to study the thermal properties of raw banana fiber and jute fiber.

M. Thiruchitrambalam et. al. [14]conducted a study on the effects of hybridising Banana and sisal fibers on their mechanical properties. The composite was prepared using molding method using polyester as matrix, cobalt and methyl ethyl ketone were used as catalyst and accelerators respectively. To prepare a homogeneous mixture, 150ml of polyester was mixed with 30 gm of chopped fiber 0.5 cm long using fiber cutter, the mixture is stirred using a stirrer. 20drops of accelerator was added along with 12 drops of catalyst for the purpose of curing. The final specimen was procured from the mold after two days.

The test specimen was subjected to water absorption, tensile, compression, flexural and impact tests. The tests were conducted according to ASTM standards and performed on 1000 ton Universal Testing Machine (UTM). The hybrid composites showed comparatively better performance than the raw fibers themselves. Sisal fiber composites, on tensile loading condition, showed a brittle like failure. Less fiber pull out observed can be reasoned to be the cause of reduced tensile strength, whereas banana fiber showed tensile failure, plastic deformation, low fiber pull out and more percentage elongation can also be observed in the banana fiber. The hybrid fiber composites on the other hand, exhibit partial brittle nature of fracture due to the presence of sisal fibers. The hybrid fiber showed increased percentage elongation due moisture uptake.

The hybrid and sisal fibers performed well in compression test. The performance of hybrid and sisal fibers are more or less equal in dry condition, however, sisal fiber lacks in performance under moisture condition. Hybrid composite proves to withstand more stress as compared to sisal fiber under moist condition. Hybrid composite also showed better performance in Impact test.

Maries Idicula et.al. [15]analysed the dynamic mechanical properties of randomly oriented intimately mixed banana sisal hybrid fiber reinforces composites. The composite was prepared by taking 30 mm length chopped banana and sisal fibers. For the purpose of mixing hand lay-up method followed by compression molding was adopted. Polyester resin was cured with the help of one volume percentage of methyl ethyl ketone peroxide (MEKP) catalyst, cobalt naphthenate (accelerator) was also added in one volume percentage. Such composites were prepared keeping the volume ratio of banana and sisal fiber as 1:1 and varying volume fraction of fibers from 0.2 to 0.5. After chopping and air drying for 5 hrs at 50ºC, fibers are intimately mixed and the mats were prepared. It was then injected with polyester resin in a mold of dimensions 150 mm x 150 mm x 3 mm. The sample was cured at 30ºC for 24 hrs under constant pressure of 10 Kg/cm^2.

The specimen was subjected to various mechanical tests and dynamic mechanical analysis. The result of storage modulus versus time analysis showed that the effectiveness of fiber is highest at volume fraction of 0.4. At this volume fraction maximum stress transfer between fiber and matrix takes place. The same result can be observed in impact test where the composite of volume fraction 0.4 peaked in damping factor value (tan δ) due maximum stress transfer between matrix and the fiber. The same trend could be observed in the static mechanical tests. Unhybridized matrix of different volume fractions were also studied and their results were compared to that of hybrid, the maximum stress transfer was found in banana and sisal hybrid of relative volume fraction of 3:1.

N. Venkateshwaran et. al. [16]studied the mechanical properties and water absorption behaviour of Banana sisal reinforced hybrid composites. The hybrid was prepared using Epoxy LY556 mixed with hardener HY951 in weight ratio of 10:1. The epoxy mixture is mixed with fiber. The fibers are laid uniformly in the mold and compressed for few minutes. The compressed fiber is then laid over coat of epoxy, ensuring uniform distribution of fibers. The epoxy mixture is then poured uniformly over the fiber and compressed for curing time of 24 hrs.

The results of the tests showed that the mechanical properties of hybrid fiber increased with the increase in weight ratio of hybrid. In order to study the water absorption behaviour of banana/sisal hybrid composites in water at room temperature specimen were submerged in water. The specimen were taken out periodically and weighed to find out the content of water absorbed. It was observed that composite of 50:50 weight composition showed the lowest water uptake and permeability coefficient.

Narra Ravi Kumar et. al. [17] investigated the mechanical properties of banana fiber glass reinforced thermoplastic composites. To prepare the composite, firstly, the extracted fiber and the polypropylene pellets are dried in oven for 2 hrs at 800 ̊C to expel the moisture before they were used for injection. The samples of composite were prepared by mixing fibers in proportion of 0, 5, 7.5, 10, 12.5 and 15% by weight of glass fiber. The mixture is then placed in in a 2.5 tonne hydraulic Injection Molding Machine at a temperature of 210°C and pressure of 1100 kgf/cm².

The result of the tensile test shows that the tensile strength of the specimen increases with increase in weight and the maximum tensile strength is observed at 7.5% by weight of banana to that of glass fiber. Similarly the flexural strength and impact strength values increased with increasing weight fraction of banana fire and the maximum value was obtained at 10%.

U Tamilarasan et. al. [9]analysed the mechanical properties of banana-jute fiber epoxy composite with carbon fiber. For the purpose of analysis two specimen were prepared, Specimen A consists of banana-jute hybrid composite while Specimen B consists of banana, jute and carbon fiber composites. The composite are prepared by hand lay-up method. The specimen were subjected to mechanical tests complying to respective ASTM standards. The ultimate tensile strength of the composite Banana-Jute hybrid came out to be 21.308 MPa and the flexural strength 65.35 MPa while the ultimate tensile strength of the composite Carbon Banana Jute came to be 59.586 MPa and the flexural strength 87.17 MPa. Thus, banana fiber with jute and carbon fiber increases the mechanical properties with respect to the original fiber by a considerable amount.

V. P. Arthanarieswaran et. al. [18]evaluated the mechanical properties of banana and sisal reinforced epoxy composites and effects of glass fiberhybridization. For the purpose of study nine different laminates were prepared as plain banana fiber, plain sisal, banana-sisal hybrid of random composition and hybrid with layers of glass fiber on them. The laminates were subjected to different mechanical tests complying to the respective ASTM standards.

The maximum tensile strength of 104 MPa was observed in banana-sisal hybrid combination with three layers of fiber glass. On the other hand, the laminates with banana–sisal fibers as a sandwich and glass fibers at the extreme layers showed better performance in the flexural strength and it withstands up to 192 MPa. By studying the test results the hybrid composite laminates seem suitable for medium load applications such as welding helmet, chair, table, roof, and automobile body panels.

Z. M. Hanafee et. al. [19]studied the effects of hybridising banana-pineapple leaf-glass fiber in different volume fractions. To prepare the composite the natural fiber were cut into 30cm length, woven glass fiber was cut into 30cm x 30cm size. The constituents were weighted per the calculated ratio and the composites of three volume percentages of 30, 40, and 50 % were prepared for the study.

The specimen were subjected to tensile test according to ASTM D3039. It was observed in the results of the test that the tensile strength of hybrid increased with increasing volume fraction, based on study the optimum volume fraction of banana and palf came out to be 50%. Additional 85% tensile strength increment was observed on addition single layer of glass fiber on banana-palf hybrid.

I. N. Hanifawati et. al. [20]evaluated the tensile and flexural behaviour of hybrid banana-glass fiber reinforced polyester composite. The composite were prepared in 10, 20, 30, 40 % volume fraction by fiber loading method and fabricated with hand lay-up method followed by compression molding. The hybrid banana-glass fiber of 100/0, 75/25, 50/50, 25/75, 0/100 ratio were evenly arranged in the mold and covered in the matrix. The specimen were kept at constant pressure of 10 Kg/cm^2 for 24 hrs for curing.

The ready specimen were then subjected to tensile and flexural tests according to respective ASTM standards. The tensile test shows that the strength and Young's modulus linearly increase with increasing net fiber content also the specimen of fiber content 40% showed highent tensile strength. Also the flexural property increases with the increase in volume fraction of hybrid fiber, it is observed that 40% volume of fiber has highest strength.

V. Arumuga Prabu et. al. [21]studied the influence of hybridising redmud fiber to banana-sisal composites. The banana and sisal were chopped into 300 mm of length, the polyester resin is mixed with1.5 ml of curing catalyst and accelerator at room temperature. The redmud is then added to the resin and stirred properly. The solution is then poured into the mold of 300mm x 125mm x 3mm and let to cure in the mold for 24 hrs.

In the tensile test, it is observed that the tensile strength increases substantially on addition on redmud particles to banana-sisal hybrid. Similar trend is observed in case of flexural strength and impact strength.

L. A. Pothan et. al. [22] studied the effects of layering pattern on water absorption behaviour of banana fiber glass hybrid. The mats of banana glass fiber were prepared as sample, the mats were then impregnated with the polyester resin to which 0.9 % of polyester resin cobalt naphthenate and 1% methyl ethyl ketone peroxide were added. After degassing of, it was added to the fiber mats. In different hybrid samples, different layering pattern were used.

The specimen were subjected to water absorption test according to ASTM D570 standards. It was concluded that the water absorption characteristics mainly dependent on the properties of the lignocellulosic fibers and the diffusion coefficient is minimum for Cg-b-g sample. Hence, it has lowest water uptake.

A. Alavudeen et. al. [23]investigated the mechanical properties of banana/ kenaf fiber reinforced hybrid polyester composite and the effects of woven fabric and random orientation. The fibers of banana kenaf and composite were fabricated using hand lay-up method followed by compression molding. The woven fabric were placed in a mold of 300 x 300 x 3 mm. The air bubbles were removed by degassing, the accelerator was added to the resin and catalyst was added to the mold. After this the mold was closed by a deadweight of 45 Kg and allowed to cure for 24 hrs, following which post curing was done in a oven at 50 ̊C.

The sample was tested for tensile, flexural and impact strengths and also scanning electron microscopy was performed according to respective ASTM standards. In the tensile test, it was seen that the banana-kenaf reinforced hybrid showed increase in strength when compared to plain banana and plain kenaf fibers. The same pattern was observed in flexural and impact tests.

K. Senthil Kumar et. al. [24]studied the effects of layering pattern on vibrational behaviour of banana-coconut sheath hybrid composite. For composite preparation, banana fiber and naturally woven coconut sheath were laid inside the mold with random orientation. The fibers were pre-compressed at 10 Kgf/cm^2 for a day before molding. Firstly, the resin was poured in the mold cavity and then fibers were stacked in it. Finally, the mold was closed with a dead weight of 50 Kgf/cm^2 pressure and kept closed for 24 hrs for curing. The hybrid composites were produced in four different layering patterns, i.e., CBC, CCB, BCB and BBC. The results of mechanical and vibrational tests showed that the skin eccentric fiber yielded higher tensile strength with higher wt. % hybridization of banana fiber. Also damping value were found to be higher in hybrid composites alkali treated.

Nirupama Prasad et. al. [25]evaluated the effects of hybridising banana and coir fibers on their physico-mechanical properties. To produce the hybrid, firstly, the banana and coir fibers were dried in the oven at 70 ̊C for 24 hrs to avoid formation of voids and to improve the adhesion between the fiber and the matrix. The fiber and matrix were mixed and stirred using a stirrer for 15 mins at 2400 rpm.\ to obtain a homogeneous mixture. The mixture was then poured into a mold of 140 x 140 x 2.6 mm and pressed on a mat. The sheets were prepared by pressing the mold in compression molding machine at 20 MPa and 180 °C temperature for 24 hrs. The prepared sample were tested for mechanical, morphological, thermogravimetric and water absorption analysis according to the respective ASTM standards. The results of the tests clearly showed that hybridising coir fiber on banana fiber improved its tensile properties, flexural properties, toughness, thermal stability, and water resistance by a considerable margin. It was also seen that hybrid composite of banana: coir ratio of 1:1 showed best mechanical properties. From the SEM studies it could be inferred that the addition of coir fiber into the banana fiber composites reduced the fiber pull-out and improved the fiber/matrix interfacial bonding.

Anshida Haneefa et. al. [26]studied the tensile and flexural properties of short banana/glass hybrid fiber reinforced polystyrene composites. For the preparation of composite Banana and glass fibers were cut into 6mm lengths, the composite was made using solution mixing method. Firstly, the fiber were mixed with viscous slurry of polysterene in toluene then the mixture was dried in an oven and chopped in small pieces. The composite were then processed to get 4mm cylindrical rods using injection molding machine. Specimen of dimensions 120 x 26.5 x 2.5 mm were prepared then compression molded at 8 MPa and temperature of 150 °C. The specimen were subjected to mechanical tests and scanning electron microscopy. It was found in the tensile test that the tensile strength and Young's modulus of the composite increase with increase in volume fraction of fiber glass due to the greater compatibility of glass fiber than banana fiber with polystyrene. On the other hand, the elongation decreases with increase in volume fraction of glass fibers due to lower elongation at break value of glass fiber. Similar trend could be observed in flexural strength and flexural modulus. It was seen in scanning electron microscopy that the tensile failure of composite is mainly due to fiber pull out.

Norizzati Zulkafli et. al. [27]studied the quasi and dynamic impact performance of hybrid cross-ply banana/glass fiber reinforced polypropylene composites. The composite were prepared in four sets of staching sequences, i.e., BBB, GGG, BGB, GBG of dimension 250 x 250 mm using compression molding machine. The fibers of cross-ply and banana were placed with PP sheet and compressed at 3.5 MPa pressure and 170 °C temperature. The quasi-static indentation test was performed according to ASTM D6264 using UTM machine with 150 kN load cell and a steel hemispherical tip impactor with a diameter of 12.7 mm and dimensions of sample were 100 x 100 x thickness (mm). The specimen was also subjected to low viscosity impact test according to ASTM D7136. The results indicated that adding of glass fiber in composite increases energy absorption.

M. R. Sanjay et. al. [28]conducted a study on the mechanical properties of banana/e-glass fabrics reinforced polyester hybrid composites. For the purpose of composite fabrication, different laminates of various combinations of banana and glass fiber were prepared using vacuum bagging method. Firstly, wax was applied on the mat, then the 6 laminates were impregnated with resin isophthalic polyester resin, catalyst and accelerator, later the laminates are sealed with a vacuum bag. Later, the air is extracted from the vacuum pump in order for compacting and hardening to take place. The laminates are allowed to cure for 4 hrs in the vacuum bag at a pressure of 60-70 bar. Further, post curing is carried out for 4 hrs at 70 °C. The laminates were subjected to tensile, flexural, impact, water absorption, and hardness tests complying to corresponding ASTM standards. The results showed that since the laminates are cured using vacuum bagging method, void fractions in the laminates are very less. In the tensile test it was seen that increasing layers of glass fibers in banana-glass hybrid increases the breaking lod, tensile modulus, UTS of the hybrid. Similar trend could be observed in flexural strength, Impact strength and water absorption behaviour and hardness tests.

G. Navaneethakrishnan et. al. [8]studied the development and mechanical effects of hybridising Banana and glass fiber reinforced with silica nano-particles and epoxy bio-nanocomposites. For hybrid fabrication, a mold of dimensions 300 mm × 280 mm × 30 mm was used and releasing agent was applied on its surfaces. The fibers were pre-impregnated with matrix material constituting of epoxy and silica nanoparticles in 0.5, 1, 3 and 5 % wt. The hybrid composites were then cured for 3 hrs at 100 °C and then post cured at 140 °C for 4 hrs. It is seen that the incorporation of silica nanoparticles into glass fiber and banana reinforced epoxy composites increases the values of tensile strength (14%) and tensile modulus (12%) by the addition 3wt. % nanoparticles. The Scanning Electron Microscopy (SEM) shows that the silicon dioxide nanoparticles are equally dispersed throughout the composites and It has been infered that adding of 3% of silicon dioxide nanoparticle has enhanced the mechanical properties of the composite to a great extent.

Ashwani Kumar et. al. [29]studied the effects of hybridising banana and glass fibers. For fabrication of composites glass fiber, banana fiber and epoxy hardener were used as raw materials. The composite was subjected to tensile, flexural and impact tests. It is seen in the results that 30 % hybridization had better mechanical properties than 10% and 20%. Also banana fiber glass hybrid had more tensile, flexural and impact strength then both glass fiber reinforced epoxy composite and banana fiber reinforced epoxy composite.

Manickam Ramesh et.al. [30]investigated the mechanical and water absorption properties of banana-carbon hybrid fiber reinforced composites. For production of composite banana and carbon fibers of 300 mm length were used. Five layers of carbon fiber and banana fiber were arranged in alternate fashion. The epoxy resin was applied on the surface and distributed by the help of a roller. Finally, the laminate is cured under load for 24 hrs. The size of laminate is 300 x 300 x 5 mm. tensile test, flexural test, impact test, water intake test and morphological test were conducted on the test specimen. It was concluded that, the hybrid composites which contains 20% carbon fiber and 80% banana fiber has more tensile strength than other composites. Similarly flexural strength and impact strength values are also maximum for this composite immediately following the values of pure carbon fiber. Water intake comes show a decreasing trend with increasing percentage of hybridization of carbon fiber over banana fiber.

Madhukiran. J et. al. [31]evaluated the tensile and hardness properties of banana/pineapple natural fiber reinforced hybrid composites. To fabricate the composite the fibers were arranged uniformly and compressed in the mold for few minutes, the compressed form of fibers are removed followed by application of releasing agent on the mold and application of epoxy coat. The epoxy mixture was then poured over the fiber uniformly and compressed under 5 Kg load for 24 hrs. Such composites of different weight fractions of banana and pineapple are prepared. The samples were subjected to tensile and micro-hardness tests according to the corresponding ASTM standards. It was observed that the hybrid of weight fraction of 25/15 showed maximum tensile strength, hardness, breaking load and percentage elongation.

P Samivel et. al. [12]analysed the mechanical behaviour of stacking sequence in kenaf and banana fiber reinforced-polyester laminate. The composite was prepared by mixing the unsaturated polyester and monomer of styrene in the ratio of 100:25 parts by weight. This is followed by addition of accelerator methyl ethyl ketene peroxide 1% and catalyst cobalt naphthenate 1%. Hand lay-up technique was used for fabrication, silicon was used as releasing agent and matrix mixture is poured into the mold. The casting are led to cure in the mold for 24 hrs at room temperature then post cured at 80 ℃ for 4 hrs. The specimen was subjected to tensile, flexural, impact and water intake tests. The result shows that hybridization improved the mechanical properties of composites by a considerable margin. Also, the least amount of water intake was in hybrid composite was negligible.

M. Harikrishna et. al. [32]studied the fabrication and mechanical properties of Jute/Banana/ glass hybrid. Fiber composites of three different combinations were fabricated using hand lay-up method. The epoxy resin and hardener were mixed in ratio of 10:1. The three sets of laminates were led cured under load for 24 hrs using a weight press. The laminates were subjected to mechanical tests and their results were compared. It was observed that Jute-Banana-Glass hybrid showed most tensile strength amongst the three, also maximum flexural strength and impact strength were observed in the same.

N. Venkateshwaran et. al. [33]analysed the mechanical properties and water absorption behaviour of woven jute/banana hybrid composite. The fabrication was done by hand lay-up technique. The mold was coated with epoxy then a layer of epoxy was poured in the mold in which the fabric was laid uniformly. The mats are compressed for a curing time of 24 hrs after which it is compression molded under 3 MPa pressure and 50 ℃ for 15 mins. The sample were subjected to various mechanical and water absorption tests corresponding to respective ASTM standards. It was concluded in the tests that effect of layering pattern is higher on the mechanical properties of composite when compared to that of hybridising. Further, it is observed that banana-jute-banana hybrid is suitable for tensile and bending applications.

Aniket A Terwadkar et. al. [13]evaluated the mechanical properties of banana fabric and kenaf fiber reinforced epoxy composites and theeffects of treatment and hybridization. For the purpose of fabrication hand lay-up method and vacuum bagging technique are used. Firstly, the kenaf fiber are sandwiched between layers of plain woven banana fibers. The mold is coated with releasing agent after which epoxy with 50% hardener is added. The composite is placed in a vacuum bag and the air is pumped out using vacuum pump. After hand lay-up process, the the composite is let to cure at 25-30 °C for 48 hrs. The specimen was further tested for mechanical properties. The tests showed the hybrid banana and kenaf fiber has higher elastic modulus than chemically treated individual banana and kenaf fibers.

Laly A. Pothan et. al. [34]studied the dynamic mechanical and dielectric behaviour of banana–glass hybrid fiber reinforced polyester composites. Firstly, randomly oriented glass fiber mats and separated banana fiber are cut in 30 mm length and evenly arranged in the mold of dimensions 150 x 150 x 2.5 mm in desired layering pattern. The fiber was impregnated with polyester resin in which 1% methyl ethyl ketone peroxide and 0.9 % cobalt naphthenate were added. The resin was degassed and the mold was closed for 12 to cure after which post curing was done for 48 hrs at room temperature. The tests show that more than hybridization, it is rather the layering pattern that has more effect on dynamic mechanical properties of composite.

Khalid Imran et. al. [35]investigated the mechanical and dynamic characteristics of hybrid natural fiber composite. The composite was manufactures by hand lay-up method in a poly propylene mold of dimensions 250 x 250 x 5 mm. The banana and sisal fibers were chopped into 10 mm length and laid in the mold. The epoxy and hardener were mixed in the fraction of 10:1 and stirred for 10 mins. The release film in placed on the mold and mold in let to solidify under loaded condition for 24 hrs. The vibrational characteristics of the specimen were studied and it was observed that hybrid composite of banana-sisal fibers with volume fraction b-s 30-10% gives a maximum damping factor 3.681 which is 2.10 times higher than the damping factor 1.751 of banana fiber laminate and gives better vibrational absorbing capacity.

G V Naveen Prakash et. al. [36]investigated the mechanical behavior of the glass/ banana fibers reinforced epoxy composite. The hybrid was produced by hand lay-up technique using epoxy resin. The curing is done under load of 10-20 Kg for 24 hrs. The specimen was tested for tensile, flexural, impact, hardness, inter-laminar shear strength and water absorption characteristics according to corresponding ASTM standards. It was observed in the results that banana-glass hybrid fiber had better strengths than banana fiber reinforced epoxy composite and the strength values are closer to that of glass fiber reinforced epoxy composite.

IV. CONCLUSION

In order to investigate the effects of hybridization of different natural and synthetic fibers on the mechanical, morphological and water absorption properties of banana fibers, various researches and their results were studied. It is seen that the mechanical properties (Tensile, percentage elongation, flexural, impact and hardness) of the hybrid composite improve with the percentage of hybridization of banana fiber and the percentage water intake decreases with the increase in percentage of hybridization. Hybridization also improves the damping characteristics of the fiber and thus can be used as Anti Vibration Mountings. The Banana fiber hybrid is suitable for low to medium bending and tensile applications. Judicial usage of Banana fiber due to its varying properties and differing usages is going to serve an important part in the development of the future of fiber industry.

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