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Analysis of Mechanical Properties of Hybrid Cocous Nucifera and Ananas Comosus Woven Fiber Laminate Composites

G.Tharanitharan[1], T.Aravinth[2], S.Ariharan[3], S.Arun Kumar[4] and M.Ashok Kumar[5]

[1]*Assistant Professor, Department of Mechanical Engineering, SNS College of Technology, Coimbatore, India. Email: gtharanitharan@gmail.com*
[2]*UG Student, Department of Mechanical Engineering, SNS College of Technology, Coimbatore, India. Email: aravinth.thangavel9894@gmail.com*
[3]*UG Student, Department of Mechanical Engineering, SNS College of Technology, Coimbatore, India. Email: scap.ari1995@gmail.com*
[4]*UG Student, Department of Mechanical Engineering, SNS College of Technology, Coimbatore, India. Email: arunkumars1195@gmail.com*
[5]*UG Student, Department of Mechanical Engineering, SNS College of Technology, Coimbatore, India. Email: ashok199517@gmail.com*

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ABSTRACT

This paper deals with the production of a composite material with intensified mechanical properties than the existing natural composites. The material is produced by using cocous nucifera (Coir) & ananas comosus (Pineapple) fibers with epoxy as the matrix material. Here the woven fibers are used to obtain the similar properties all over material, whereas in chopped fibers the fibers are made into small pieces and they are randomly oriented. So we implement the woven fibers to obtain the uniformity. The laminate composite concept are also implemented so as to improve the mechanical properties of the material. In this method the fibers are kept in alternate layers as Coir & Pine apple one over another to produce laminate composites (3 layers of Coir & 2 layers of Pine apple). The fibers are initially treated with NaOH to improve interfacial compatibility between the fibers and matrix and also to reduce the moisture absorbing capacity of the natural fibers. Alkaline treatment also improves certain mechanical properties which is experimented by varying the parameters such as length of the fiber, volume of the fiber and time of alkaline treatment and the best possible combination of the parameters are found by Design of Experiment (DOE). As a result, combination of hybridization and alkaline treatment will improve the mechanical properties of natural fibers. It is identified that the major factors that influence the mechanical properties of the composites are the time for which alkaline treatment is done and the volume of the fiber used in the material. As a result, woven laminate fiber composites have more properties than that of randomly oriented composites.

Keywords: Cocous Nucifera, Ananas Comosus and Alkaline treatment.

1. INTRODUCTION

Composites are fiber reinforced plastics used in a variety of products. While the term at “composites” can applied to any combination of individual materials. Composites are strong, light weight, corrosion resistant and dimensionally stable. They also provide good design flexibility and high dielectric strength, and usually required lower tooling cost. High strength light weight premium composites material such as carbon fibre and epoxies are being used for aerospace application and in high performance of sporting goods. Composites superior electrical insulating properties also make them ideal for appliances, tools and machinery. Natural fibers have traditionally been used in culturals of the world to meet basic requirements of clothing, storage, building material and for items of daily use such as mate finishing nets.

A composite material is defined as a material system which consists of a mixture or a combination of two or more distinctly differing materials which are insoluble in each other and differ in form or chemical composition. The high modulus fiber provides the stiffness and load bearing qualities, whereas the low-modulus fiber makes the composite more damage tolerant and keeps the material cost low. The mechanical properties of a hybrid composite can be varied by changing volume ratio and stacking sequence of different plies. Hybrid composites are more advanced composites as compared to conventional FRP composites. Hybrids can have more than one reinforcing phase and a single matrix phase or single reinforcing phase with multiple matrix phases or multiple reinforcing and multiple matrix phases. Fiber is a hair-like strand of material. It is flexible and can be spun or twisted for weaving, braiding, knotting, crocheting, etc. to make desired products. Fibers can be obtained in natural form from plants and animals as well as in synthetic form. Natural resin is a resin product which comes from a plant (consisting of amorphous mixture of carboxylic acids, essential oils and isoprene – based hydrocarbons) in contrast with synthetic resin.

Bio-resin is a resin system based on vegetable oil and or other natural ingredients. The hardener, (the integral part of the resin system), generally contains blocked isocyanate, with the intention to achieve its role and in the same time preventing the escape of the potential harmful substance. With the main advantages that these bio-resins are suitable for all major fibers and are compatible with polyesters and epoxy substrate, presents the major characteristics the free odour and shrinkage, the free toxic fumes without being flammable. Incorporating renewable sources as raw materials to replace synthetic petroleum based polymers. Fiber or fibre is a rope or string used as a component of composite materials, or matted into sheets to make products such as paper or felt. Fibers are often used in the manufacture of other materials. The strongest engineering materials are generally made as fibers, for example carbon fiber and Ultra-high-molecular-weight polyethylene. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix). Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. A composite material is defined as a material system which consists of a mixture or a combination of two or more distinctly differing materials which are insoluble in each other and differ in form or chemical composition. In other words "A combination of two or more materials (reinforcements, resin filler, etc...), differing in form or composition in macro scale". The advantage of composite materials over conventional materials stem large from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile.

By definition, composite materials consist of two or more constituents with physically separable phases. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material. Reinforcement provides strength and rigidity, helping to support structural load.

The matrix or binder maintains the position and orientation of the reinforcement. The composites retain their individual, physical and chemical properties, yet together they produce a combination of qualities which individual constituents would be incapable of producing alone. The reinforcement may be platelets, particles or fiber and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material.

[1] Kumaresan. Metal had reported about varying orientation angles. According to his studies, 0^0 and 90^0 showed greater results. During production of composites, hydraulic press and unidirectional fibers showed greater properties.

[2] Netrawali. N & Luo. S were prepared composite of pineapple fiber and PHBV resin of different fiber weight ratio wary from 20% to 30%. The tensile and flexural properties of these were tested & make a comparative study of these results with different types of wood specimens.

[3] Amalia. N & Hidayatullah. S et al made a detailed study on pineapple fiber in the geopolymers matrix produced a new type of inorganic hybrid composite. The fibers were found to improve the mechanical properties, compressive and flexural strength of the composites. The addition of pineapple fibers was also found did not change the nature of geopolymers as a fire or acid resistance material. Microstructure examinations show that the space between the geopolymers matrix and pineapple fibers reduce the mechanical strength of the resulting composite.

[4] S.M. Sapuan et al stated that the tensile and flexural strengths of the epoxy coconut filler composites were affected by the amount of filler in the composites. The more the filler content, the higher the strength. In tensile testing, filler composites demonstrated linear behavior with sharp fracture. In flexural testing, filler composites demonstrated slightly nonlinear behavior prior to sharp fracture.

[5] Navdeep Malhotra et al has reported about the impact of volume fraction over the fiber reinforced composites. He concluded that volume fraction of about 40-50% showed good impact for epoxy resin. He also stated that epoxy composites had showed good results than compared with polyester resin.

2. MATERIAL SELECTION

2.1 Coir

Coir fiber is found between the hard internal shell and the outer coat of a coconut. The fiber is pale when immature, but latter become hardened and yellowed as a layer of lignin. The coir fiber exists in two types: brown coir and white coir. Brown coir is harvested from fully ripened coconuts. It is thick, strong and has high abrasion resistance. Generally it is used in mats, breeches and sacking. Mature brown coir contains more lignin and less cellulose than fibers such as flax and cotton, and thus make then stronger but less flexible. White coir fibers are harvested from the coconuts before they are ripe. This fibers are white or light brown colour, are smoother and finer and usually weaker than brown coir.

2.2 Pineapple

Pineapple leaf fiber is a nature hemp leaf fiber extracted from pineapple leaves. Structural characteristics were investigated by means of scanning electron microscope, x-ray diffraction, differential scanning calorimeter and thermo gravimetric analysis. The result should the percent crystalline and prefer orientation of crystallites in pineapple fibers where 60.82 % and 95.5% respectively. The average fracture strength of pineapple leaf fiber is high and linear density is low, so there is high fiber spinability and yarn quality. The present study is expected to provide essential information for the preparation and processing of pineapple leaf fibers.

2.3 Epoxy

Epoxy have adhesive strength, hardness, elasticity, luster, properties of insulation and heat dissipation and ease of repair, Epoxy resins also known as polyepoxides class of reactive pre polymers. Epoxy resins may be reacted either with themselves through catalytic homopolymerisation, or with the wide range of co-reactance including poly functional amines, acids, phenols, alcohols. These co-reactance are often referred to us harderners or curitives, and the cross linking reactions is commonly referred to as curing. Reaction of poly epoxides 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, high tension electrical insulators, paint brushes manufacturing, fiber reinforced plastic materials and structural adhesives.

3. EXPERIMENTATION

3.1 Weaving of fiber

The bundles of coir and pineapple fibers are taken to the waving machine. Individual fibers of coir are first kept into the machine for weaving. In order to weave the fiber, the alternately at an angle 90^0 since earlier researches show that only 90^0 orientation showed greater results than other angles. Then the same procedure is repeated for pineapple fiber.

3.2 Materials
Weaved fibers of coir and pineapple are kept in alternate layers to form the laminated composites. In this coir is kept as first, third and fifth layer, while pineapple is kept as second and fourth layer. Epoxy is used as resin material.

3.3 Alkali Treatment
The fibers are to be treated with NaOH to reduce absorptivity of the fibers since natural fibers highly absorb liquid content. The fibers are kept in NaOH for 1 day and 2 days and their volume fraction are changed accordingly.

3.4 Sample Preparation
The composite material is manufactured with the selected reagents. A total number of 27 specimens are manufactured varying the three given parameters. The 3 given parameters are Length, volume of Fiber and Time for alkaline treatment. Each parameter Consist of 3 Levels, hence the total experiments lead to 3x3x3 =27.

3.5 Fabrication Process
The fabrication process consists of preparation of alkaline solution, preparation of cocousnucifera and agvapineappleana fiber, preparation of moulding box. Which are discussed below in detail.

3.6 Preparation of alkaline solution
A 10% alkaline solution is prepared from Sodium Hydroxide Crystals. The solution is prepared by preparing a 10ml of saturated solution of Sodium Hydroxide (mixing about 10mg of Sodium Hydroxide in 10ml of distilled water). The saturated solution of Sodium Hydroxide is then mixed with 90ml of distilled water to get 10% alkaline solution.

3.7 Preparation of cocousnucifera and agvapineappleana fiber
The cocousnucifera and agvapineappleana fiber is cut for the required dimensions and is separated into individual strands and Mixed together. The fiber is then alkaline treated. The cut and cleaned fiber is taken and is immersed in 10% alkaline solution and is kept immersed for 1 hour, 2 hour and 3 hour. After the necessary time fiber is taken out and is cleaned by washing the fiber with distilled water. The cleaned fiber is taken out separated and is allowed to dry overnight. After the fiber is completely dried the fiber is weighed according to requirement and is used for moulding.

3.8 Moulding box Preparation
The moulding box is made of Aluminum sheet and is a box with dimensions of 20x20x2 cm. The moulding box is thoroughly cleaned and is applied with a reliving agent (Polyvinyl Acetate) and is allowed to dry for about 3 hours. The Polyester resin (IS052) is taken in a measuring jar and the weight is measured as the percentage weight of the fiber and 1% of Ethyl Methyl Ketone and 1% of Cobalt Napthalate. The solution is mixed using mixer for about 2 minutes

4. EXPERIMENTAL PROCEDURE

4.1 Work station preparation
An initial preparation of all the materials and tools that are going to be used is a fundamental standard procedure when working with composites. This is mainly because once the resin and the hardener are mixed, the working time (prior to the resin mix gelling) is limited by the speed of the hardener chemically reacting with the epoxy producing an exothermic reaction. Each group of student must prepare ALL materials and supplies available and set up before proceeding. Also, as part of the initial preparation, the woven cloth must be cut according to the shape of the part. In this experiment the student needs to have two pieces of fiberglass material cut into one foot squares.

4.2 Mold preparation
Before starting with the lay-up process an adequate mold preparation must be done. Mainly, this preparation consists of cleaning the mold and applying a release agent in the surface of it to avoid the resin to stick. In this experiment the mold preparation is simply taping the plastic sheeting to the tabletop. Clean the mold with a clean cloth, apply and spread release agent in the surface of the mold, Wait certain to set up the release agent, Buff with clean cloth.

4.3 Lay-up process
Once all the materials are prepared, the workstation is ready and the mold preparation done, the lay-up process can be started. The first step is to mix the resin and the hardener. The proportions are usually given by the supplier and can be found on the containers of the hardener or resin. The portions can be either measured by weight for by volume but it is important to follow these proportions exactly as this is a complete chemical reaction and all components must react completely for maximum strength of the matrix. Then initially the mold box layer is coated with the resin material, in order to improve surface coating and to ensure that the resin is spread throughout the material. Then weaved coir fiber is taken and it is placed over the mold box. Then calculated amount of resin is poured over the fiber so as to improve internal bonding. Then the pineapple fiber is placed over the coir fiber and the roller press is rolled over the fiber, high pressure is to be given so that, the resin spreads over the material evenly. Then again calculated amount of resin is poured over the material and the same procedure is repeated until the fifth layer of fiber is being placed. At this situation, all the remaining amount of resin is to be poured over the material and it is rolled with high pressure given by hand so that the resin spreads throughout the material. It is to be kept in room temperature for about 5-10 minutes and then it is to be done in compression molding process.

4.4 Cleaning
Once that part is ready to be cured, it must be moved to an adequate location. In this case it can be moved to a curing oven or simply left to cure in place until the next day. Then a cleanup must be done before going to compression molding process. All the materials used (brushes, rollers, mixing tools, scissor), including the table, must be cleaned using acetone and cloth. Also, the rest of the fibers and woven reinforcement must be collected from the table and floor. Soap and water can be used on skin if exposed. Any excess acetone should be properly disposed of, it is a good idea to put it in a proper disposal can with lid and disposed of correctly.

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4.5 Compression molding

Compression molding is a well-known technique to develop variety of composite products. It is a closed molding process with high pressure application. In this method, two matched metal molds are used to fabricate composite product. In compression molder, base plate is stationary while upper plate is movable. Reinforcement and matrix are placed in the metallic mold and the whole assembly is kept in between the compression molder. Heat and pressure is applied as per the requirement of composite for a definite period of time. The material placed in between the molding plates flows due to application of pressure and heat and acquires the shape of the mold cavity with high dimensional accuracy which depends upon mold design. Curing of the composite may carried out either at room temperature or at some elevated temperature. After curing, mold is opened and the hybrid composite product is removed for further processing.

In principle, a compression molding machine is a kind of press which is oriented vertically with two molding halves (top and bottom halves). Generally, hydraulic mechanism is used for pressure application in compression molding. The controlling parameters in compression molding method to develop superior and desired properties of the composite. All the three dimensions of the model (pressure, temperature and time of application) are critical and have to be optimized effectively to achieve tailored composite product as every dimension of the model is equally important to other one. If applied pressure is not sufficient, it will lead to poor interfacial adhesion of fiber and matrix. If pressure is too high, it may cause fiber breakage, expulsion of enough resin from the composite system.

If temperature is too high, properties of fibers and matrix may get changed. If temperature is low than desired, fibers may not get properly wetted due to high viscosity of polymers especially for thermoplastics. If time of application of these factors (pressure and temperature) is not sufficient (high or low), it may cause any of defects associated with insufficient pressure or temperature. The other manufacturing factors such as mold wall heating, closing rate of two matched plates of the plates and de-molding time also affect the production process.

Generally, the raw materials used to fabricate composites through compression molding process. The main need of compression molding process is that in order to make the resin spread evenly throughout the material, there may be formation of bubbles of resin material during the lay-up process, which is removed automatically during the compression molding process, to get a proper structure and to ensure smoother surface finish. During this process, the resin spreads throughout the surface and forms a smoother surface.

4.6 Final Curing

In order to make the material for use, final curing is to be done. Also during the compression molding process, the structure of the material distorts slightly. To ensure proper structure, final curing is done. So that the material evolved from compression molding process is kept at room temperature for about 20-24 hours to cure it. The material is now capable for all testing procedures to be done.

5. TESTING OF MECHANICAL PROPERTIES

5.1 ASTM Standards

ASTM International, known until 2001 as the American Society for Testing and Materials (ASTM), is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services.

5.2 Tensile testing (ASTM D-638)

A Tensile specimen is a standardized and performed by sample cross-section. The commonly used specimen for tensile test is the dog-bone specimen with end tabs. Preferred size by ASTM Standard is thickness of greater than 7mm but not more than 14mm.Tensile testing utilizes test geometry as shown above and consists of two regions: a central Core region called the gauge length, within which the possibility of failure is expected to occur, and the Extreme two core end regions which are clamped into a grip mechanism connected to a Tensile testing machine.

5.3 Flexural Testing (ASTM D-798)

The flexural strength of a Hybrid composite is the higher tensile stress that it can withstand during bending before reaching the critical breaking point. The rectangular test pieces of 127x12.7 x3 mm dimension for test are cut from the prepared NFRP composite. Flexural test is conducted as per ASTMD798.There are three different type of loading System (Two point Loading System and Three point Load System). The three point bend load test is conducted on every composite samples in the universal testing machine Instron1195, cross head speed of 10 mm/min are maintained.

5.4 Impact Testing (ASTM D 256)

The required standard dimension for the impact specimen is 63.5 x 21.7 x 6 mm. The thickness of the impact sample can vary between the limit 3-6. The v notch in the sample affects the results of the impact test, thus it is necessary for the notch to be of regular dimensions and geometry. The figure 4.3 shows the specimen manufactured for impact test.

6. DESIGN OF EXPERIMENT

Design of Experiment is a powerful tool which is used to estimate the relation between the process parameters. This method has more advantages compared to traditional methods. DOE gives accurate results and it is less time consuming process. DOE not only consider contribution factors individually but also consider interactions. In this paper the responses are tensile, impact, flexural strength.

7. RESULTS

Thus after conducting testing procedure, the results can be compared with glass fiber’s properties, and comparable applications are determined. Thus these materials can be replaced instead of conventional materials and high cost fiber reinforced composites. These materials have more advantages than that of glass fiber and certain other composites. These fibers are also bio degradable and hence used in a variety of applications.

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AUTHORS BIOGRAPHIES

Mr.G.Tharanitharan, Working as an Assistant Professor in the department of Mechanical Engineering, at SNS College of Technology , Coimbatore, Tamil Nadu. He pursued his B.E degree in SNS College of Technology. He pursued his M.E degree in Kongu Engineering College. His area of interest is Manufacturing.

T.Aravinth, Pursuing his Bachelor of Engineering degree in the stream of Mechanical Engineering, at SNS College of Technology, Coimbatore, Tamil Nadu. His area of interest is Manufacturing.

S.Ariharan, Pursuing his Bachelor of Engineering degree in the stream of Mechanical Engineering, at SNS College of Technology, Coimbatore, Tamil Nadu. His area of interest is Manufacturing.

S.Arun Kumar, Pursuing his Bachelor of Engineering degree in the stream of Mechanical Engineering, at SNS College of Technology, Coimbatore, Tamil Nadu. His area of interest is Manufacturing.

M.Ashok Kumar, Pursuing his Bachelor of Engineering degree in the stream of Mechanical Engineering, at SNS College of Technology, Coimbatore, Tamil Nadu. His area of interest is Manufacturing.