Analysis of Mechanical Properties of Hybrid Cocous Nucifera & Agva Sisalana Woven Fiber Laminate Composites

G.Tharanitharan[1],
[1] AP/MECH,
Dept. of Mechanical Engineering,
SNS College of Technology, Coimbatore.

P. Dhivakar[2], M.Chakravarthy[3], N.Dilbar[4], Akshai Bal Murali[5]
[2, 3, 4, 5] Dept. of Mechanical Engineering,
SNS College of Technology, Coimbatore

***Abstract* -The main objective of the present proposed work is to produce a composite material with enhanced mechanical properties than the existing natural composites. The existing material is produced by using *cocous nucifera* (Coir) *& Agva sisalana* (Sisal) fibers with epoxy as the matrix material, in which the fibers are chopped into small pieces and they are randomly oriented. Thus the properties in that composites are not even throughout the surface. In order to obtain similar properties throughout the material, woven fibers are being implemented. The concept of laminate composites are also implemented so as to improve the mechanical properties of the material. Hence, alternate layers of Coir & Sisal fibers are placed one over another to produce laminate composites (3 layers of Coir & 2 layers of Sisal). The fibers extracted are treated with NaOH to improve interfacial compatibility between the fibers and matrix and also to reduce the 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 fiber laminate composites have more properties than that of randomly oriented composites.**

***Keywords:* Coir, Sisal, Laminates, Alkaline Treatment, Hybridization, DOE, Volume fraction.**

1. INTRODUCTION

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 (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. 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. Long fibers that are oriented in the direction of loading offer the most efficient load transfer. This is because the stress transfer zone extends only over a small part of the fiber-matrix interface and perturbation effects at fiber ends may be neglected. Popular fibers available as continuous filaments for use in high performance composites are glass, carbon and aramid fibers. [1]Kumaresan.M et al 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]Gluespe Cristaldi et al made a detailed study on mechanical properties of natural fiber composites due to change in weaving. According to him Plain weaved fibers showed greater results than the other types of weaving.

[3]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 has showed good results than compared with polyester resin.

[4]K.P.Ashik et al studied about the properties of hybrid natural reinforced composites. It showed that individual fibers lacked certain properties. But hybridized fibers resulted in improved properties that can be comparable with properties of glass fibers.

2. MATERIAL SELECTION

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 color, are smoother and finer and usually weaker than brown coir. The fibers are strong, light and they can easily withstand heat and salt water. Coir is an abundant, versatile, renewable, cheap fiber. The addition of coir reduces thermal conductivity of the material.

Sisal

Sisal fiber is one of the most widely used natural fibers and is very easily cultivated. Almost 4.5 million tones are produced in each year all over the world. Generally the sisal fibers are defined by their source, age and cellulose content, giving it the strength and stiffness. The tensile properties of the sisal fiber are not uniform along its length. The root or lower part has low tensile strength and modulus but high fracture strain. The fiber becomes stronger and stiffer at mid-span and the tip has moderate properties. The price of sisal fiber is about one-ninth of the glass fiber. Sisal fibers resist seawater and have high mechanical properties which are comparable to those of glass fibers. Sisal is natural fiber fully biodegradable and it is exceptionally durable and a low maintenance with minimal wear and tear.

Epoxy

In case of high strength structural application, where stiffness, durability and light weight are required, epoxy resins are used as the best standard of performance. This is why in aircraft and aerospace applications, as well as off racing boats, epoxies have been the norm for years. It is also preferred due to its low cost. The use of epoxy as resin constitute of 4-% to 50%, has a significant impact on the cost of laminate. Epoxy has better ability to bond the reinforcement or core. It also has superior mechanical properties particularly strength and stiffness. It also has improved resistance to micro cracking and to osmosis. It has a reduced degradation from water ingress.

3. EXPERIMENTATION

3.1 Weaving of fiber

The bundles of coir and sisal 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 kept in an angle of 0^0 and 90^0 since earlier researches show that only 90^0 orientation showed greater results than other angles. Then the same procedure is repeated for sisal fiber.

3.2 Materials

Weaved fibers of coir and sisal are kept in alternate layers to form the laminated composites. In this coir is kept as first, third and fifth layer, while sisal 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 8 specimens are manufactured varying the three given parameters such as time for which the alkaline treatment is done, volume of fiber used and top and bottom layer of the fiber respectively. Each parameter consists of two levels. Hence, the total experiments lead to 2x2x2=8.

4. Fabrication Process

The fabrication process consists of preparation of alkaline solution, preparation of cocous nucifera and agva sisalana fiber, preparation of molding box. Which are discussed below in detail.

4.1 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.

4.2 Preparation of cocous nucifera and agva sisalana fiber

The *cocous nucifera* and *agva sisalana* 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 molding.

4.3 Molding box Preparation:

The molding box is made of Aluminum sheet and is a box with dimensions of 23x30x10cm. The molding box is thoroughly cleaned and is applied with a reliving agent (Polyvinyl Acetate) and is allowed to dry for about 3 hours. The Epoxy 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 a mixer for about 2 minutes.

5. EXPERIMENTAL PROCEDURE:

5.1 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.

5.2 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.

5.3 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 sisal 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.

5.4 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.

5.5 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.

5.6 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.

6. TESTING OF MECHANICAL PROPERTIES

6.1 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.

6.2 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. Fig. 4.1 Manufactured Materials for ASTM638.

4.3 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. 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. The figure 4.2 shows the specimen manufactured for flexural test.

4.4 Impact Testing (ASTM D 256)

The required standard dimension for the impact specimen is 63.5x21.7x6mm. 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.

5. 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.

6. 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.

7. REFERENCES

[1] Kumaresan.M, "Effect of fiber orientation on mechanical properties of Sisal reinforced composites," 2013.

[2] Gluespe Cristaldi, "Composites based on Natural fibers," 2012.

[3] Navdeep Malhotra, "Review on Mechanical properties and characters of Natural fiber reinforced composites," 2012.

[4] K.P.Ashik, "Mechanical properties of Natural fiber reinforced composites," 2015.

[5] N.Arvind, "Optimal stacking sequence and design of Laminate Composites," 2007.

[6] Galal.A.Hasan, "Effects of fiber orientation and Laminate stacking sequence on Laminate Composite Beams," 2009.

[7] M.H.Haj Mohammed, "Optimization of stacking sequence of Laminate Composites for Impact load," 2008.

[8] D.Selvaraju, "A review on applications of Composites," EISSN0976-7916, 2014.

[9] Gourav Gupta and Ankit Thakur, "A Review on Applications of Future Composites," ISSN2319-8753, 2016.

[10] G.L.Eashwara Prasad, "Comparative Study of Properties of Coir and Sisal Fiber Reinforced Composites," ISSN2347-6710, 2016.