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INFLUENCE OF HYBRIDISATION IN SISAL/JUTE FIBER REINFORCED POLYMERIC COMPOSITES

*Abilash N[1] and Sivapragash M[2]

[1] Faculty, Department of Mechanical Engineering, Noorul Islam University, Thuckalay, Tamilnadu-629180, India
[2] Research Director, Department of Mechanical Engineering, Noorul Islam University, Thuckalay, Tamilnadu-629180, India

ABSTRACT

Recently, immense interest was paid to new technologies dealing with environmental aspect. Upholding of natural resources such as natural fiber reinforced polymeric composite leads the upcoming manufacturing industry to search and scrutinize ecofriendly materials. The use of composites in manufacturing equipment and products is taking a very important space in the industry in general. Moreover these materials have unique characteristics when analyzed separately from constituents who are part of them. However it is know that care must be taken in their manufacture, as the use of appropriate process and the composition of each element, in addition to the adherence of fiber, which is a major factor in obtaining of the final mechanical strength of the product. One should also take into account whether the composites are environmentally friendly. For this reason, in this paper, a composite partially ecological was made, using natural fibers as reinforcement (sisal fiber and jute fiber), as strand which is a hybrid form of reinforcement in the polyester resin matrix phase to form a composite, seeking to improve the mechanical behaviour among its class of materials.

Keywords: *Natural fibers; FRP; Composites; Sisal; Jute; Resin; Polyester*

1. Introduction

A composite is formed by different materials, is homogeneous when examined macroscopically and, moreover, may have long or short fibers, which are used in a phase of the material that is called reinforcement [1]. Another phase of the composite is the matrix, which has an agglutinant function and causes the reinforcement to work in an integrated manner, supporting the mechanical stress [2]. Several recent technological achievements, particularly those related to relevant applications in areas such as aeronautic, aerospace, petrochemical, shipbuilding, bioengineering, automotive, construction, and sporting goods, among others, became possible only after the advent of structural composites [3]. In the quest for sustainability, several researches and works in the composites area have been made to ensure environmental preservation and provide a better standard of living to the society.

Among the researches in this area, those that seeking the application of natural resources in the preparation of materials are growing, and we could highlight the use of natural fibers of vegetable origin, due to the enormous variety of possible species to be surveyed.

Several vegetable fibers are produced in virtually every country and they are usually identified as lignocellulosic materials. Some fibers occur spontaneously in nature, others are grown as agricultural activity and still others are wastes generated mainly by agro industry [4]. However, according to factors such as weather, age, soil type, extraction method, etc., can seriously affect the structure of plant fibers, their chemical composition and physical properties [5]. As states, natural fibers (lingo-cellulosic) are lightweight and nontoxic, may have high elastic modulus and specific strength, cost about ten times less than the glass fiber and, unlike this inorganic fiber, cause less damage by abrasion to equipment and molds [6] . Among the various natural fibers, one make salient, in the manufacture of composite materials, the use of sisal, jute, hemp, ramie, palm, pineapple, sugar cane bagasse, wood fibers, coconut fibers, etc., which exhibit good mechanical properties as tensile, impact and others in various polymer matrices, especially the thermosetting ones [7]. The versatility of sisal fibers, which adapt to different forming processes of composites such as filament winding, lamination, resin transfer molding, extrusion, injection, etc., gives to these fibers strategically importance in the development of new composites.

Among other advantages of sisal, one can mention the facility of characteristic surface modification of vegetable fibers, their abundance in Brazil and easiness of cultivation. The hollow helical microstructure of the sisal is responsible for a failure mechanism distinct from other vegetable fibers, and the sisal reinforced composites show a work of fracture

Corresponding Author - E- mail: niceabi@rediffmail.com

similar to the composites of ultra high molecular weight polyethylene (UHMWPE) reinforced by fiber glass [8]. The utilization of natural fiber has gained attentions due to the reduction of waste disposal problems especially in agricultural fields, environmental pollution and hence can find various applications in engineering, electronic and automotive fields [2]. Green composites are environmentally friendly, sustainable, renewable, and biodegradable. Most cellulosic fibers are harvested yearly and the supply should be inexhaustible compared to the limited supply of other synthetic fibers. Natural fiber reinforced polymers also have exhibited numerous advantages such as high mechanical properties, low weight, low cost, low density, high specific properties [2], posses better electrical resistance, good thermal and acoustic insulating properties and higher resistance to fracture. Additionally, the natural fibers reinforced composites can decrease wearing of machines due to its low abrasiveness and absence of health hazardness during processing, application and upon disposal.

2. Fibers and its Types

Fibers are hair-like materials that are in discrete elongated pieces, similar to pieces of thread. They can be spun into thread. They can be used as an important component of composite materials. Fiber can be classified into two main groups; they are man-made fiber and natural fiber. In general, natural fibers can be subdivided as to their origin such as plants, animals, or minerals; while man-made fibers can be subdivided to synthetic and natural polymers. The first fibers used by man were natural fibers such as cotton, wool, silk, flax, hemp and sisal. The first man-made fiber was probably glass [2]. Both natural and synthetic fibers are now available and always being used as fillers in making a good properties of composites. In the last decade, there is a growing interest in Natural fiber reinforced composites because of their high performance in terms of mechanical properties, significant processing advantages, chemical resistance, and low cost/low density ratio. Natural fiber represents environmentally friendly alternatives to conventional reinforcing fibers. The main reward of Natural fiber over traditional ones are low cost, high toughness, low density, good specific strength properties, reduced tool wear, enhanced energy recovery, CO2 neutral when burned, biodegradability. Because of their hollow and cellular nature, Natural fiber performs as acoustic and thermal insulators, and exhibit reduced bulk density. Lingo cellulosic fibers can be classified in three categories: (1) wood flour particulate, which increases the tensile and flexural modulus of the composites, (2) fibers of higher aspect ratio that contribute to improve the composites modulus and strength when suitable additives are used to regulate the stress transfer between the matrix and the fibers, (3) long Natural fibers with highest efficiency among the lignocellulosic reinforcements. The most efficient Natural fibers have been considered those that have high cellulose content coupled with a low micro fibril angle, resulting in high filament mechanical properties. Depending on their origin, the major classifications of fibers used nowadays are given in Fig 1. Though even glass fibers have considerable advantages, the property of biodegradation in Natural fibers uplifts the usage of Natural Fiber Reinforced Polymeric materials in our daily life. Also, this fiber which doesn't possess any abrasion or emission of toxic gases and the recyclability proves why modern industries and researchers focused their attention in to NFRP composites.

2.1 Sisal

Sisal fiber is shown in Fig.2 which is valued for cordage use because of its strength, durability, ability to stretch, affinity for certain dyestuffs, and resistance to deterioration in saltwater. Sisal is used by industry in three grades. The lower grade fiber is processed by the paper industry because of its high content of cellulose and hemicelluloses. The medium grade fiber is used in the cordage industry for making ropes, baler and binders twine. Ropes and twines are widely employed for marine, agricultural, and general industrial use. The higher-grade fiber after treatment is converted into yarns and used by the carpet industry.

2.2 Jute

Fig. 3 shows the knitted jute fabric, Jute fiber is obtained from two herbaceous annual plants, white Corchorus capsularis (white jute) originating from Asia and Corchorus olitorius (Tossa jute) originating from Africa. Next to cotton, it is the second most common natural fiber, cultivated in the world and extensively grown in Bangladesh, China, India, Indonesia, Brazil; the jute plant grows six to ten feet in height and has no branches. The stem of the jute plant is covered with thick bark, which contains the fibers. In two or three month time, the plants grow up and then are cut, tied up in bundles and kept under water for several days for fermentation. Thus, the stems rot and the fibers from the bark become loose.

Then the cultivators pull off the fibers from the bark, wash very carefully and dry them in the sun. Jute is multi celled in structure. The cell wall of a fiber is made up of a number of layers: the so-called primary wall (the first layer deposited during cell development) and the secondary wall (S), which again is made up of the three layers (S1, S2 and S3). As in all lingo lamella.cellulosic fibers, these layers mainly contain cellulose, hemi cellulose and lignin in varying amounts. The individual fibers are bonded together by a lignin-rich region known as the middle lamella.

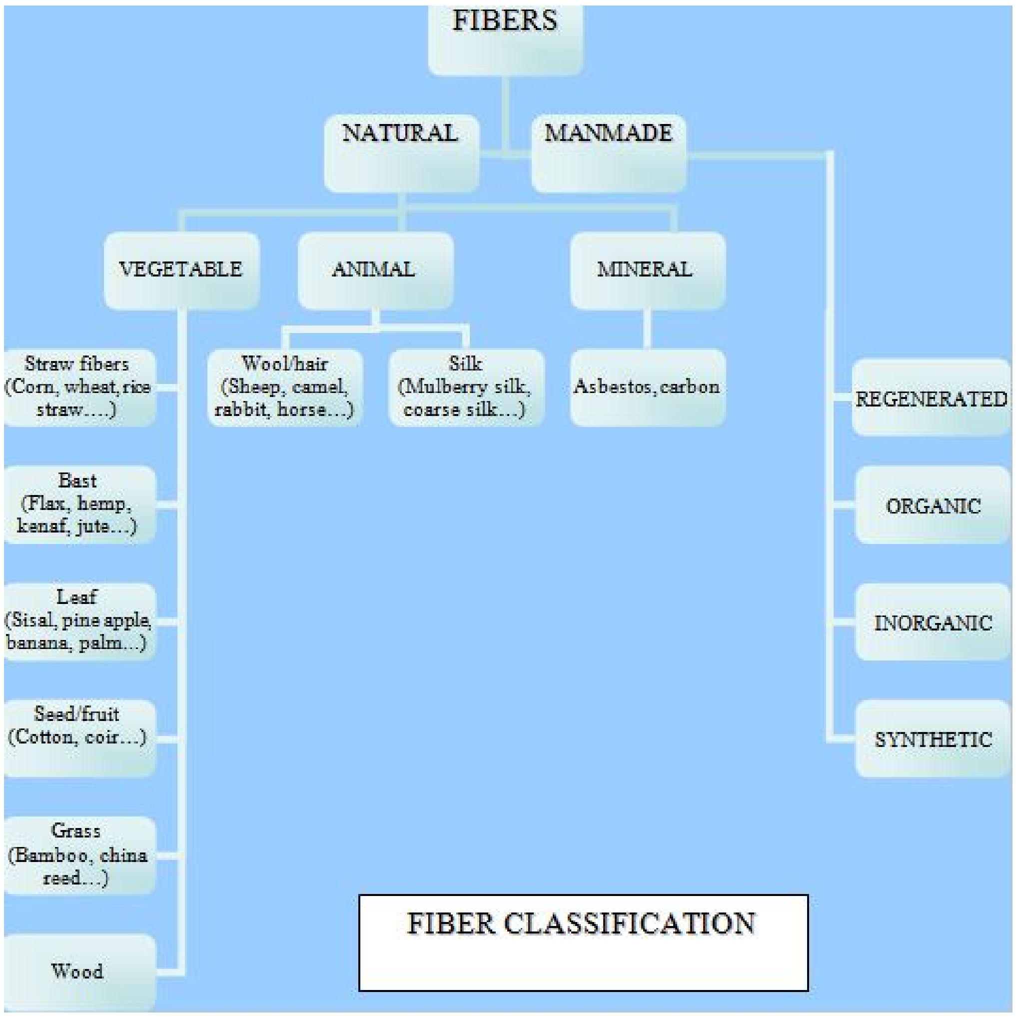

Fig.1 Fiber Classification

Fig.2 Extracted Sisal fiber

Fig.3 Jute fiber fabric

Cellulose attains highest concentration in the S2 layer (about 50%) and lignin is most concentrated in the middle lamella (about 90%) which, in principle, is free of cellulose. The S2 layer is usually by far the thickest layer and dominates the properties of the fibers .cellulose, a primary component of the fiber, is a linear condensation polymer consisting of Dan hydro-glucopyranose units joined together by ß-1, 4-glucosidic bonds . The long chains of cellulose are linked together in bundles called micro-fibrils. The most important types of natural fibers used in composite materials are flax, hemp, jute, kenaf, and sisal due to their properties and availability. Jute is an important bast fiber with a number of advantages. Jute has high specific properties, low density, less abrasive behavior to the processing equipment, good dimensional stability and harmlessness. Jute textile is a low cost Eco-friendly product and is abundantly available, easy to transport and has superior drapability and moisture retention capacity. It is widely being used as a natural choice for plant mulching and rural road pavement construction. The biodegradable and low priced jute products merge with the soil after using providing nourishment to the soil. Being made of cellulose, on combustion, jute does not generate toxic gases.

3. Fiber Reinforced Plastic

Fiber-reinforced plastic (FRP) are composite materials made of a polymer matrix reinforced with fibers. The fibers are usually fiberglass, carbon, or aramid, while the polymer is usually an epoxy, vinyl ester or polyester thermosetting plastic. FRPs are commonly used in the aerospace, automotive, marine, and construction industries.

4. Process Definition

A polymer is generally manufactured by polycondensation, Polymerization or polyaddition, when combined with various agents to enhance or in any way alter the material properties of polymers the result is referred to as a plastic. Composite plastics refer to those types of plastics that result from bonding two or more homogeneous materials with different material properties to derive a final product with certain desired material and mechanical properties. fiber reinforced plastics are a category of composite plastics that specifically use fibrous materials to mechanically enhance the strength and elasticity of plastics. The original plastic material without fiber reinforcement is known as the matrix. The matrix is a tough but relatively weak plastic that is reinforced by stronger stiffer reinforcing filaments or fibers.

5. Process Description

FRP involves two distinct processes, the first is the process whereby the fibrous material is manufactured and formed, and the second is the process whereby fibrous materials are bonded with the matrix during the molding process.

6. The Manufacture of Fiber Preforms

Fiber preforms are how the fibers are manufactured before being bonded to the matrix. Fiber preforms are often manufactured in sheets, continuous mats, or as continuous filaments for spray applications. The four major ways to manufacture the fiber preform is though the textile processing techniques of Weaving, knitting, braiding and stitching.

7. Molding Process

There are two distinct categories of molding processes using FRP plastics; this includes composite molding and wet molding. Composite molding uses Prepreg FRP, meaning the plastics are fiber reinforced before being put through further the molding process. Sheets of Prepreg FRP are heated or compressed in different ways to create geometric shapes. Wet molding combines fiber reinforcement and the matrix or resist during the molding process. The different forms of composite and wet molding are listed below.

7.1 Bladder Molding

Individual sheets of prepreg material are laid - up and placed in a female-style mold along with a balloon-like bladder. The mold is closed and placed in a heated press. Finally, the bladder is pressurized forcing the layers of material against the mold walls. The part is cured and removed from the hot mold. Bladder molding is a closed molding process with a relatively short cure cycle between 15 and 60 minutes making it ideal for making complex hollow geometric shapes at competitive costs.

7.2 Compression Molding

A "preform" or "charge", of SMC, BMC or sometimes prepreg fabric, is placed into mold cavity. The mold is closed and the material is compacted & cured inside by pressure and heat. Compression molding offers excellent detailing for geometric shapes ranging from pattern and relief detailing to complex curves and creative forms, to precision engineering all within a maximum curing time of 20 minutes.

7.3 Autoclave / Vacuum Bag

Individual sheets of prepreg material are laid-up and placed in an open mold. The material is covered with release film, bleeder/breather material and a vacuum bag. A vacuum is pulled on part and the entire mold is placed into an autoclave (heated pressure vessel). The part is cured with a continuous vacuum to extract entrapped gasses from laminate. This precise control creates the exact laminate geometric forms needed to ensure strength and safety in the aerospace industry, but it is also slow and labor intensive, meaning costs often confine it to the aerospace industry.

7.4 Mandrel wrapping

Sheets of prepreg material are wrapped around a steel or aluminum mandrel. The prepreg material is compacted by nylon or polypropylene cello tape. Parts are typically batch cured by hanging in an oven. After cure the cello and mandrel are removed leaving a hollow carbon tube. This process creates strong and robust hollow carbon tubes.

7.5 Wet layup

Fiber reinforcing fabric is placed in an open mold and then saturated with a wet [resin] by pouring it over the fabric and working it into the fabric and mold. The mold is then left so that the resin will cure, usually at room temperature, though heat is sometimes used to ensure a proper curing process.

7.6 Chopper gun

Continuous strand of fiber glass are pushed through a hand-held gun that both chops the strands and combines them with a catalyzed resin such as polyester. The impregnated chopped glass is shot onto the mold surface in whatever thickness the design and human operator think is appropriate. This process is good for large production runs at economical cost.

7.7 Filament winding

Machines pull fiber bundles through a wet bath of resin and wound over a rotating steel mandrel in specific orientations Parts are cured either room temperature or elevated temperatures. Mandrel is extracted, leaving a final geometric shape but can be left in some cases.

7.8 Pultrusion

Fiber bundles and slit fabrics are pulled through a wet bath of resin and formed into the rough part shape. Saturated material is extruded from a heated closed die curing while being continuously pulled through die. Process is could be done for any extruded material and geometric shape such as roadside reflector poles and ladder rails.

8. Fabrication of Hybrid Fiber Polyester Composite

Natural sisal/jute fiber reinforced polymeric composite is fabricated by closed-mold system. Fig.4 shows the individual view of male and female mold which is mainly used for composite fabrication. To make sisal/jute fiber composite, the fibers are weighed according to the fiber volume ratio. To maintain homogeneity, the fibers are arranged systematically according to the weight. Firstly, the weighed fibers are divided into two groups and they are knitted together as like a fabric mesh which represents a layer. The procedures are repeated for the second layers. Both layers are separated by polymeric resin placed inside the mold die along with the additives before fabrication as explained below. Initially the resin is measured according to the desired volume and the catalyst is measured for 0.9% by volume of the resin. The resin is mixed with catalyst and the mixture is stirred. A quarter of mixture is poured to the mold to ensure the mold surface is wetted. Then, the first layer of the fibers is laid gently without disturbing the fiber orientation. Then another quarter of mixture is poured to wet the fibers. Trowel is used to remove the air. Another quarter of mixture is poured before laying the second layer of the fibers. The last quarter of mixture is poured before the mold is closed and screwed by means of hydraulic press. The composite plate is removed from the mold after 24 hours. The procedures are repeated for all specimens. The specimen is ready for testing after 7 days of composite fabrication to ensure the resin is fully cured and hardened. The renewability of natural fiber provides an attractive Eco-friendly quality to the resulting composites. We studied the use of fiber gives higher tensile module (E) and applicable for using the composite material in the above mentioned application more effectively than the old one. Fig.4&5 shows the male and female mold and the compression molding setup used to fabricate the sisal reinforced polymeric composite as shown in Fig.6.

Fig. 4 Male & Female Mold

Fig. 5 Molding Setup

Fig. 6 Fabricated Composite

9. Measured Values of Various Properties

The measures values of various properties of the four specimens A, B, C, D are given in Table.1 which states specimen D gives maximum tensile property when the test is carried out in Instron UTM machine. In this specimens A, B, C, D are hybrid specimens with varying fiber weight percentages, among this specimen D with 65% of fiber shows maximum properties, which is very clear in Fig 7&8.

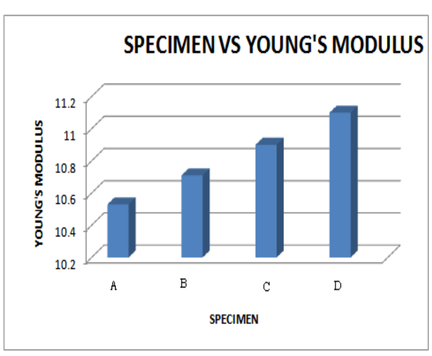

Fig.7 Specimen Vs Modulus

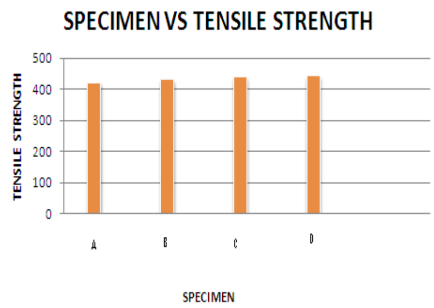

Fig. 8 Specimen Vs Tensile strength

Table 1: Measured Values of Various Properties

Properties of hybrid specimen	Specimen A	Specimen B	Specimen C	Specimen D
Yield strength N/mm^2	61.4	66.14	77.16	83.5
Tensile strength N/mm^2	322	330.5	341.4	351.96
% Elongation	1.79%	1.83%	1.89%	1.98%
% reduction area	0.299%	0.393%	0.48%	0.629%
Young's modulus Gpa	8.1	8.3	8.58	8.74
Lateral strain	3.93×10^{-3}	5.581×10^{-3}	7.086×10^{-3}	9.448×10^{-3}
Linear strain	0.0179	0.0183	0.0189	0.0198
Poisson 's ratio	0.22	0.30	0.37	0.5

10. Conclusion

Natural fibers show signs of better advantages over the man-made fibers especially in cost, environmental aspects and high specific modulus when compared to synthetic fibers. The drawbacks can be somewhat overcome by introducing chemical or physical treatments to the natural fibers. A lot trials and testing have been reported in the past few decades, the advancements in materials technology leads the successful usage of treated fibers in majority of the composites. In this sisal reinforced polymeric composite with the laminates thereby reducing the chances of delaminating failures and considerable rise in the tensile module by adding appropriate quantity of fiber. This gives a positive approach to conduct further studies in the characterization of this composite.

11. Scope for Future Work

This study leaves wide scope for future investigations. It can be extended to newer composites using other reinforcing phases and the resulting experimental findings can be analyzed. Tribological evaluation of coconut fiber reinforced epoxy resin composite has been a much less studied area. There is a very wide scope for future scholars to explore this area of research. Many other aspects of this problem like effect of fiber orientation, loading pattern, weight fraction of ceramic fillers on wear response of such composites requires further investigation.

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