



BIO-DESIGN AND FABRICATION OF BIOCOMPOSITE HELMET (JUTE, SISAL & GLASS FIBER)

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ABSTRACT

Recently, bio composite materials are synthesized using natural cellulose fibers as reinforcements together with matrix, which have attracted the attention of researchers due to their low density with high specific mechanical strengths, availability, and renewability, degradable and being environmentally friendly. The present work attempts to make an improvement in the current existing helmet manufacturing methodology and materials used to have better mechanical properties as well as to enhance the compatibility between fibers and the matrix. The bio-composite are prepared with the epoxy matrix and fibers such as jute, sisal using hand lay-up method with appropriate proportions to result in rectangular composite samples. The fabricated samples are planned to evaluate its mechanical properties such as tensile strength, impact strength, cross breaking strength and density.

Keywords: Natural fiber, Epoxy resin, Reinforcement, Jute Cloth, Sisal, Glass Fiber

INTRODUCTION

Overview of composites

Over the last thirty years composite materials, plastics and ceramics have been the dominant emerging materials. The

volume and number of applications of composite materials have grown steadily, penetrating and conquering new markets relentlessly [1]. Modern composite materials

constitute a significant proportion of the engineered materials market ranging from everyday products to sophisticated niche applications. While composites have already proven their worth as weight-saving materials, the current challenge is to make them cost effective [2]. The efforts to produce economically attractive composite components have resulted in several innovative manufacturing techniques currently being used in the composites industry. It is obvious, especially for composites, that the improvement in manufacturing technology alone is not enough to overcome the cost hurdle. It is essential that there be an integrated effort in design, material, process, tooling, quality assurance, manufacturing, and even program management for composites to become competitive with metals [3]. The composites industry has begun to recognize that the commercial applications of composites promise to offer much larger business opportunities than the aerospace sector due to the sheer size of transportation industry. Thus, the shift of composite applications from aircraft to other commercial uses has become prominent in recent years. Increasingly enabled by the introduction of newer polymer resin matrix materials and high-performance reinforcement fibers of

glass, carbon and aramid, the penetration of these advanced materials has witnessed a steady expansion in uses and volume. The increased volume has resulted in an expected reduction in costs. High performance FRP can now be found in such diverse applications as composite armoring designed to resist explosive impacts, fuel cylinders for natural gas vehicles, windmill blades, industrial drive shafts, support beams of highway bridges and even paper making rollers. For certain applications, the use of composites rather than metals has in fact resulted in savings of both cost and weight. Some examples are cascades for engines, curved fairing and fillets, replacements for welded metallic parts, cylinders, tubes, ducts, blade containment bands etc. Further, the need of composite for lighter construction materials and more seismic resistant structures has emphasis on the use of new and advanced material that not only decreases dead weight but also absorbs the shock & vibration through tailored microstructures. Composites are now extensively being used for rehabilitation/strengthening of pre-existing structures that must be retrofitted to make them seismic resistant, or to repair damage caused by seismic activity. Unlike conventional materials (e.g., steel), the properties of the

composite material can be designed considering the structural aspects [4]. A composite material consists of two or more physically and or chemically distinct, suitably arranged, or distributed phases, with an interface separating them. It has characteristics that are not depicted by any of the components in isolation. Most commonly, composite materials have a bulk phase, which is continuous, called the matrix, and one dispersed, non-continuous, phase called the reinforcement, which is usually harder and stronger. The belief is that biodegradable polymer materials will reduce the need for synthetic polymer production (thus reducing pollution) at a low cost, thereby producing a positive effect both environmentally and economically. This paper is intended to provide a brief outline of work that is under way in biodegradable polymer research and development, the scientific theory behind these materials, areas in which this research is being applied, and future work that awaits.

Yan Le at all presents a summary of recent developments of sisal fiber and its composites [5]. The properties of sisal fiber itself interface between sisal fiber and matrix, properties of sisal fiber-reinforced composites and their hybrid composites have been reviewed. Suggestions for future work

are also given. In the review they describe in detail about the properties of sisal fiber, Interface properties between sisal fiber and matrix; Properties of sisal-fiber-reinforced composites; Sisal/glass-fiber-reinforced hybrid composites; Price; Interface modifications; Treatment of sisal fiber; Alkali treatment; Isocyanate treatment; Peroxide treatment; Permanganate treatment; surface Treatment of fiber/matrix interfaces; Sisal/ polyestercomposites; Sisal/ epoxycomposites; Sisal/ phenolformaldehyde composites; Sisal/polyethylene composites; Sisal-fiber-reinforced thermo set matrices; Sisal-fiber-reinforced thermoplastics matrices; Processing methods; Properties of sisal fiber reinforced polyethylene; Properties of sisal fiber-reinforced polystyrene matrices; Properties of sisal-fiber-reinforced PVC composite; Sisal-fiber-reinforced rubber matrix; Sisal-fiber-reinforced gypsum and cement matrices; Sisal and synthetic hybrid-fiber composites; and they evaluate the Dynamic mechanical properties. Electrical properties and Ageing properties. Finally, they conclude that different matrix systems have different properties. The mechanical and physical properties of sisal-fiber-reinforced composites are very sensitive to processing methods, fiber length, fiber orientation and fiber-volume fraction. Sisal

and glass fiber can be combined to produce hybrid composites which take full advantage of the best properties of the constituents; almost all the mechanical properties have shown positive hybrid effects. K. Murali Mohan Rao. *et al* aims at introducing new natural fibers used as fillers in a polymeric matrix enabling production of economical and lightweight composites for load carrying structures [6]. An investigation of the extraction procedures of vakka (Roystonea regia), date and bamboo fibers has been undertaken. The cross-sectional shape, the density, and tensile properties of these fibers, along with established fibers like sisal, banana, coconut, and palm are determined experimentally under similar conditions and compared. The fibers introduced in the present study could be used as ineffective reinforcement for making composites, which have an added advantage of being lightweight. K. Murali Mohan Rao. *et al* have carried out a study to investigate the tensile, flexural, and dielectric properties of composites made by reinforcing vakka as a new natural fiber into a poly ester in matrix [7]. The fibers extracted by retting and manual processes have been used to fabricate the composites. These composites are tested for tensile, flexural, and dielectric properties and compared with those of

established composites like sisal, bamboo and banana made under the same laboratory conditions [8]. The composites are fabricated up to a maximum volume fraction of fiber of 0.37 in the case of tensile testing and 0.39 for flexural and dielectric testing [9]. It has been observed that the tensile properties increase with respect to volume fraction of fiber for vakka fiber composite and are also more than those of sisal and banana composites and comparable to those of bamboo composites [10]. The flexural strength of vakka fiber composite is more than that of banana composite and is closer to sisal fiber composite with respect to the volume fraction of fiber, whereas the flexural modulus is much higher than those of banana and sisal fiber composites and very much closer to bamboo fiber composites [11].

MATERIALS AND METHODS

Natural fibers such as Sisal/Jute fiber cloth & Synthetic fibers such as Glass fiber cloth

Fiber-reinforced polymer composites have played a dominant role for a long time in a variety of applications for their high specific strength and modulus [12]. The manufacture, use and removal of traditional fiber-reinforced plastic, usually made of glass, carbon or aramid fibers-reinforced thermoplastic and thermoset resins are

considered critically because of environmental problems [13]. By natural fiber composites we mean a composite material that is reinforced with fibers, particles or platelets from natural or renewable resources, in contrast to for example jute or sisal fibers that have to be synthesized [14].

ADVANTAGES OF NATURAL FIBERS

Comparing to conventional reinforcing fibers like glass, carbon and Kevlar, natural fibers have the following advantages:

- Environmentally friendly
- Fully biodegradable

- Non toxic
- Easy to handle
- Non abrasive during processing and use
- Low density/light weight
- Source of income for rural/agricultural community
- Renewable, abundant and continuous supply of raw materials
- Low cost
- Free from health hazard (cause no skin irritations)
- High toughness
- Good Thermal Properties.

Table 1: Properties of natural fiber

Plant Fibers	Density (Kg/m ³)	Tensile Strength (MPa)	Young's Modulus (GPa)
Jute Fiber	1300-1500	200-450	20-55
Sisal Fiber	1300-1500	80-840	9-22

Step 1: Selection of matrix material

Epoxy LY-556 (di-glycidal ether of Bisphenol-A, DGEBA having density 1.16gm/cm³) resin belonging to the Epoxide family was taken as the matrix.

HY 951 (tri-ethylene tetra-amine having density 0.95 gm/cm³) was used as the hardener.

Step 2: Selection of reinforcement and Natural fibers

Natural fibers such as Sisal and jute were taken to fill as reinforcements in the Polymer composite.

Synthetic fiber that is glass fiber (7 mill, 200 ± 20 GSM) [15]

Step 3: Availability of Natural fiber (Sisal & Jute) 0.7mm thickness each, Sisal Fiber cloth:

Sisal is a natural fiber (Scientific name is Agave sisalana) of Agavaceae (Agave) family yields a stiff fiber traditionally used in making twine and rope.

Sisal is fully biodegradable and highly renewable resource.

Sisal fiber is exceptionally durable and a low maintenance with minimal wear and tear.



Figure 1: Sisal Fiber

Jute Fiber cloth:

□ Jute is a long, soft, shiny plant fiber that can be spun into coarse, strong threads. It is produced from plants in the genus *Corchorus*.

□ Jute is one of the cheapest natural fibers, and is second only to cotton in amount produced and variety of uses.

□ Jute fibers are composed primarily of the plant materials cellulose and lignin. Jute is a rainy season crop, growing best in warm, humid climates [16].

□ It is 100% bio-degradable & recyclable and thus environment friendly.



Figure 2: Jute cloth

Step 4: Availability of Synthetic fiber (Glass) 7mill & 200±20 GSM

Glass Fiber cloth:

□ **Strong and long-lasting:** Pound for Pound fiberglass is stronger than sheet metal. Fiberglass has a high resistance to corrosion, it will not rust.

□ **Design Freedom:** There are very few restrictions with molding fiberglass, giving the engineer unlimited possibilities.

□ **Appearance:** Using fiberglass for product covers and enclosures definitely improves its esthetics. Achieve any look and feel desired.

Finishes give fiberglass components a high tech appearance.

□ **Cost Effectiveness:** With steel being dependent on China's steel prices, you will have stable prices with fiberglass. Lower costs for maintenance and warranty work.

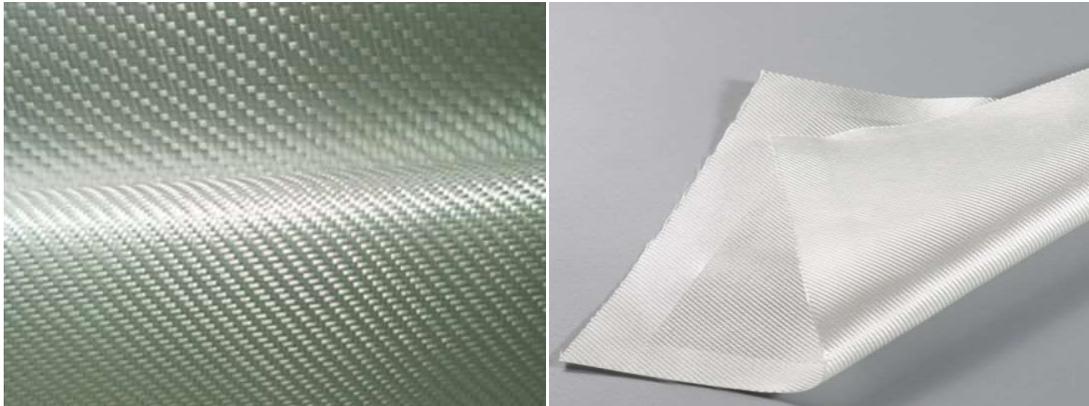


Figure 3: Glass Fiber Cloth

Freshly drawn fibers generally include lots of impurities that can adversely affect the fiber matrix bonding. Consequently the composite material made from such fibers may not possess satisfactory mechanical properties. Therefore it is desirable to eliminate the impurity content of the fibers and perhaps

□ **Special Characteristics:** Fiberglass is non-conductive and radio frequency transparent. Perfect for housing electronics without disturbing their performance and protect employees from hazards inside.

enhance the surface topography of the fibers to obtain a stronger fiber-matrix bonding. The fibers were left to treat with 5% NaOH for 3-4 hrs. Later they were drawn and dried under sunlight for 1-2 hours.

Surface treatment of fibers:



Figure 4: (a) 5% NaOH solution



Figure 5: (b) Fibers in NaOH solution



Figure 6: (c) Fibers after Pre-treatment

Step 5: Wet Hand lay-up technique

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardner (curing agent) and poured onto the surface of mat already placed in the mold.

The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the

mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied.

After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The schematic of hand lay-up is shown. The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Capital and infrastructural requirements less as compared to other methods. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites. Hand

lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, dias board, deck etc.

SAMPLE PREPARATION

PREPARATION OF SHEET 1

First sheet was prepared using Epoxy resin system (LY-556 & HY-951) & Glass cloth (7 mill , 200± 20 GSM)

SHEET SPECIFICATION

Sheet size : (250 X 250 X 5) mm
 Weight of sheet : (250 X 250 X 250 X 1.8) = 562.5 gm
 Glass cloth (7mill) : 337 gm i.e. 60% of total sheet weight
 Resin system : 40% of total sheet weight (Epoxy resin : 85% = 210gm + Hardener: 15% = 32gm)
 Layers used : 26 layers of Glass fiber cloth (250 X 250 X 0.18)
 Curing time : 8 - 10 hours (Cold cure)
 Weight applied : 10 - 15 kgs.

PREPARATION OF SHEET 2

Second sheet was prepared using Epoxy resin system (LY-556 & HY-951) & Hybrid fiber system (85% natural fiber such as jute & sisal of thickness 0.7mm each , 15% Glass fiber of thickness 0.18mm i.e. 7 mill).

SHEET SPECIFICATION:

Sheet size : (250 X 250 X 5) mm
 Weight of sheet : (250 X 250 X 5 X 1.8) = 562.5 gm
 Glass cloth (7mill) : 42.187 gm i.e. 15% of total fiber weight
 Natural fiber : 239.062 gm i.e. 85% of total fiber weight
 Total fiber weight : 281.25 gm
 Resin system : 50% of total sheet weight [Epoxy resin:85% = (244.565gm+60gm) + Hardener: 15% = (36.685gm+15gm)]
 Layers used : 8 Layers (6 layers of Natural fiber & 2 layers of glass fiber).
 Curing time : 8 - 10 hours (Cold cure) Weight applied : 10 - 15 kgs.

TESTING AND RESULTS

Impact Strength Testing of Composites:

ASTM D 256: Standard test method for impact properties of polymer matrix composites. Charpy impact strength of composite samples is evaluated as per ASTM D256, using Impact Testing.

The test specimen geometry as specified in the above standard for balance symmetric glass and carbon fiber (0/90) composites are 120 mm long × 15mm wide × 5mm thick. The charpy test specimens are clamped in an horizontal position so that the end of the specimen faced its striking edge and impact

energy absorbed for breaking the specimen is directly obtained. Impact strength is calculated using the expression.

Impact strength = Impact energy in joules / thickness of the specimen (mm).

Tensile Strength Testing of Composites

Tensile strength is defined as the ability of the material to be withstand tensile force when pulled apart. It is expressed in kg/cm². The test specimen geometry as specified in the above standard for balanced symmetric carbon and glass fiber composites (0/90) are , width 32 mm, length 220 mm, and specified thickness in mm. Tensile strength can be calculated using the following formula: Tensile strength = Tensile load at break / Cross-section area of sample.

FABRICATION OF HELMET

FABRICATION OF A SIMPLE HELMET USING THIS HYBRID COMPOSITE

After having testing results we have found that the composition of hybrid natural fiber/glass fibre epoxy resin system (Sheet 2) has more or equivalent mechanical properties such as tensile strength, cross-breaking strength and charpy impact strength. So, we have taken the Sheet 2 composition for the fabrication of helmet as it contain 85%

natural fiber (jute and sisal). Fabrication of the helmet was carried out by adopting the following hand lay process procedure. For this fabrication procedure a old ABS helmet was taken as a mould as shown in **Figure 1 (a)**. Initially a layer of silicon release film was spread over which a layer of epoxy – LY-556 and hardener HY-951 mixture is coated inside the ABS helmet mould shown in **Figure 1 (a)**, which will act as an adhesive for a bottom layer of jute cloth. Over the jute cloth once again a layer of epoxy resin system is applied, subsequently the synthetic fiber reinforcement such as glass fiber cloth & natural fiber reinforcement jute & sisal fiber cloth are placed respectively. Finally, a layer jute mat is placed as a top layer as shown in **Figure 1 (b)**. Now these fibers are compressed with help of metal blocks and C-clamps, to ensure the proper bonding between reinforcement and fibers. Subsequently, allowed for settling time of about 6 – 8 hours, then mould was released. The jute mat used prevents the de-bonding of the fibers. After releasing well cured and dried helmet from the mould (**Figure 1 (c)**), the extra projections were cut, filed and smoothened with help of sand paper to achieve the desired shape.



Figure 7: Sequential Stages in Bio-Composite Helmet Fabrication

CONCLUSION

In the present work, bio-composite with multiple natural fibers such as jute fibers, sisal fibers and synthetic fibre such as glass fibre have been successfully reinforced with the epoxy resin by simple and inexpensive hand lay-up technique. The mechanical testing results of fabricated bio composite helmet indicate that, concept of using multiple natural fibers is viable for helmet application. However, there is a scope to optimize the volume fraction of natural fibers as reinforcements to achieve enhanced mechanical properties of helmet. So, it is clearly indicates that reinforcement of hybrid natural fibers/glass fiber have good and comparable mechanical properties as conventional composite materials.

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