

BIO COMPOSITE HELMET USING NATURAL CELLULOSE FIBERS AS REINFORCEMENTS**G. Gunalan*, P. Magudapathi**, J. Sedhupathi***, B. Sudarsan***
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Abstract:

Recently, bio-composite materials are synthesized using natural cellulose fibres as reinforcements together with matrix, which have attracted the attention of researchers due to their low density with high specific mechanical strengths, availability, renewability, degradable and being environmental-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 unsaturated polyester matrix and fibers such as jute mat, coconut coir, and banana fibers using hand lay-up method with appropriate proportions to result in helmet shell structure. The fabricated helmet are planned to evaluate its mechanical properties such as tensile strength, impact strength and compression strength.

Key Words: Metal Matrix Composites, Heat Treatment, Wear, Hybrid Aluminium Matrix Composites.

1. Introduction:

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. 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. 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. 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 armouring 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 placed high emphasis on the use of new and advanced materials 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 have to 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. 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 function of individual components has been described as:

Matrix Phase:

The primary phase, having a continuous character, is called matrix. Matrix is usually more ductile and less hard phase. It holds the dispersed phase and shares a load with it.

Dispersed (Reinforcing) Phase:

The second phase (or phases) is embedded in the matrix in a discontinuous form. This secondary phase is called dispersed phase. Dispersed phase is usually stronger than the matrix, therefore it is sometimes called reinforcing phase. Many of common materials (metal alloys, doped Ceramics and Polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (physical properties of steel are similar to those of pure iron). There are two classification systems of composite materials. One of them is based on the matrix material (metal, ceramic, polymer) and the second is based on the material structure. Animal fiber generally comprise proteins; examples mohair, wool, silk, alpaca, angora. Animal hair (wool or

hair) are the fibers taken from animals or hairy mammals. E.g. Sheep's wool, goat hair (cashmere, mohair), alpaca hair, horse hair, etc. Silk fiber are the fibers collected from dried saliva of bugs or insects during the preparation of cocoons. Examples include silk from silk worms. Avian fiber are the fibers from birds, e.g. feathers and feather fiber.

Experimental Procedure:

Selection of Matrix Material: HY 951 was used as the hardener.

Selection of Reinforcement and Natural Fibers: Natural fibers such as Sisal, Coconut coir, Arecanut, Ridge gourd and Tamarind were taken to fill as reinforcements in the Polymer composite.

Extraction of fibers - Jute Mat Fiber: 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.
- It is 100% bio-degradable & recyclable and thus environment friendly.

Banana Fiber: Banana Fiber contains cellulose, hemicelluloses and lignin. Available at reasonable prices, our Banana Fiber is widely appreciated for its characteristics such as high strength, strong moisture absorption, good luster, light weight, fast moisture absorption and release, small elongation, easy degradation and many more.

Coconut Coir Fiber: Coconut coir- Coconut fruit peel were gathered and soaked in water. Later clean fibers were drawn manually from them.

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 in figure 1. 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, diase board, deck etc.



Step-1



Step-2



Step-3

Figure 1: Sample preparation by wet hand layup process

Age Hardening Process:

Hardening is a metallurgical and metal working process used to increase the hardness of a metal. The hardness of a metal is directly proportional to the uniaxial yield stress at the location of the imposed strain. A harder metal will have a higher

resistance to plastic deformation than a less hard metal. Precipitation hardening also called age hardening is a heat treatment technique used to increase the yield strength of malleable materials, including most structural alloys of aluminium, magnesium, nickel, titanium, and some stainless steels. In this each proportion of specimen is heated at temperature of 440K in the muffle furnace. The temperature is maintained for 2 hours of duration then water quenching has been done immediately. After age hardening process wear testing has been done to study the wear behavior of the each proportion.

Impact Strength Testing of Composites:

ASTM D 256: Standard test method for impact properties of polymer matrix composites. Izod impact strength of composite samples is evaluated as per astm d256, using impact testing machine supplied by international equipments, Mumbai, India

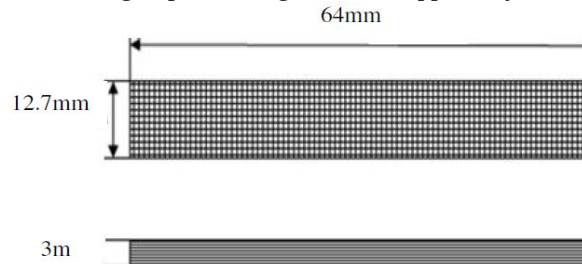


Fig. 5.5: Impact test specimen

The test specimen geometry as specified in the above standard for balance symmetric glass and carbon fiber (0/90) composites are 64 mm long $\times$ 12.7 mm wide $\times$ 3 mm thick (fig 5.5). The izod test specimens are clamped in an upright 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)



Figure 3: Izod Impact Testing Machine

Result and Discussion:

The following tables provides the details of the Impact test results obtained for various combinations of Natural fibers reinforced bio-composites.

Impact Test Result:

Specimen	Impact Energy Absorbed Joules
Sample-1	6
Sample-2	4
Sample-3	4

Table 1: Impact Test Result

Test Result of Bio Composite Helmet:

The drop weight impact tests were performed on the fabricated bio-composite helmet. Although, the maximum permissible limit of 19.5 kN (as per BIS standard) impact load is required for drop weight impact analysis, due to limitation of test rig, we performed the test with drop mass of 430 N. Figure 3, shows the impact load against displacement for tested bio-composite helmet. It could be observed that maximum permissible load withstood by the helmet is 68.57 KN and the impact energy absorbed by the helmet was found to be 1397.913 KJ by post processing the experimentally acquired data.

Conclusion:

Important conclusions of this investigation are:

- The natural fibers have been successfully reinforced with the epoxy resin by simple wet hand lay-up technique. The aim of this project is to find the tensile, Bending, ILSS and impact strength of natural fiber reinforced bio-composites.
- The fibers like jute fibers, coconut coir, areca nut fibers, sisal fibers were successfully used to fabricate bio-composites with varying the fiber percentage.
- The new hybrid composite produced with natural fibers as reinforcements gives good mechanical properties as compared with pure matrix material. These hybridbio- composite can be used in Aerospace and automobile applications.

In the present work, bio-composite with multiple natural fibers such as jute fibers, Coconut coir, areca fibers, sisal fibers, banana fibers 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 natural fibers have good and comparable mechanical properties as conventional composite materials.

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