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DESIGN, ANALYSIS and MANUFACTURING of POLYMER COMPOSITE HELMET

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Abstract-

A prototype model of the safety helmet is made using successive layers of natural composite fibre using hand layup technique. The work aims at developing a safer industrial helmet with better physical properties along with improved strength as compared to present day safety helmets. The 3D model was drawn with the help of CATIA software. The analysis was carried out on the ANSYS Workbench software. The prototype along with existing safety helmet both were then subjected to impact testing and flexural testing. The comparison between results from the mechanical testing of both specimens shows that the natural fibre helmet shows better load bearing capacity as against conventional safety helmet. A comparative study of results from mechanical testing and software analysis will help us to arrive at an appropriate conclusion and suitable future scope will be suggested.

Keywords— Jute, ABS, ANSYS, CATIA, impact testing, flexural testing.

I. INTRODUCTION

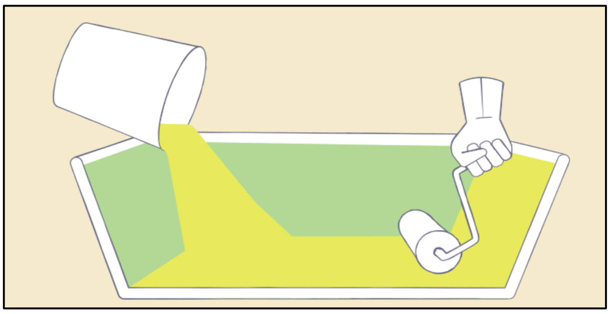
Recently, the major environmental problem faced today is the non-degradable plastic wastes. The continuous manufacturing and utilization of plastics in each sector of our life has expanded the plastic waste in enormous scales. The waste management issues, have coordinated extraordinary part of the investigative exploration to eco composite materials that can be effortlessly debased or bio acclimatized. The bio composite would consists of characteristic strands of natural fibers and suitable polymer matrix. In addition, bio composites are mixture of regular natural fiber strands with a polymer matrix of biodegradable nature. Composite material can be the answer to such needs. Composites can provide better combination of properties which is achieved by cohesion of materials made by physically combining two or more materials with different characteristics. Another reason is the generation of extreme amount of greenhouse gases and need of high energy levels for producing products from raw materials that are obtained from crude oil has drawn the attention of manufacturers towards green composites fabricated from renewable and sustainable materials. The green composites reduce carbon foot print and dependence on crude oil derived raw materials. Green composites are basically made up of natural fibres which are abundantly available and many times are left in the atmosphere as waste, Due to their low density, low cost, eco-friendly character and biodegradability natural fibres are attracting the attention of researchers worldwide. But natural fibre reinforced competition have high water absorption tendency and are mechanically inferior to synthetic fibres. Jute fibre, consisting of hydro folic polar groups, is one such natural fibre. These polar groups enable formation of hydrogen bonds when jute is in contact with water molecules. This water absorption capacity of jute contributes to poor interfacial bonding between fibres and matrix. Hybrid composites may answer the question of high water absorption capacity of natural fibre and inferior mechanical properties of natural fibre reinforced composites.

Generally, a composite material can be defined as a non-homogeneous material which consists of at least two individual materials. These components are clearly noticeable, and thus between two components a clear boundary line exists. There are two categories of constituent materials: matrix and reinforcement. The matrix material surrounds and supports the reinforcement materials by maintaining their relative positions. The reinforcements impart their mechanical and physical properties to enhance the matrix properties. This Fibre reinforced material is used as construction material due to its mechanical properties. The material has very good mechanical properties (strength and stiffness) in the direction of the Fibre, combined with a low mass density. The stiffness of a component means how much it deflects under a given load. The strength of a material is its resistance to failure by permanent deformation. The mechanical properties depend on the direction of the fibre, this gives the material an anisotropic character. This is in contrast with isotropic materials such as steel and aluminium, there the material properties are the same in every direction.

MANUFACTURING PROCESS-

Hand Lay-Up

Hand lay-up is the simplest composites molding method, offering low cost tooling, simple processing, and a wide range of part sizes. Design changes are readily made. There is a minimum investment in equipment. With skilled operators, good production rates and consistent quality are obtainable.



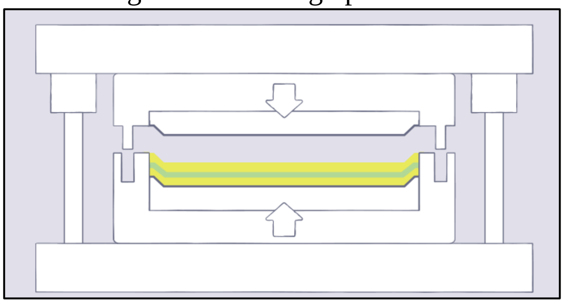
Process

Gel coat is first applied to the mold using a spray gun for a high quality surface. When the gel coat has cured sufficiently, roll stock fiberglass reinforcement is manually placed on the mold. The laminating resin is applied by pouring, brushing, spraying, or using a paint roller. FRP rollers, paint rollers, or squeegees are used to consolidate the laminate, thoroughly wetting the reinforcement and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness. Low density core materials such as end-grain balsa, foam, and honeycomb, are commonly used to stiffen the laminate. This is known as sandwich construction.

Compression molding

Compression molding is a high-volume, high-pressure method suitable for molding complex, fiberglass-reinforced polymer parts on a rapid cycle time.\

Compression molding tooling consists of heated metal molds mounted in large hydraulic presses. The process can be automated. Compression molding enables part design flexibility and features such as inserts, ribs, bosses and attachments. Good surface finishes are obtainable, contributing to lower part finishing cost. Subsequent trimming and machining operations are minimized in compression molding and labor costs are low.



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Process

The mold set is mounted in a hydraulic or mechanical molding press and the molds are heated from 250° to 400° F. A weighed charge of molding material is placed in the open mold. The two halves of the mold are closed and pressure is applied. Depending on thickness, size, and shape of the part, curing cycles range from less than a minute to about five minutes. After cure, the mold is opened and the finished part is removed. Typical parts include automobile components, appliance housings and structural components, furniture, electrical components, and business machine housings and parts

EXPERIMENTAL DESIGN:

The pilot study is done with an aim to understand the behaviour of the newly developed class of composite.
CAD design Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

Fig. CATIA model of Helmet

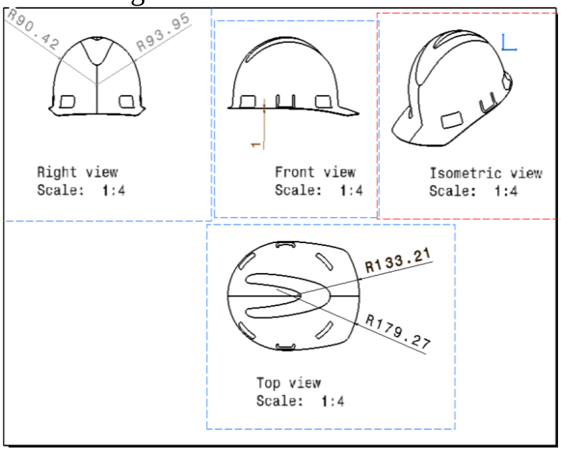

Fig Drafting of Helmet

ANALYSIS:

The pilot study is done with an aim to understand the behaviour of the newly developed class of composite.

of helmet

Properties of Outline Row 10: HDPE

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Isotropic Elasticity		
4	Derive from	Young's Modulu...	
5	Young's Modulus	600	MPa
6	Poisson's Ratio	0.46	
7	Bulk Modulus	2500	MPa
8	Shear Modulus	205.48	MPa

Fig. 13Material properties of Plastic

YIELD STRENGTH OF HDPE = 30.3MPa

WEIGHT OF PLASTIC HELMET

Properties of Outline Row 7: JUTE

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Isotropic Elasticity		
4	Derive from	Young's Modulu...	
5	Young's Modulus	26500	MPa
6	Poisson's Ratio	0.1	
7	Bulk Modulus	11042	MPa
8	Shear Modulus	12045	MPa

Fig. 14 Material properties of jute

YIELD STRENGTH OF JUTE = 133 MPa

WEIGHT OF JUTE HELMET

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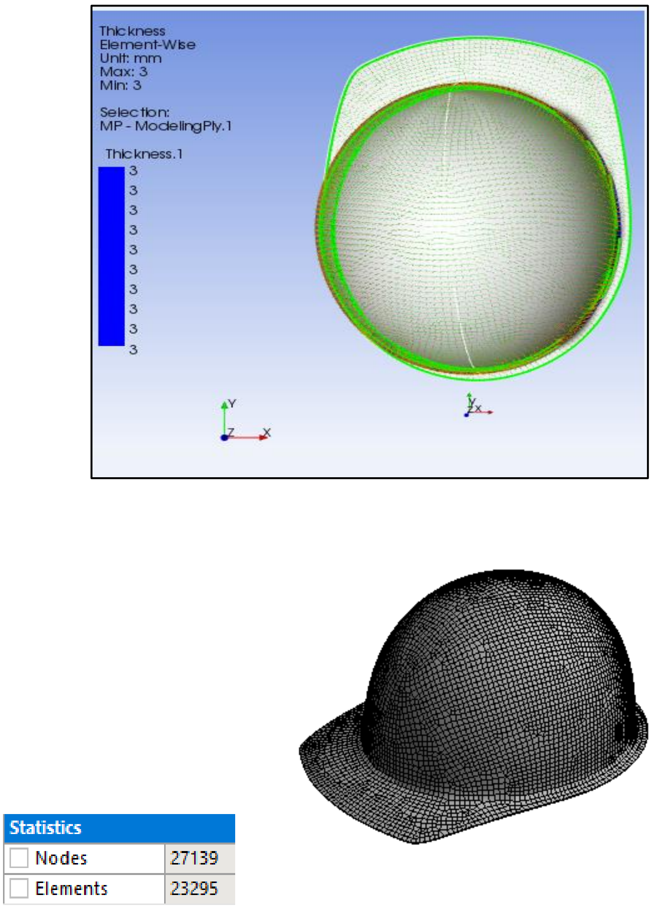

Fig. 15 Meshing of jute helmet

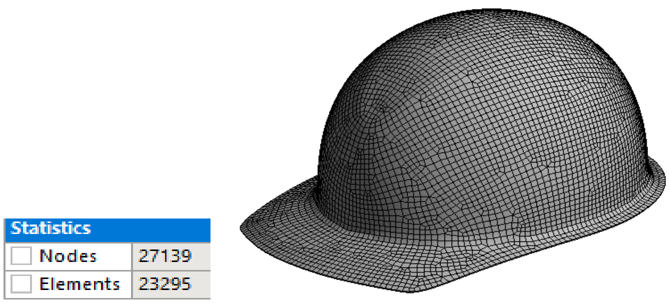

Fig. 16 Meshing of Plastic helmet

Boundary Condition

A boundary condition for the model is the setting of a known value for a displacement or an associated load. For a particular node you can set either the load or the displacement but not both.

The main types of loading available in FEA include force, pressure and temperature. These can be applied to points, surfaces, edges, nodes and elements or remotely offset from a feature. The way that the model is constrained can significantly affect the results and requires special consideration. Over or under constrained models can give stress that is so inaccurate that it is worthless to the engineer. In an ideal world we could have massive assemblies of components all connected to each other with contact elements but this is beyond the budget and resource of most people. We can however, use the computing hardware we have available to its full potential and this means understanding how to apply realistic boundary conditions.

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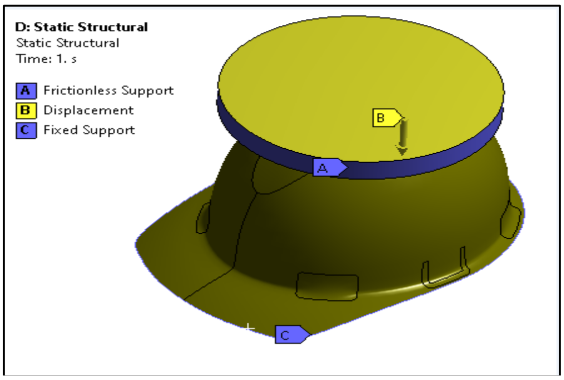

Fig. 17 Boundary condition of Plastic helmet

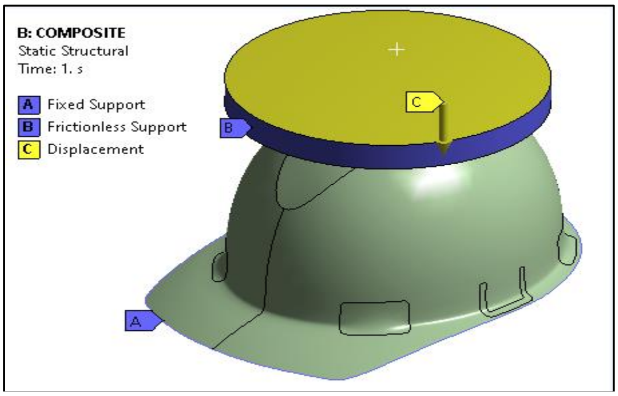

Fig. 18 Boundary condition of jute helmet

Total Deformation

The total deformation & directional deformation are general terms in finite element methods irrespective of software being used.
Directional deformation can be put as the displacement of the system in a particular axis or user defined direction.

Total deformation is the vector sums all directional displacements of the systems.

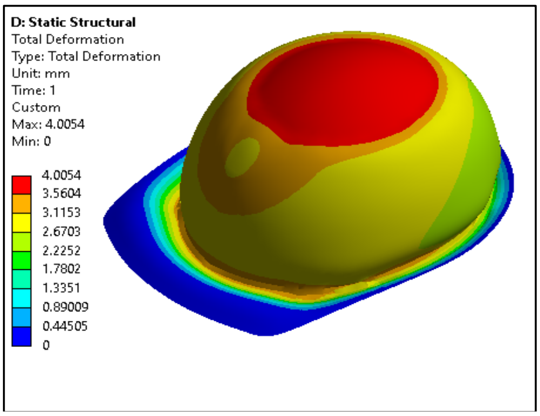

Fig. 19 Total deformation of Plastic helmet.

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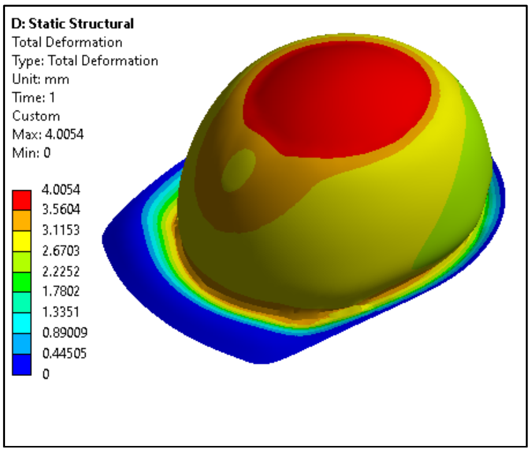

Fig. 20 Total deformation of jute helmet

Equivalent Stress

Equivalent stress is related to the principal stresses by the equation:

$$\sigma_e = \left[\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2} \right]^{1/2}$$

Equivalent stress (also called *von Mises stress*) is often used in design work because it allows any arbitrary three-dimensional stress state to be represented as a single positive stress value. Equivalent stress is part of the maximum equivalent stress failure theory used to predict yielding in a ductile material.The von Mises or equivalent strain ε_e is computed as:

$$\varepsilon_e = \frac{1}{1+\nu'} \left(\frac{1}{2} \left[(\varepsilon_1 - \varepsilon_2)^2 + (\varepsilon_2 - \varepsilon_3)^2 + (\varepsilon_3 - \varepsilon_1)^2 \right] \right)^{\frac{1}{2}}$$

Where: ν' = effective Poisson's ratio

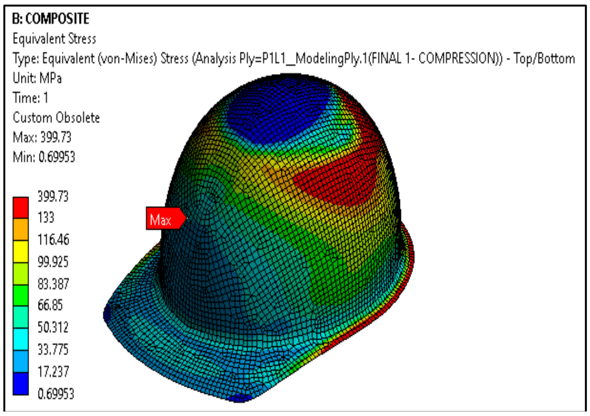

Fig. 21 Equivalent stress of jute helmet

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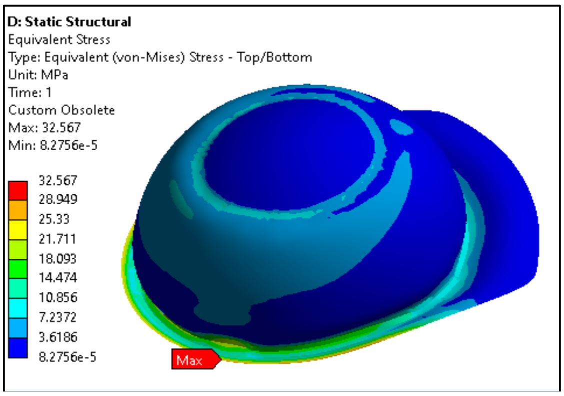


Fig. 20 Equivalent stress of plastic helmet

Maximum Shear Stress

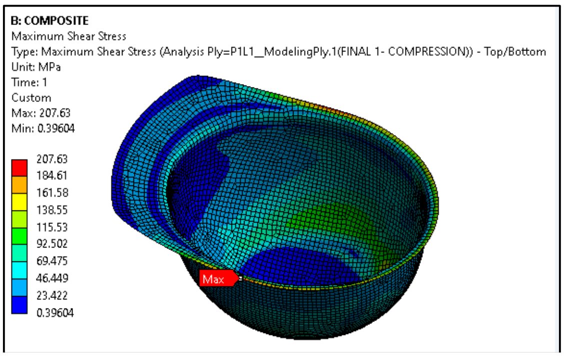


Fig. 21 Maximum shear stress of jute helmet

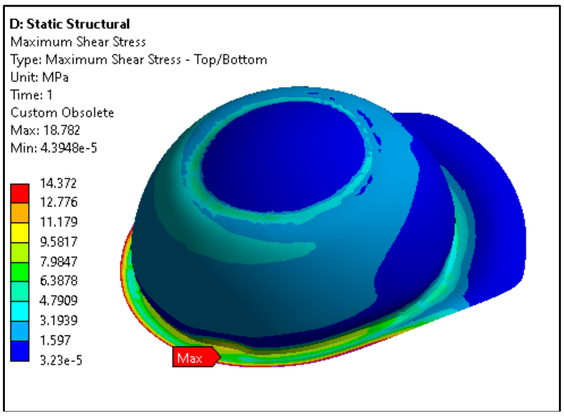


Fig. 22 Maximum shear stress of plastic helmet

Maximum Principle Stress

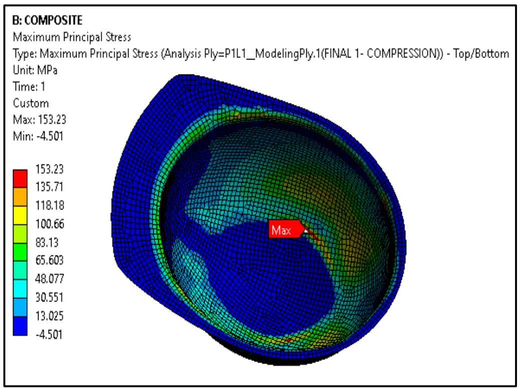


Fig. 23 Maximum principal stress of Jute helmet

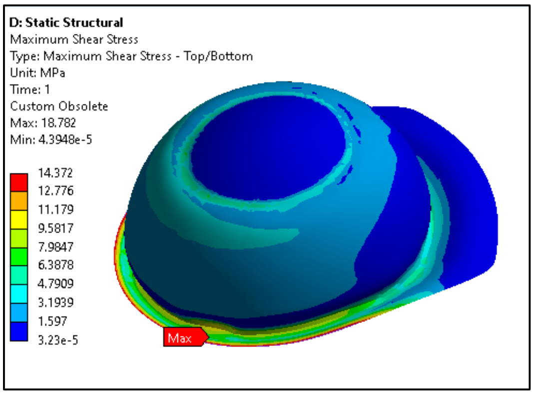
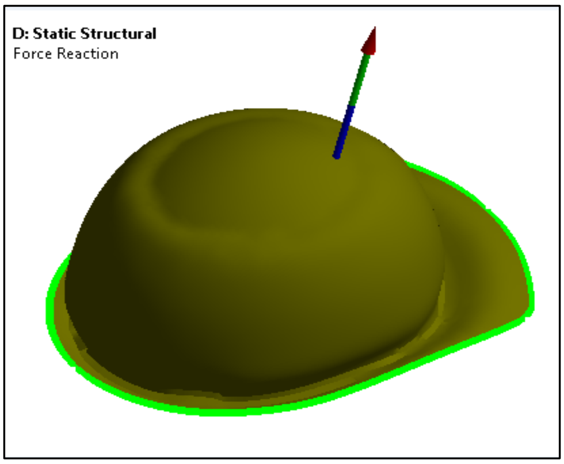


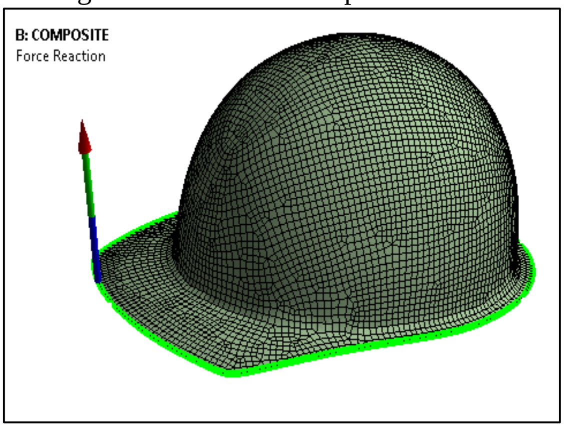
Fig. 24 Maximum shear stress of plastic helmet

Force reaction



Maximum Value Over Time	
X Axis	2.6604 N
Y Axis	273.32 N
Z Axis	1015.5 N
Total	1051.6 N

Fig. 25 reaction force of plastic helmet



Maximum Value Over Time	
X Axis	111.5 N
Y Axis	17007 N
Z Axis	76105 N
Total	77982 N

Fig. 26 reaction force of jute helmet

CONCLUSION

Due to use of jute composite material for manufacturing helmet, weight reduces from 1.8kg to 0.879 kg.

From FEA result it conclude that reaction forces obtain from Jute helmet are maximum than Plastic helmet. So jute helmet has minimum weight and maximum load impact sustain capacity.

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