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DESIGN AND FABRICATION OF HELMET BY HYBRID COMPOSITE

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ABSTRACT

In this work structural strength analysis is carried out in the Composite Helmet by Using Coconut fiber and Glass Fiber .In this recent world the fiber strengthened composite materials are synthesized using glass fiber as reinforcements together with matrix, which have attracted the attention of researchers due to their low density with high specific mechanical strengths, convenience ,and renewability. The current work efforts to make a development in the current existing helmet manufacturing procedure and materials used to have better mechanical properties as well as to enhance the compatibility between fiber sand the matrix. The composites are ready with the unsaturated polyester matrix and fibers such as, reinforced composite materials and glass fiber using hand lay-up method with suitable proportions to result in helmet shell construction. The fabricated helmet are planned to analyze through Finite element method estimate its mechanical properties such as Deformation and stress failure.

Key Words:

Coconut fiber

Epoxy risen

Glass fiber

Finite Element Analysis

1. INTRODUCTION:

All helmets attempt to protect the user's head by absorbing mechanical energy and protecting against penetration. Their structure and protective capacity are altered in high-energy impacts. Beside their energy absorption capability, their volume and weight are also important issues, since higher volume and weight increase the injury risk for the user's head and neck. Every year many workers are killed or seriously injured in the construction, manufacturing and power industry because of head injuries. Wearing an appropriate safety helmet significantly reduces the risk of injury or even death. Protective headwear could save your life. At present strength of the helmet using industry is less due to improper selection and filling of material, uneven pressure distribution and blow holes. The aim of the project is to increase the strength of industrial helmet shell by using composite material. The safety helmet selected should satisfy certain Performance requirements including shock absorption, resistance to penetration. To achieve this an improvement in shell material by using composite material will be studied in this project.

2. METHODOLOGY

Selection of Matrix Material Epoxy LY-556 (di-glycidal ether of Bisphenol-A, DGEBA, with a density of 1.16 gm/cm^3) was chosen as the matrix material, belonging to the Epoxide family. HY 951, a tri-ethylene tetra-amine with a density of 0.95 gm/cm^3, was used as the hardener. Both materials were sourced from Araldite Industrial Adhesives Selection of Reinforcement and Natural Fibers Natural fibers, including Sisal and Jute, were selected as reinforcements for the polymer composite. Additionally, Glass fiber (7 mil, 200 ± 20 GSM) was chosen as a synthetic fiber for reinforcement. Availability of Natural Fiber (Sisal & Jute) 0.7mm Thickness Sisal (Agave sisalana) is a biodegradable and renewable natural fiber commonly used in twine and rope production. Coconut fiberclothis durable, low-maintenance, and resistant to wear and tear. Availability of Synthetic Fiber Glass fiber cloth (7 mil & 200 ± 20 GSM) was sourced from TEXPLAS INDIA PVT. LTD. (Haridwar) Fiberglass is known for its strength, corrosion resistance, moldability, and cost-effectiveness, making it ideal for composite applications. Its non-conductive and radio frequency transparent properties are beneficial in electronics housing Surface Treatment of Fibers .To improve fiber-matrix bonding, the natural fibers were treated with a 5% NaOH solution for 3-4 hours to remove impurities. After treatment, the fibers were dried under sunlight for 1-2 hours. Wet Hand Lay-up Technique The wet hand lay-up technique was used for composite processing. A release gel was applied to the mold surface to prevent polymer sticking. Thin plastic sheets were used for a good surface finish. Woven mats or chopped strand mats were cut and placed on the mold surface, followed by pouring a mixture of thermosetting polymer and hardener. Each layer of polymer and reinforcement was spread and pressed to remove air and excess polymer. This process was repeated until the required layers were stacked. After curing, the composite was removed from the mold. The typical curing time for an epoxy-based system is 24-48 hours at room temperature. This method is suitable for thermosetting polymer-based composites and is commonly used in aircraft, automotive parts, and other applications requiring lower production rates and cost-effective solutions.

3. MATERIAL SELECTION:

Epoxy Resin (LY-556)

Epoxy resin, specifically LY-556, is a widely used material due to its remarkable properties. It is light in weight and highly resistant to most alkalis and acids, making it an ideal choice for applications where chemical exposure is a concern. Additionally, it resists stress cracking, retains both stiffness and flexibility, and has low moisture absorption. These characteristics ensure the material maintains its structural integrity under varying conditions. Epoxy resin is non-staining and can be easily fabricated, which makes it versatile for a range of uses. Some of the primary applications of epoxy resin include structural applications, industrial tooling, composites, and electrical systems or electronics. Its resilience and adaptability make it an essential material in industries where durability and reliability are crucial.

Hardener (HY-951)

The hardener (HY-951) is a key component in the epoxy resin curing process. This curing agent, often referred to as a catalyst, is necessary to initiate the hardening of the epoxy resin. Without the hardener, the resin would remain in a liquid or semi-solid form and would not achieve the desired solid and durable state. The selection of an appropriate hardener is crucial, as it influences the final characteristics of the epoxy composite, such as its hardness, flexibility, and overall strength. The combination of epoxy resin and hardener determines the final properties of the composite, ensuring it meets the specific requirements of the intended application.

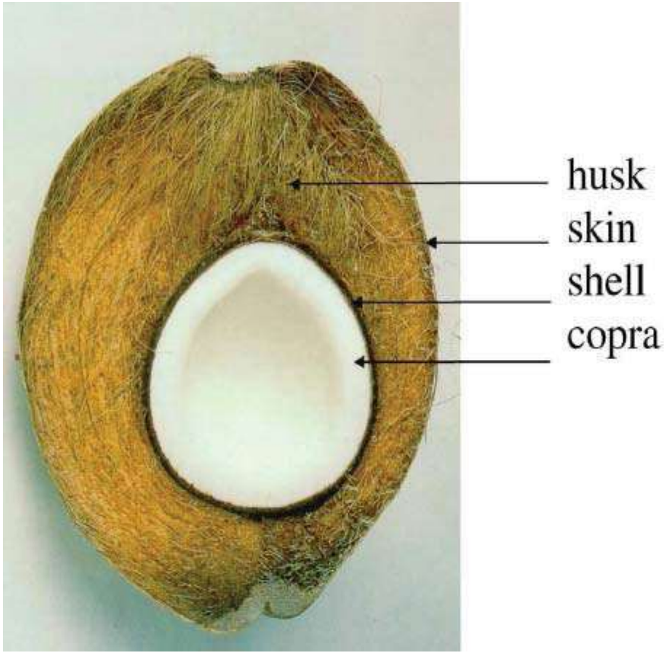
Natural Fibers (Coconut Fiber) and Synthetic Fibers (Glass Fiber Cloth)

Fiber-reinforced polymer composites are a critical category of materials used across various industries due to their high specific strength and modulus. Traditional fiber-reinforced plastics, often made with glass, carbon, or aramid fibers, are facing increasing scrutiny because of their environmental impact. The production, use, and disposal of these synthetic fibers are contributing to environmental concerns. In response, natural fiber composites have emerged as a sustainable alternative. These composites use fibers, particles, or platelets derived from renewable resources, such as coconut fiber. Unlike synthetic fibers, these natural fibers are biodegradable and non-toxic, offering a more eco-friendly option for reinforcing polymer composites.

Advantages of Natural Fibers

When compared to conventional reinforcing fibers like glass, carbon, and Kevlar, natural fibers offer several key advantages that make them a preferable choice in various applications. Notably, natural fibers are environmentally friendly, as they are fully biodegradable, unlike synthetic fibers that persist in the environment for long periods. They are non-toxic, making them safer for both the environment and human health. Furthermore, natural fibers often come from renewable sources, offering an inherently sustainable option for the production of composite materials. These properties make natural fibers an attractive choice for industries looking to reduce their environmental footprint while still achieving high-performance material characteristics.

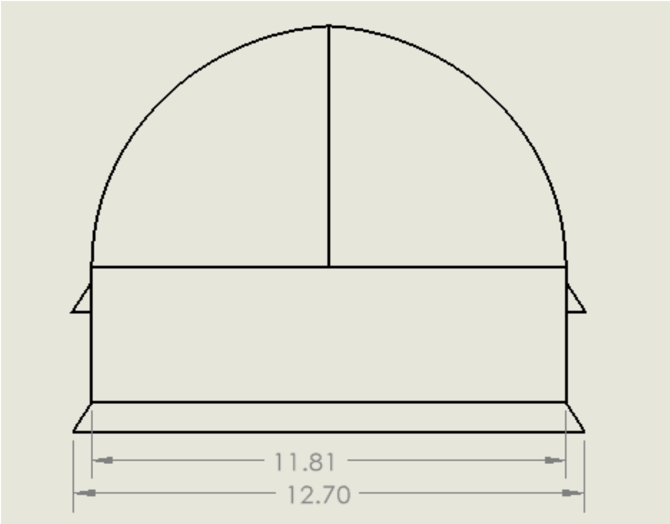
In summary, the materials used in this work—epoxy resin, hardener, synthetic fibers, and natural fibers—play a crucial role in the development of composites with specific mechanical properties. The combination of these materials allows for the creation of composites that are durable, environmentally friendly, and suitable for a wide range of applications.

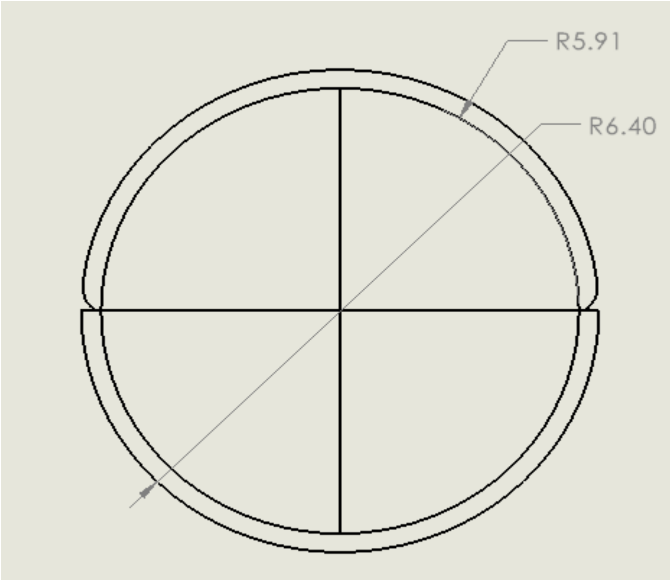


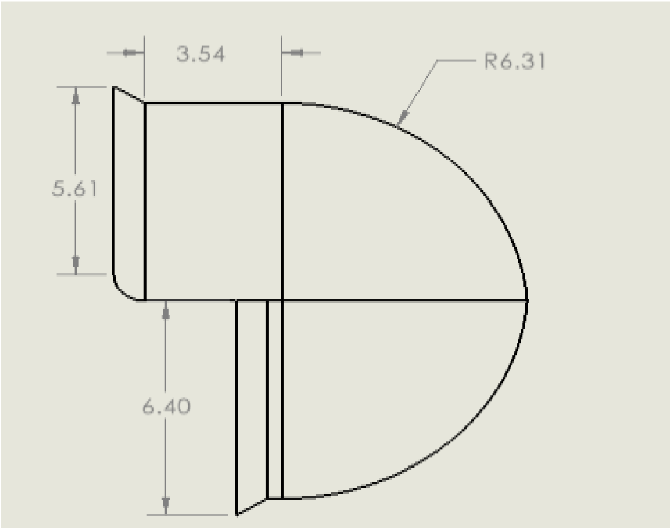
4. DESIGN MODELING:

The helmet is designed for lightweight, high impact resistance, and ergonomic comfort. The outer shell consists of E-glass fiber-reinforced epoxy for strength, while coconut fiber layers enhance shock absorption. 3D modeling is performed using SolidWorks, ensuring an aerodynamic shape and proper head fit. Finite Element Analysis (FEA) in ANSYS evaluates stress distribution and impact resistance. The layering sequence is optimized for maximum energy dissipation. Thickness variations reinforce high-impact zones, ensuring safety. Ventilation and padding improve wearability. This hybrid composite approach aims to enhance sustainability and performance over conventional helmets.

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Surface_helmet	Coconut fiber, epoxy risen,glass fiber	1







5. FEA ANALYSIS:
INTRODUCTION OF FINITE ELEMENT SOFTWARE

The Basic concept in FEA is that the body or structure may be divided into smaller elements of finite dimensions called “Finite Elements”. The original body or the structure is then considered as an assemblage of these elements connected at a finite number of joints called “Nodes” or “Nodal Points”. Simple functions are chosen to approximate the displacements over each finite element. Such assumed functions are called “shape functions”. This will represent the displacement within the element in terms of the displacement at the nodes of the element. Mathematically, the structure to be analyzed is subdivided into a mesh of finite sized elements of simple shape. Within each element, the variation of displacement is assumed to be determined by simple polynomial shape functions and nodal displacements. Equations for the strains and stresses are developed in terms of the unknown nodal displacements. From this, the equations of equilibrium are assembled in a matrix form which can be easily be programmed and solved in software. After applying the appropriate boundary conditions, the nodal displacements are found by solving the matrix stiffness equation. Once the nodal displacements are known, element stresses and strains can be calculated.

4.1ANSYS

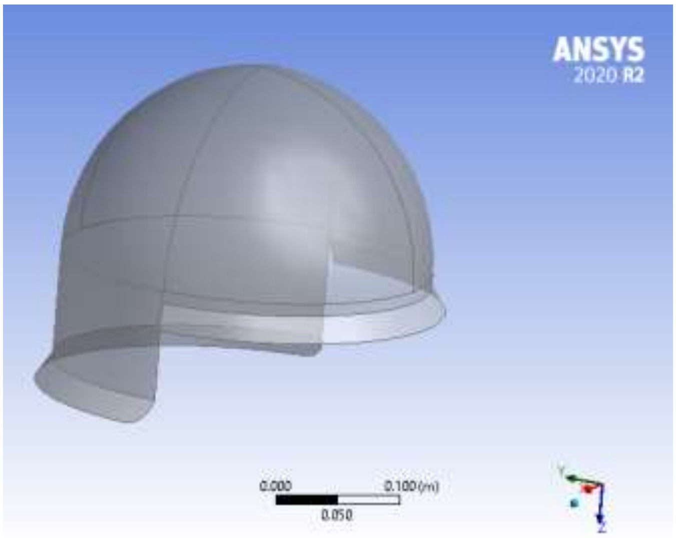
ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated, or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyze by hand. Systems that may fit into this category are too complex due to their geometry, scale, or governing equations.

Static structural Solver

A. Importing External geometry
B. Meshing
C. Material Properties Apply 0
D. Boundary Condition
E. Solveig
F. Post processing

Importing External Geometry;

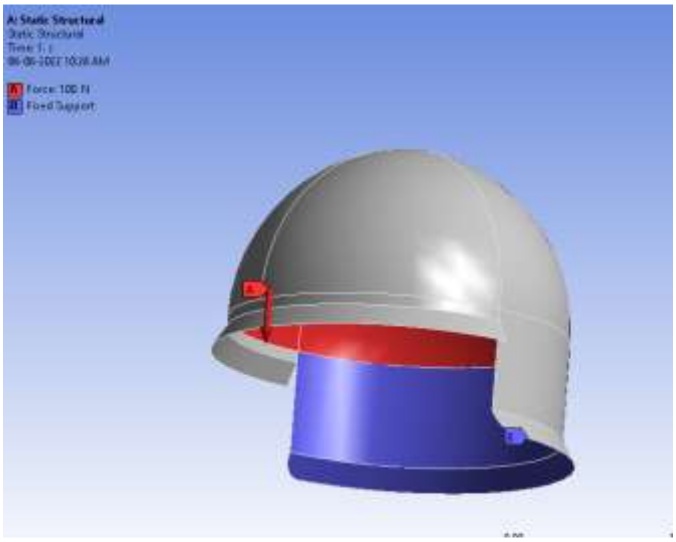
After preparing the model in CATIA it is improved to ANSYS. the file is imported from CATIA by file>import>STEP



4.3.3GENERATE MESHES:

For Solving purpose and boundary condition we want to generate element which was done through mesh option

Sizing	
Use Advanced Size Function	On: Curvature
Relevance Center	Medium
Initial Size Seed	Active Assembly
Smoothing	Medium
Span Angle Center	Coarse
Curvature Normal Angle	Default (30.0 °)
Min Size	Default (4.0980 mm)
Max Face Size	Default (20.490 mm)
Growth Rate	Default
Minimum Edge Length	10.0 mm
Inflation	
Use Automatic Inflation	None
Inflation Option	Smooth Transition
Transition Ratio	0.272
Maximum Layers	2
Growth Rate	1.2
Inflation Algorithm	Pre
View Advanced Options	No
Statistics	
Nodes	754
Elements	724



Material Data

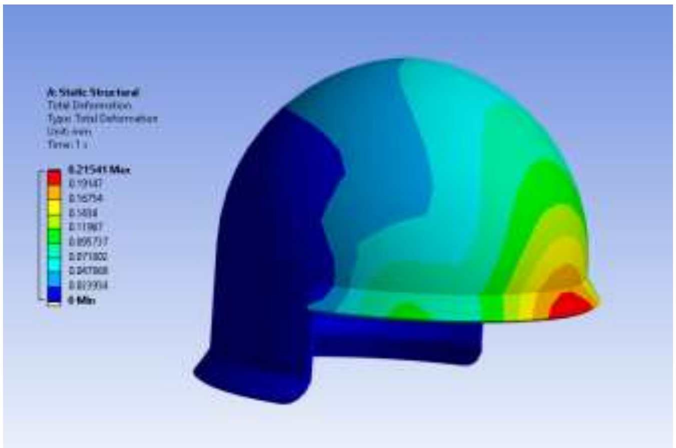
1) Polyethylene

TABLE 15
Polyethylene > Constants

Density	9.5e-007 kg mm^-3
Coefficient of Thermal Expansion	2.3e-004 C^-1
Specific Heat	2.96e+005 mJ kg^-1 C^-1
Thermal Conductivity	2.8e-004 W mm^-1 C^-1

Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa	
	1100	0.42	2291.7	387.32

Deformation:



Total deformation of helmet

Elastic strain

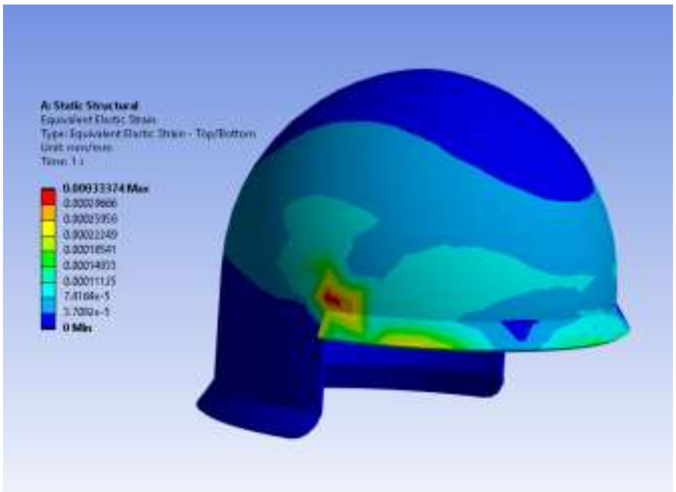
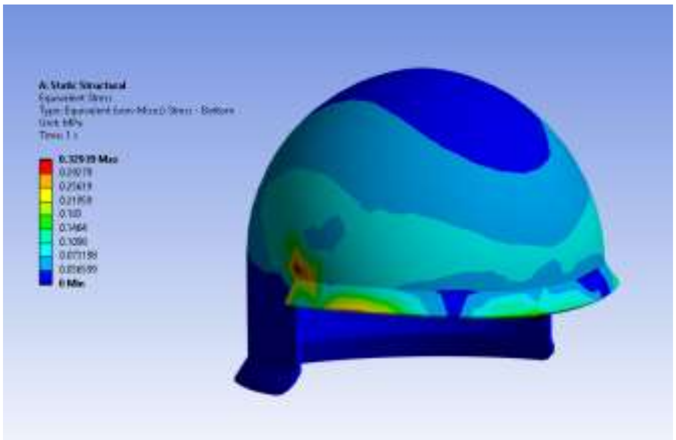


Fig maximum stress of in plastic helmet



COMPOSITE MATERIAL ANALYSIS IN ANSYS

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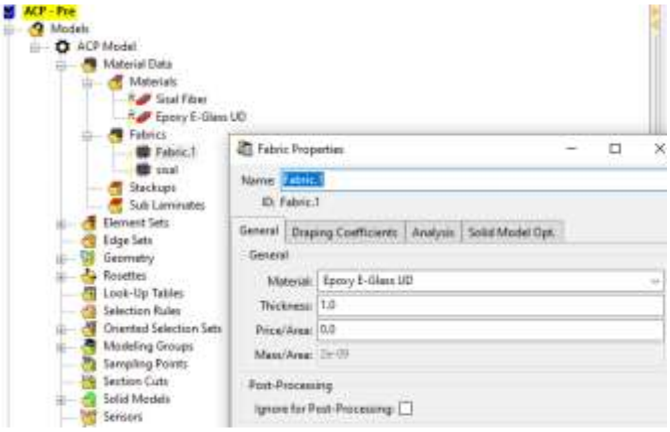

Material constrain:

Material Data

2) Sisal Fibre

TABLE 22
Sisal Fibre> Constants

Density	1.45e-006 kg mm^-3
Coefficient of Thermal Expansion	1.2e-005 C^-1
Specific Heat	4.34e+005 mJ kg^-1 C^-1
Thermal Conductivity	6.05e-002 W mm^-1 C^-1
Resistivity	1.7e-004 ohm mm

TABLE 23
Sisal Fibre> Compressive Ultimate Strength

Compressive Ultimate Strength MPa
0

TABLE 24
Sisal Fiber> Compressive Yield Strength

Compressive Yield Strength MPa
250

TABLE 25
Sisal Fiber> Tensile Yield Strength

Tensile Yield Strength MPa
250

TABLE 26
Sisal Fiber> Tensile Ultimate Strength

Tensile Ultimate Strength MPa
460

TABLE 27
Sisal Fiber> Isotropic Secant Coefficient of Thermal Expansion

Reference Temperature C
22

TABLE 28
Sisal Fiber> Alternating Stress Mean Stress

Alternating Stress MPa	Cycles	Mean Stress MPa
3999	10	0
2827	20	0
1896	50	0
1413	100	0
1069	200	0
441	2000	0
262	10000	0
214	20000	0
138	1.e+005	0
114	2.e+005	0
86.2	1.e+006	0

TABLE 29
Sisal Fiber> Strain-Life Parameters

Strength Coefficient MPa	Strength Exponent	Ductility Coefficient	Ductility Exponent	Cyclic Strength Coefficient MPa	Cyclic Strain Hardening Exponent

920	-0.106	0.213	-0.47	1000	0.2

TABLE 30
Sisal Fiber> Isotropic Elasticity

Temperature C	Young's Modulus MPa	Poisson's Ratio	Bulk Modulus MPa	Shear Modulus MPa
	3770	0.32	3490.7	1428

TABLE 31
Sisal Fiber> Isotropic Relative Permeability

Relative Permeability
10000

3) Epoxy E-Glass UD

TABLE 32
Epoxy E-Glass UD > Constants

Density	2.e-006 kg mm^-3

TABLE 33
Epoxy E-Glass UD > Orthotropic Elasticity

Temperature C	Young's Modulus X direction MPa	Young's Modulus Y direction MPa	Young's Modulus Z direction MPa	Poisson's Ratio XY	Poisson's Ratio YZ	Poisson's Ratio XZ	Shear Modulus XY MPa	Shear Modulus YZ MPa	Shear Modulus XZ MPa
	45000	10000	10000	0.3	0.4	0.3	5000	3846.1	5000

TABLE 34
Epoxy E-Glass UD > Orthotropic Strain Limits

Temperature C	Tensile X direction	Tensile Y direction	Tensile Z direction	Compressive X direction	Compressive Y direction	Compressive Z direction	Shear XY	Shear YZ	Shear XZ
	2.44e-002	3.5e-003	3.5e-003	-1.5e-002	-1.2e-002	-1.2e-002	1.6e-002	1.2e-002	1.6e-002

TABLE 35
Epoxy E-Glass UD > Orthotropic Stress Limits

Temperature C	Tensile X direction MPa	Tensile Y direction MPa	Tensile Z direction MPa	Compressive X direction MPa	Compressive Y direction MPa	Compressive Z direction MPa	Shear XY MPa	Shear YZ MPa	Shear XZ MPa
	1100	35	35	-675	-120	-120	80	46.154	80

TABLE 36
Epoxy E-Glass UD > Puck Constants

Temperature C	Compressive Inclination XZ	Compressive Inclination YZ	Tensile Inclination XZ	Tensile Inclination YZ
	0.25	0.2	0.3	0.2

TABLE 37
Epoxy E-Glass UD > Additional Puck Constants

Interface Weakening Factor	Degradation Parameter s	Degradation Parameter M
0.8	0.5	0.5

TABLE 38
Epoxy E-Glass UD > Tsai-Wu Constants

Temperature C	Coupling Coefficient XY	Coupling Coefficient YZ	Coupling Coefficient XZ
	-1	-1	-1

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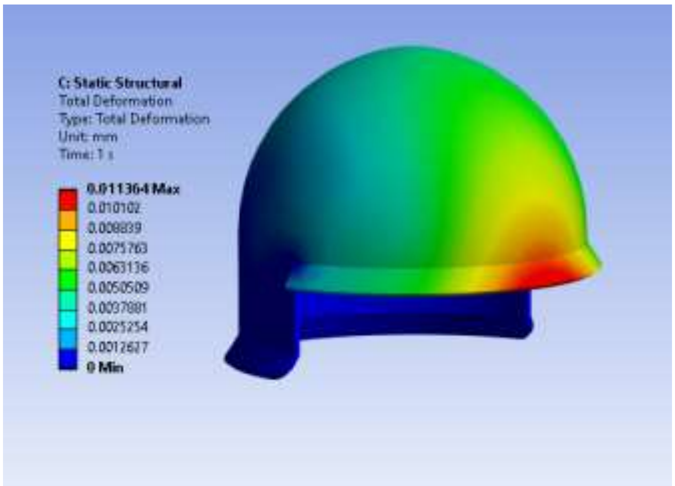
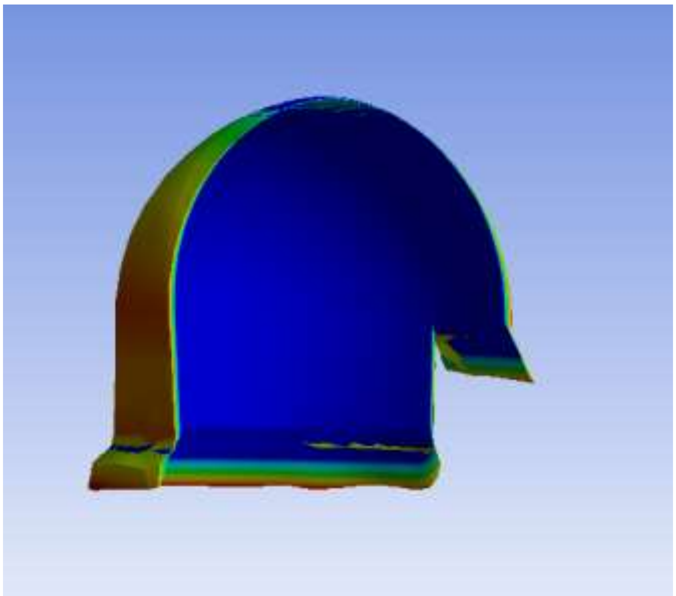
SIMULATION RESULT WITH COMPOSITE MATERIAL:

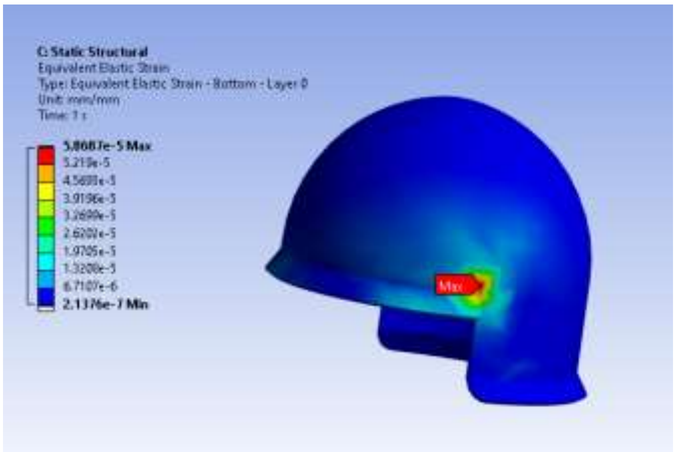
Total deformation:



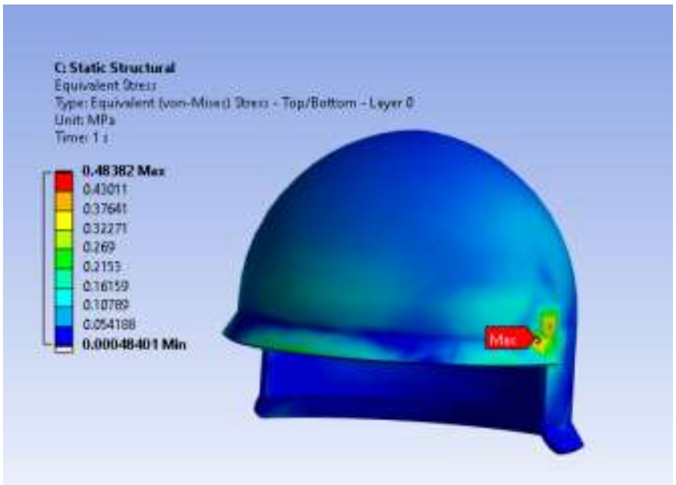


Cross sectional view of deformation

Strain of composite helmet



Equivalent stress



CONCLUSION

S.no	Material	Total deformation(mm)	Strain	Stress (MPa)
1	Polyethylene	0.215	0.00033	0.33
2	Natural fiber	0.01136	5.57×10^{-5}	0.48

Based on the structural analysis results, the helmet material significantly influences deformation, strain, and stress distribution. The analysis compared

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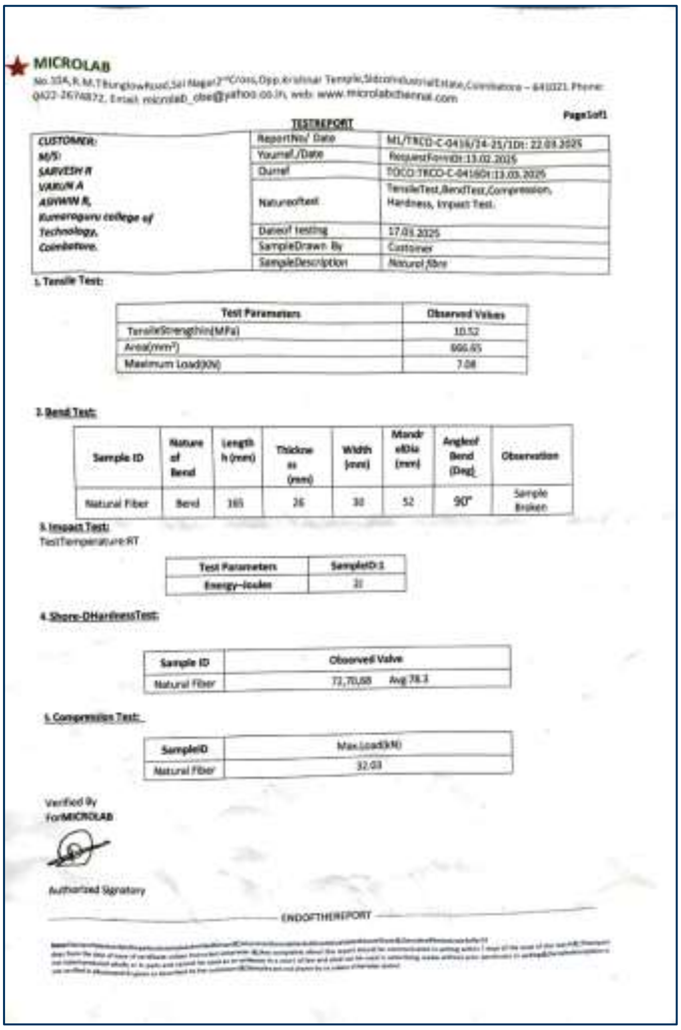
polyethylene and natural fiber composites under loading conditions: **Polyethylene** exhibited a total deformation of **0.215 mm**, a strain of **0.00033**, and a stress of **0.33 MPa**. This indicates relatively higher deformation but lower stress absorption. **Natural fiber composite** showed significantly lower deformation at **0.01136 mm**, with a strain of **5.57 × 10^{-5}** and a higher stress of **0.48 MPa**, indicating better rigidity and load-bearing capacity. The results suggest that **natural fiber composites offer superior stiffness and reduced deformation compared to polyethylene**, making them a promising material for impact-resistant helmet applications. However, further testing on durability, energy absorption, and long-term performance is recommended for practical implementation.



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TESTREPORT

CUSTOMER: M/S: SARVESH R, VARUN A, ASWIN R, Kumaraguru college of Technology, Coimbatore.	ReportNo/ Date	ML/TRCD-C-0416/24-25/1Dt: 22.03.2025
	Yourref./Date	RequestFormDt:13.02.2025
	Ourref	TOCO TRCD-C-0416Dt:13.03.2025
	Natureoftest	TensileTest,BendTest,Compression, Hardness, Impact Test.
	Dateof testing	17.03.2025
	SampleDrawn By	Customer
	SampleDescription	Natural fibre

1. Tensile Test:

Test Parameters	Observed Values
TensileStrengthin(MPa)	10.52
Area(mm²)	666.65
Maximum Load(KN)	7.08

2. Bend Test:

Sample ID	Nature of Bend	Length (mm)	Thickness (mm)	Width (mm)	MandrelDia (mm)	Angleof Bend (Deg)	Observation
Natural Fiber	Bend	165	26	30	52	90°	Sample Broken

3. Impact Test:
TestTemperature:RT

Test Parameters	SampleID:1
Energy–Joules	31

4. Shore-DHardnessTest:

Sample ID	Observed Valve
Natural Fiber	72,70,68 Avg 70.3

5. Compression Test:

SampleID	Max.Load(kN)
Natural Fiber	32.03

Verified By
ForMICROLAB

Authorized Signatory

ENDOFTHEREPORT

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