Use of Corrugated Composite Sandwich and Hexagonal Honeycomb Plates for Helmets

Dr. Ashish Manoria[1] Dr. P. L. Verma[2] Shubhank Nayak[3]
[1,2,3]SATI, Vidisha India

Abstract— The purpose of this study is to perform a multi-disciplinary design and analysis of the materials such as Carbon Fibre material and Polypropylene materials with composite structures as corrugated structure and hexagonal honeycomb plates used for helmet structure for providing the comfort and protective padding along with lightweight property with improved overall strength of helmet. The primary goal of using these sandwich composite structures in helmets is to provide an appropriate absorption capacity while applied impact loading or pressure. For optimization of the helmet structure, this study is performed by using two materials for developing plates of composite structures such as honeycomb and corrugated sandwich structure with Carbon Fibre material and Polypropylene materials. The integrated helmet structure is then simulated on ANSYS workbench for analyzing the performances and mechanical properties and compared all the cases for achieving optimized helmet design. This paper is presented here to demonstrate the proposed methodology and analyzed results in different cases.

Key words: Honeycomb Structure, Corrugated Composite Structure, Helmet, CATIA & ANSYS

I. INTRODUCTION

Sandwich panels are designed for construction of lightweight transportation systems or other mechanical systems and majorly used in the most significant technological fields such as satellites, aircraft, missiles, high speed trains. Sandwich panels are frequently used instead of increasing material thickness in order to prevalent higher strength within minimum structural weight. Construction of these panels normally consist two facing layers and core material in between the layers. The helmets are considered for the safety concerns of rider in order to protect the rider's head during impact, thus preventing or reducing head injury and saving the rider's life. These composite systems are very basic method for making products stronger, faster, lighter, more durable, and combined package of other benefits. Several types of core shapes and core material have been applied to the construction of sandwich structures which can be used for redesigning of helmet models.

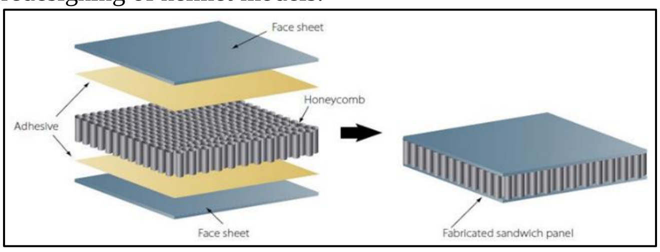


Fig. 1: Sandwich Composite Systems

Among them, the honeycomb core that consists of very thin foils in the form of hexagonal cells perpendicular to the facings is the most popular. Potential materials actively used for sandwich facings are aluminium alloys, high tensile steels, titanium and composites depending on the specific mission requirement but this project is performed by using Carbon Fibre and Polypropylene materials.

II. OBJECTIVE OF WORK

The principle aim of this project is to provide an upgraded design of helmet structure with light weight property and excellent endurance and strength during the impact loading for providing safety to rider's head. For achieving this objective, padding of composite structures such as Honeycomb and Corrugated sandwich structure is employed under the outer shell of helmet design made of Carbon Fibre and Polypropylene materials.

III. LITERATURE REVIEW

In order to perform this project work efficiently following literature reports were analyzed and followed. This literature survey report provided all the research and experimental detail on relevant topic and helped to understand the implementation needed. Literature survey was conducted for two different fields such as for Composite Structures and Helmet Designs.

A. For Composite Structures

As per the research of AjitLohote [1] the use of honeycomb composite structure continues to increase rapidly due to the variety of their application, for example: satellites, aircraft, ships, automobiles, transportation rails, etc. The sandwich composites are multi layered materials made of bonding stiff, high strength skins facings to low density core material. In structural components high stiffness to weight ratios is the major benefit of the honeycomb sandwich concept. In this study a honeycomb structure is evaluated. Static behaviour of sandwich is investigated for permissible load. Then a fatigue analysis is carried out to investigate for its life prediction. The objective of the project is to find number of cycles a structure sustains at a particular load. If a structure fails at early stage, efforts will be taken to increase its stiffness and strength as design parameters. A Finite element analysis of honeycomb structures is to be carried out with ANSYS Workbench as both pre-processor and post processor. The finite element analysis results compared with the experimental results. Fatigue testing in three point bending was performed on honeycomb structure. It shows that at 1kN load & frequency 10Hz, Crack observed after 1, 80,936 cycles of honeycomb structure with composite. Fatigue analysis has been performed for honeycomb structure without composite life cycle is 1, 60,000 cycles and honeycomb structure with composite life cycle is 2,30,000 cycles for 1kN load. Based on the results it can be used in some applications like automotive and aerospace where the structure can undergo repeated or complete reverse fatigue load.

Syed Mufeez Ahmed [2] has conducted his study on fibre composite sandwich, the new generation of material used in civil infrastructure in the last decade. A structural sandwich is a special form of a laminated composite fabricated by attaching two thin but stiff skins to the lightweight but thick core. Because of this special feature, the sectional area is increased and consequently an increase in its flexural rigidity. The strength of this type of construction results from the combination of properties from the skin, core and interface. In a sandwich structure, the strong and stiff skins carry most of the in-plane and bending loads while the core mainly bears the transverse shear and normal loads.

I. Dayyani [3] described that the corrugation has long been seen as a simple and effective means of forming lightweight structures with high anisotropic behaviour, stability under buckling load and energy absorption capability. This has been exploited in diverse industrial applications and academic research. In recent years, there have been numerous innovative developments to corrugated structures, involving more elaborate and ingenious corrugation geometries and combination of corrugations with advanced materials. This development has been largely led by the research interest in morphing structures, which seek to exploit the extreme anisotropy of a corrugated panel, using the flexible degrees of freedom to allow a structure's shape to change, whilst bearing load in other degrees of freedom. This paper presents a comprehensive review of the literature on corrugated structures, with applications ranging from traditional engineering structures such as corrugated steel beams through to morphing aircraft wing structures. As such it provides an important reference for researchers to have a broad but succinct perception of the mechanical behaviour of these structures. Such a perception is highly required in the multidisciplinary design of corrugated structures for the application in morphing aircraft.

B. For Helmet Design

Saroj Kumar Biswal, S.M.ShahrukhRais, Karanam Krishna [4] performed this study to design a standard motorcycle helmet using CATIA V5.0. Two materials i.e. Acrylonitrile butadiene styrene (ABS) and Poly vinyl chloride (PVC) are being used for dynamic analysis. The impact test analysis is performed on the helmet using ANSYS at different speeds ranging from 50-70kmph. Peak acceleration and Head Injury Criterion values derived from the head form are used to assess the protective performance of the helmet. The stresses, strains and deformations formed are evaluated. Results are compared for the prediction of material that would be suitable for the preparation of helmet.

De-Shin Liu and Yao-Te Chen [5] designed motorcycle helmet, an essential object for reducing the risk of head injuries in the event of an impact. However, during the design of helmets, a compromise must be made between user safety and user comfort. Accordingly, the present study proposes a novel open-face helmet design, in which the helmet features three ventilation slots in the upper-head region. Finite element analysis (FEA) models were constructed for both a prototype helmet design, and three traditional helmet designs (full-face, open-face, and half-face helmets). By contrast, the proposed open-face helmet with ventilation slots resulted in the lowest acceleration, irrespective of the ventilation slot width. The 8-mm ventilation slot width resulted in the optimal impact performance level (i.e., a peak head form acceleration of 160 G). Overall, the results suggest that the proposed open-face helmet design with ventilation slots provides a promising solution for ensuring both user protection and user comfort in warm climates.

The project presented by Saravana Kumar K. [6] is to fulfil the prime objective is to force the rider to wear the helmet throughout. Considering the increasing number of motor cycle riders in our country and the number of accidents happening each year, it is evident that in most cases the rider suffers injuries to the head and it leads to fatal causalities. This has thrown light on the importance of forcing the rider to wear helmet to reduce the extent of impact. The paper focuses on the methods that can be implemented to reduce the impact of road accidents. In this paper, we propose building a system that can be implemented by installing it on a bike which works with the helmet that is being worn to make the rider to wear the helmet before riding the bike.

HaixinJin and Jiang changJin [7] discussed in the paper about the non-metallic bulletproof helmet which is analysed in research. The way cannot accurately describe and transmit the shape messages of free-curve and free-camber, in design drawing by hand, design period long and a large amount of work, a large number of data are lose and man-made muff. Advance to use the way combine Rhino software and AutoCAD software in The Computer Simulation Auxiliary Design of non-metallic bulletproof helmet, raise design level.

IV. PROPOSED METHODOLOGY

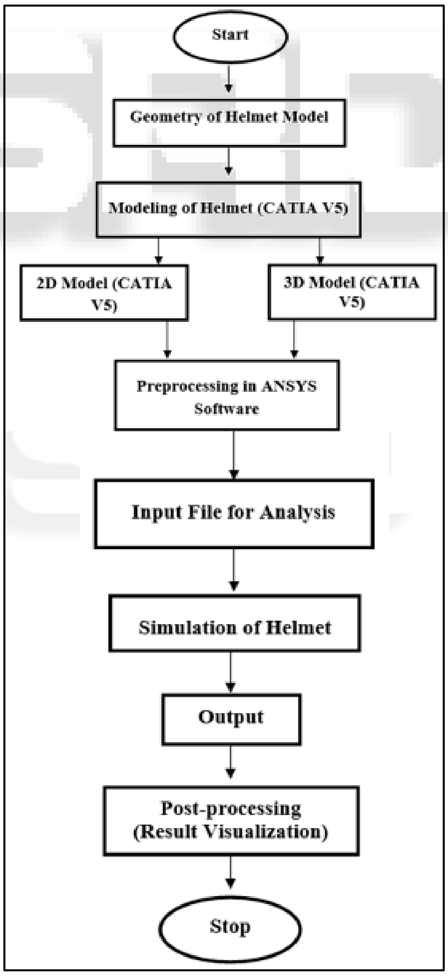


Fig. 2: Flow diagram of process

Geometric modeling of the helmet structures requires more attention in order to have a strong base for finite element analysis processes. In this development process 'modeling of helmet structure' is an initial step. The modeling of helmet structure is completed in some sections such as geometry of model, pre-processing and some other steps by following the methods given below in the form of flow diagram:

A. Modeling Process

For performing the complete analysis by Finite Element Analysis Method, following three stages are completed:

- Pre-Processing
- Analysis/Simulation
- Post-processing

B. Selection of Material

The basic purpose of performing this project is to analyze the variation of vibrational deformation due to dynamic load and sudden impact on the helmet structure using different sandwich panels. For completing this study carbon fibre and polypropylene materials are used for sandwich panel and for helmet structure is also made up of carbon fibre. The reason behind selection of carbon fibre for helmet structure is to fulfill the varying automotive perspectives. The basic steps followed in this study are mentioned below:

- Selection of an appropriate material.
- Selection of boundary conditions and mesh size for performing analysis.
- Analysis of behavior of engineering materials after applying different loading conditions.
- Comparison of developed model with different materials for achieving best performance.

Property	Value
Density	905 Kg/M^3
Young's modulus	1300 MPA
Poison's Ratio	0.42
Bulk Modulus	2.7083E + 09 Pa
Shear Modulus	4.5775E + 08 Pa

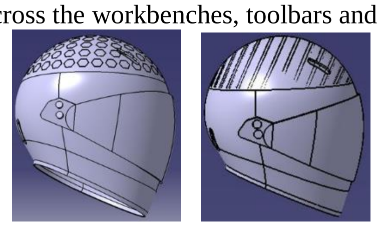
Table 1: Mechanical properties of Polypropylene (grade-3120 MG)

Parameters	Value
Density	1400 Kg/m^3
Young's modulus	1.23E + 05 Mpa
Poison's Ratio	0.282
Shear Modulus	870 Pa

Table 2: Mechanical properties of carbon fibres

C. Geometric Modeling

The geometry designing of helmet for this project has been complete by using the software designing tool CATIA V5 (Computer Aided Three Dimensional Interactive Application) version. CATIA V5 is a powerful software package of designing tools and applications which are consistent across the workbenches, toolbars and tools.



(a) (b)

Fig. 3: 3D Model of Helmet with Honeycomb Structure (A) and Corrugated Composite Sandwich Structure (B) in CATIA V5

D. Analysis/Simulation

Graphical or geometrical post-processing of a developed structure is important for collecting the simulation results and the analysis is performed on ANSYS workbench.

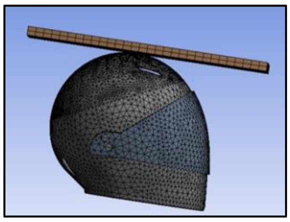


Fig. 4: Meshed helmet structure

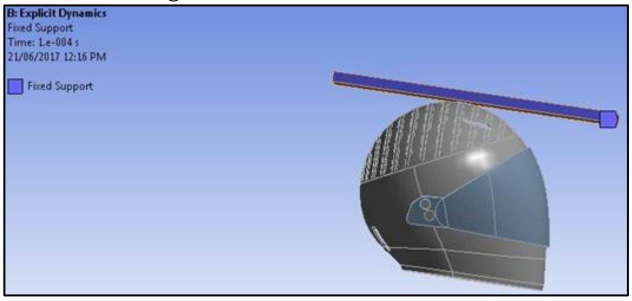


Fig. 5: Fixed support of helmet

E. Boundary Conditions & Results

Boundary Conditions of Helmet with Honeycomb Structure

1) For Carbon Fibre Material

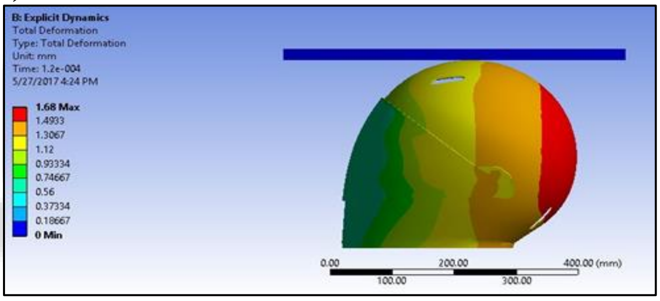


Fig. 6: Deformation in carbon fibre Honeycomb structure helmet

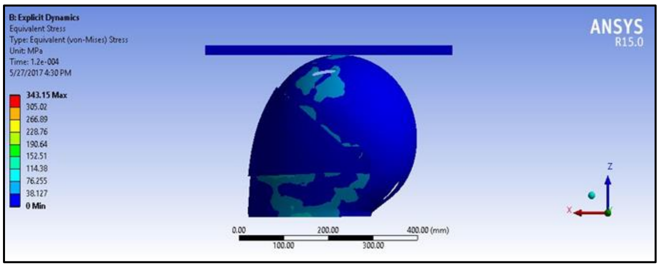


Fig. 7: Stress analysis in carbon fibre Honeycomb structure helmet

2) For Polypropylene Material

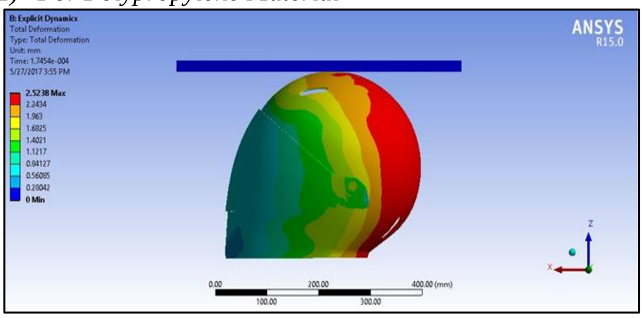


Fig. 8: Deformation in Polypropylene Material Honeycomb structure helmet

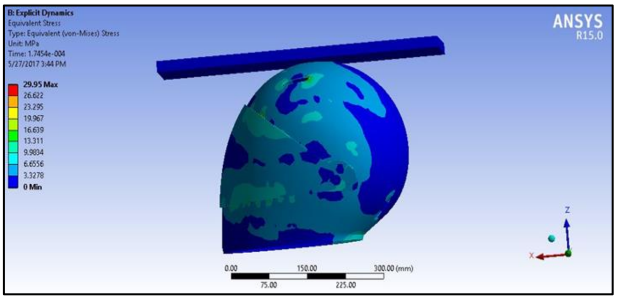


Fig. 9: Stress in Polypropylene Material Honeycomb structure helmet

Boundary Conditions of Helmet with Corrugated Composite Sandwich Structure

3) *For Carbon Fibre Material*

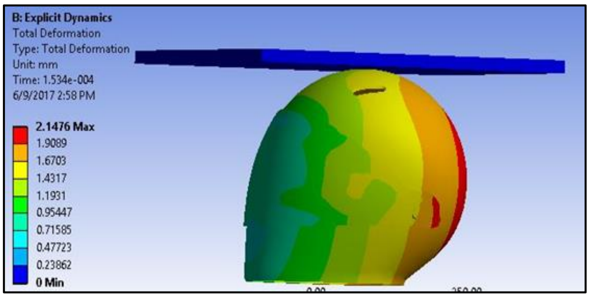


Fig. 10: Deformation in carbon fiber Corrugated Composite Sandwich Structure helmet

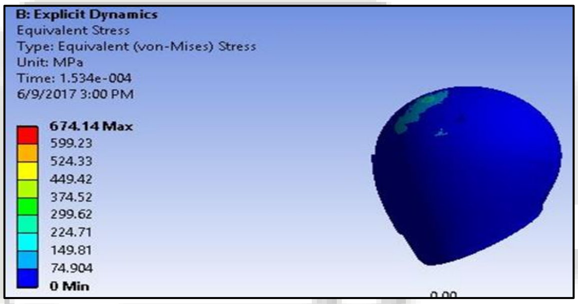


Fig. 11: Stress in carbon fiber Corrugated Composite Sandwich Structure helmet

4) *For Polypropylene Material*

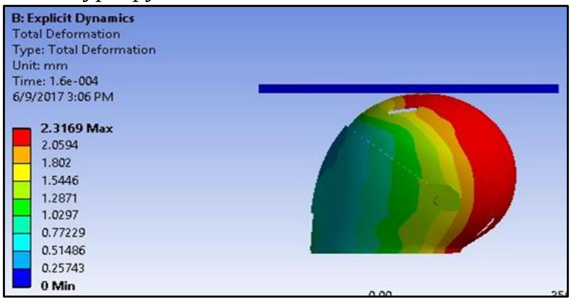


Fig. 12: Deformation in Polypropylene Material Corrugated Composite Sandwich Structure

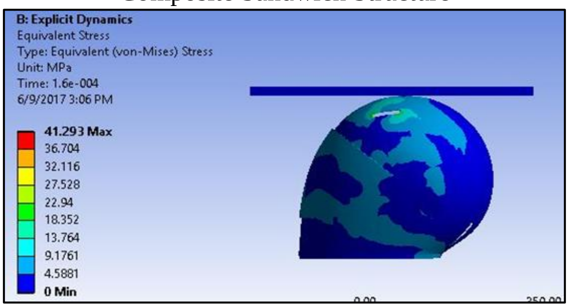


Fig. 13: Stress in Polypropylene Material Corrugated Composite Sandwich Structure

F. *Impact Analysis*

This study consisted with impact analysis in order to investigate the performance and efficiency of the Honeycomb structure and Corrugated Composite Sandwich Structure helmet with considering different materials to prevent head injuries due to sudden impact or subjected load at outer shell of helmet. For conducting this analysis procedure a 3D model of human head is placed inside the helmet to make an assumption for performing ANSYS simulation.

Parts	Young's Modulus	Poisson's Ratio	Density
Skull	1500Mpa	0.22	1300Kg/m^3
Brain	2100MPa	0.49	1040Kg/m^3

Table 3: Properties of 3D model of Human Head

V. Results

Boundary Conditions of helmet structures and impact analysis on Skull & Brain Analysis in Design of Helmet:

A. *Boundary Conditions*

Impact Analysis on Skull				
	Helmet			
Measuring Parameters	Honeycomb Structure		Corrugated Sandwich Structure	
	Carbon Fibre	Polypropylene	Carbon Fibre	Polypropylene
Total Deformation (mm)	1.68	2.5238	2.1476	2.3169
Stress (Mpa)	343.15	29.95	674.14	41.293

Table 4: Boundary Condition Analysis on Helmet Structures

B. *Impact Analysis*

Impact analysis is performed in order to test the efficiency of different helmet structures with considering two different materials in preventing head injuries while collision or accident. For subjecting impact load a fixed support is designed.

Impact Analysis on Skull				
	HELMET			
Measuring Parameters	Honeycomb Structure		Corrugated Sandwich Structure	
	Carbon Fibre	Polypropylene	Carbon Fibre	Polypropylene
Total Deformation (mm)	0	0	2.1476	2.31
Stress (Mpa)	0	0	674.14	41.293

Table 5: Impact Analysis (Brain) on different Helmet Structure

Impact Analysis on Skull				
	HELMET			
Measuring Parameters	Honeycomb Structure		Corrugated Sandwich Structure	
	Carbon Fibre	Polypropylene	Carbon Fibre	Polypropylene

Total Deformation (mm)	1.68	2.4435	2.1476	2.3169
Stress (Mpa)	Nill	Nill	674.14	41.293

Table 6: Impact Analysis (Skull) on different Helmet Structure

Here, the final results are compared based on the performances in graphical representation:

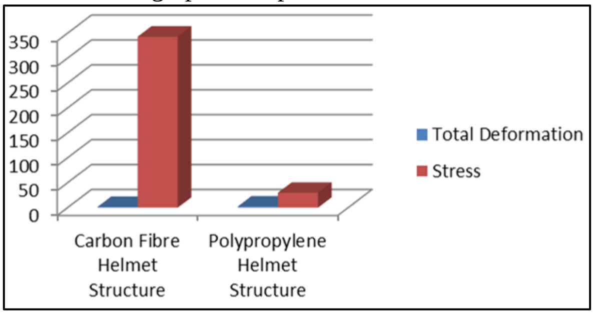


Fig. 14: Comparison of performance of Honeycomb structure helmet with different Materials

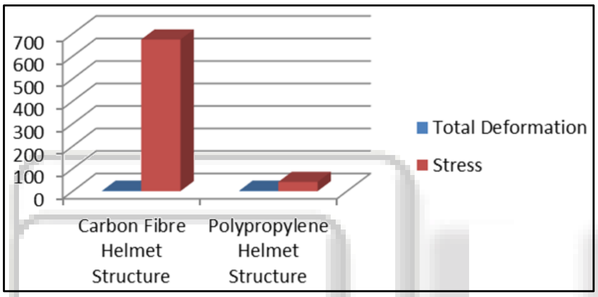


Fig. 15: Comparison of performance of Corrugated Sandwich Structure helmet with different materials

VI. Conclusion

Based on the analysis results it is concluded that total deformation is comparatively higher in polypropylene materials for both the cases while carbon fibre material structure shows minimum deformation and stress for honeycomb and corrugated sandwich structure of helmet design. Now if the structure of helmet is considered, it is concluded that honeycomb helmet structure shows more efficient performance with compare to corrugated sandwich helmet structure. In impact analysis whereas honeycomb structure shows negligible chances for head or brain injury, corrugated structures shows more values than honeycomb structures. Based on research work it is found that approximately 100Kpa stress (impact) is critically injurious to the brain, these helmet structures shows the results which can be considered under safe zone.

References

[1] AjitLohote, Prof. S. S. Kelkar – "Fatigue Analysis and Life Prediction of Honeycomb Structures" IJSART - Volume 3 Issue 2 –FEBRUARY 2017.

[2] Syed Mufeez Ahmed- "A Brief Review on Corrugated Composite Sandwich Structure" International Journal of Engineering Trends and Technology (IJETT) – Volume-40 Number-4 - October 2016.

[3] I. Dayyani, A.D. Shaw, E.I. Saavedra Flores, M.I. Friswell – "The mechanics of composite corrugated structures: A review with applications in morphing aircraft" 2015 Published by Elsevier Ltd.

[4] Saroj Kumar Biswal, S.M.ShahrukhRais, Karanam Krishna "Impact Test Analysis On A 2-Wheeler Helmet Using 3d Modelling And Analysing Software For Two Different Materials" April 2016 | IJIRT | Volume 2 Issue 11 | ISSN: 2349-6002.

[5] De-Shin Liu and Yao-Te Chen – "A Finite Element Investigation into the ImpactPerformance of an Open-Face Motorcycle Helmetwith Ventilation Slots" Applied Science, January 2017.

[6] Saravana Kumar K, Anjana.B.S, Litto.Thomas, Rahul. K. V – "Smart Helmet" International Journal of Science, Engineering and Technology Research (IJSETR), Volume 5, Issue 3, March 2016.