

# DESIGN AND FINITE ELEMENT ANALYSIS OF 3D PRINTED INDUSTRIAL HELMET USING POLYCARBONATE MATERIAL

Dhruva S L<sup>1</sup>, Batluri Tilak Chandra<sup>2</sup>, Bharath H S<sup>3</sup> and H S Shivashankar<sup>4</sup>

<sup>1</sup>M. Tech student, Department of Mechanical Engineering, Sri Siddhartha Institute of Technology, Tumkur – 572105

<sup>2</sup>Associate Professor, Department of Mechanical Engineering, Sri Siddhartha Institute of Technology, Tumkur – 572105

<sup>3</sup>Assistant professor, Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur – 572103

<sup>4</sup>Professor, Department of Mechanical Engineering, Siddaganga Institute of Technology, Tumkur - 572103

## Abstract

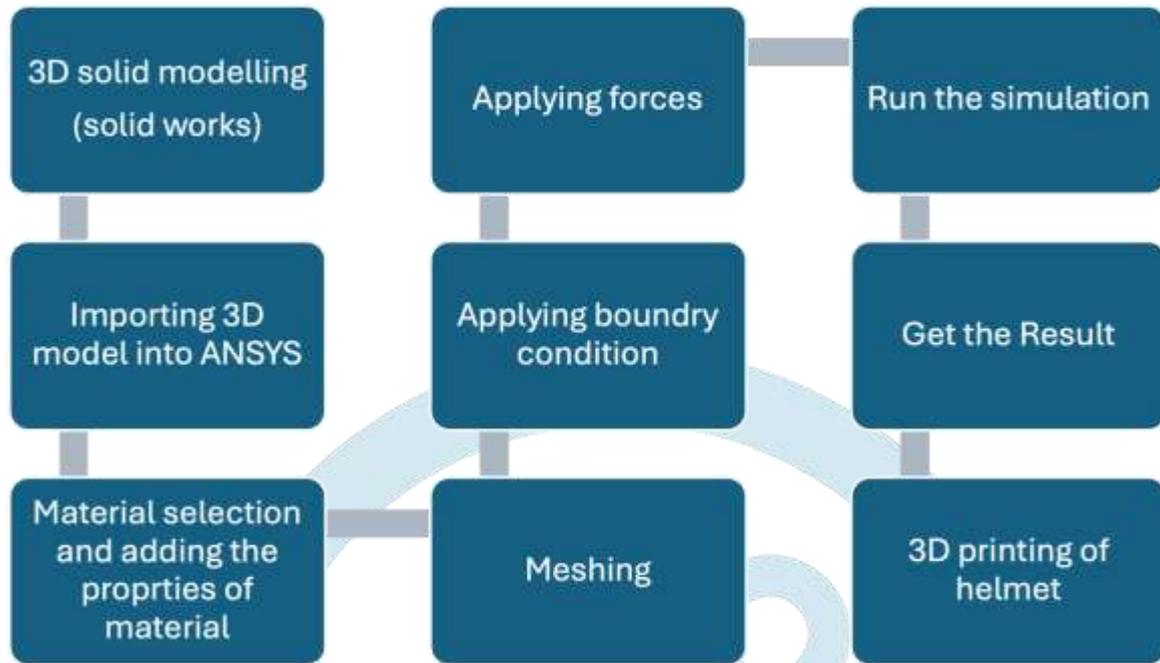
Helmets are very much needed in industries. Helmets plays pivotal role during accidents. The main objective of the helmet is to prevent head injury during working in industry. In this paper, helmet is prepared by additive manufacturing process, that is fused deposition modelling (FDM) technique is used by varying nozzle temperature 250 °C, Bed temperature 90 °C, Infill 100%. The software (slicer) is PrusaSlicer which is used to define the desired print parameters and generate G codes. For 3D modelling of industrial helmet done in solidworks 2013 and finite element analysis carried out using Ansys 2024 to know the strength of the polycarbonate industrial helmet. The obtained results shows the highest stress observed is Polycarbonate helmet when compared with Polyester.

**Keywords:** Additive manufacturing, fused deposition modelling (FDM), Polycarbonate and Finite element analysis.

## I. INTRODUCTION

Helmet is a protective gear used to wear on head when pursuing hazardous work. Helmets are used while riding motorcycles, industry works, construction works etc. a helmet generally consists of a shell of a very hard and tough material which is covered by certain padding for shock absorption and comfort. Additive manufacturing technology is increasingly represented in all spheres of life with various possibilities of application. The advantages of this technology are manifested through the possibility of manufacturing parts (products) with extremely complex geometry and the cost-effectiveness of manufacturing even small production series. According to study done by Gandhi et al.(2014) when the BIS standard of 19.5 kN force is applied to test the helmet in static and dynamic loading, it showed that least strain energy and deformation has occurred in chin side of the helmet, which means that maximum force will be imparted to the head [1]. As the thickness of the outer shell of helmet increases and the velocity of the helmet increases the force induced on head increases, so the thickness should be optimized while designing the helmet [2].

## Experimental Procedure

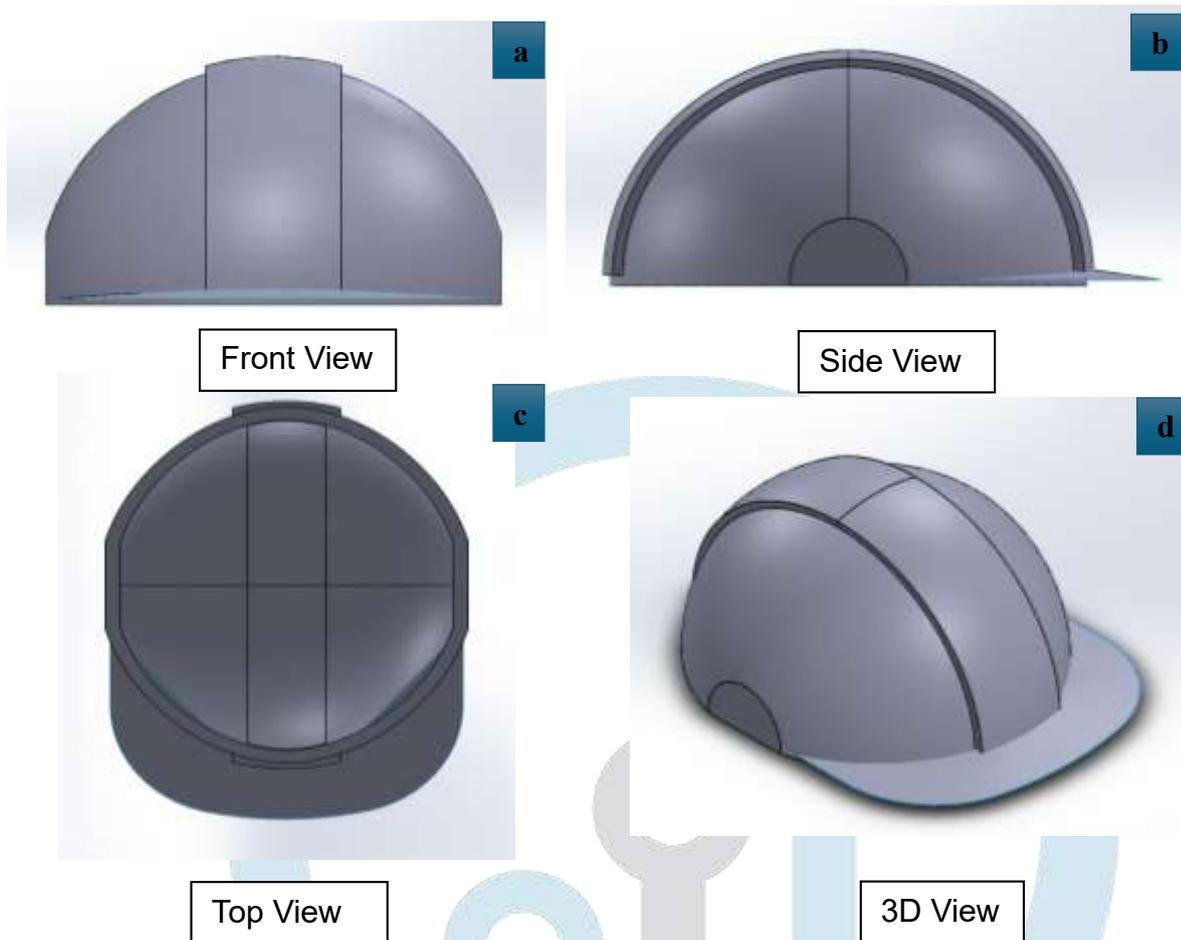


**Figure 1: Flow Chart of Design, Finite element analysis and 3D Printed Helmet**

### Design and Analysis

The solidworks 2013 is used for designing Industrial Helmet, polycarbonate (PC) material with fused deposition modelling (FDM) method on a 3D printer manufactured by AMS-HYREL 3D. The diameter of the filament used is 1.75 mm. Recommended printing temperature is 250-270°C, heated substrate temperature (bed temperature) is in the range 90 – 105 °C and printing speed 30-50 mm/min. A nozzle temperature in the amount of 250-270 °C, a bed temperature of 90 °C, Nozzle temperature 250 °C, Layer height 0.3 mm, infill 100 % and a printing speed of 40 mm/s were selected. The used software (slicer) is PrusaSlicer which is used to define the desired print parameters and generate G code.

### 3D Model developed using Soldworks 2013 software



**Figure 2: The different views of 3D Modelled Helmet**

## MATERIAL USED

**Table 1: Properties of Polycarbonate and Polyester**

PROPERTY	POLYCARBONATE	POLYESTER
Density(kg/m <sup>3</sup> )	1160	1339
Young's Modulus (Pa)	2.18e <sup>+009</sup>	2.898e <sup>+009</sup>
Poisson's Ratio	0.4002	0.3887
Bulk Modulus (Pa)	3.6406e <sup>+009</sup>	4.3396e <sup>+009</sup>
Shear Modulus (Pa)	3.6406e <sup>+009</sup>	1.0434e <sup>+009</sup>
Tensile Yield Strength	6.193e <sup>+007</sup>	5.244e <sup>+007</sup>
Compressive Yield Strength (Pa)	3.27 e <sup>+007</sup>	1.588 e <sup>+009</sup>
Tensile Ultimate Strength (Pa)	6.282e <sup>+007</sup>	5.745e <sup>+007</sup>

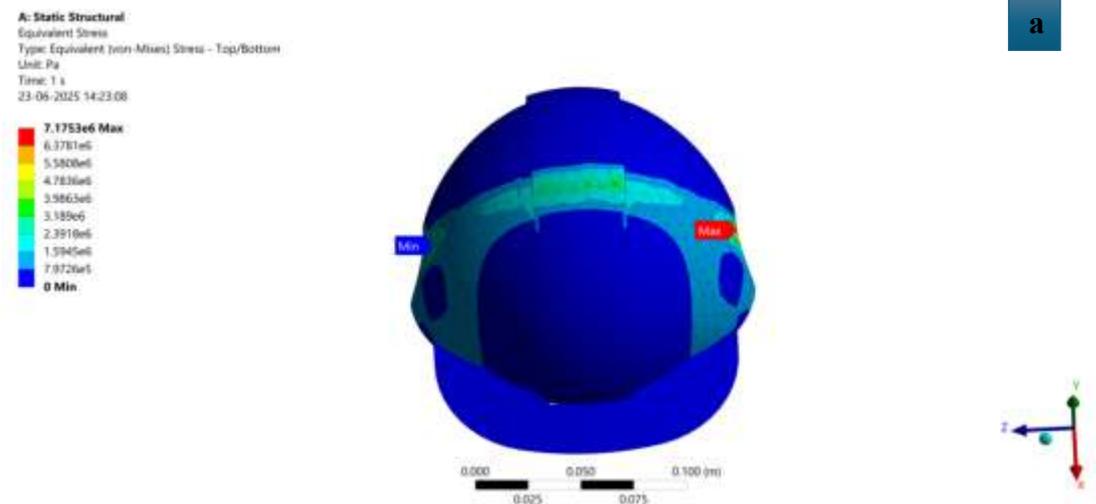
## Loads and Boundary Condition

The 3D model of Helmet was imported into ANSYS as a STEP file then the material properties were added in pre-processor as it is needed of evaluation. Then the meshing was done which is a discretization process of dividing the whole product into smaller elements and the governing equations are found for every element and the nodal results are represented in the results. So as to get the results the boundary conditions like the fixed support was given the base part of the helmet was fixed and the force was applied from the top and front so as to check the possible stress generation and so as to check the factor of safety. The 19.5 KN of force was applied as per the FMVSS (Federal Motor Vehicle Safety

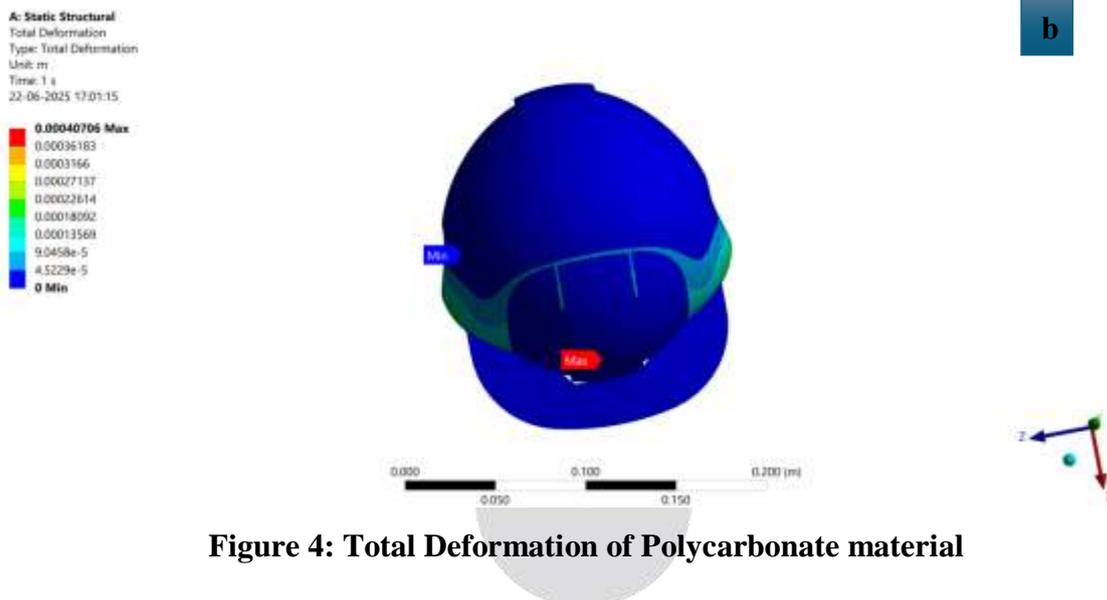
Standard) 218 standard which has to be applied in all the direction (one direction at a time) so as to check the quality of helmet [3].

## RESULTS AND DISCUSSION

The FEA was done in Ansys 2024 for deformation and stress for two different types of material which were Polycarbonate, polyester. This analysis will give a comparative aspect on the performance of the two materials.



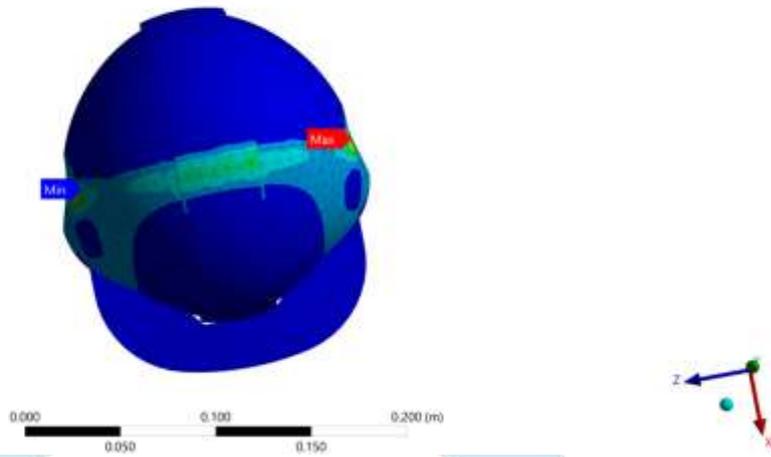
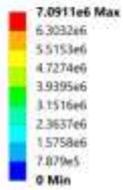
**Figure 3: von-misses stress of Polycarbonate material**



**Figure 4: Total Deformation of Polycarbonate material**

The analysis result for Polycarbonate material .The Figure 3 shows the stress generated in the model when a load of 19.5 KN was applied. The maximum stress observed was  $7.1753 \times 10^6$  Pa. Figure 4 shows the total deformation of 0.00040706 m.

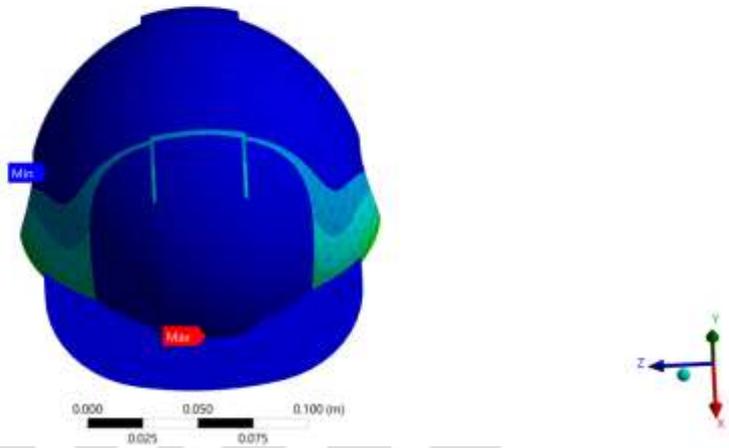
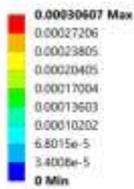
A: Static Structural  
 Equivalent Stress  
 Type: Equivalent (von-Mises) Stress - Top/Bottom  
 Unit: Pa  
 Time: 1 s  
 22-06-2025 17:00:12



c

Figure 5: von-misses stress of polyester material

A: Static Structural  
 Total Deformation  
 Type: Total Deformation  
 Unit: m  
 Time: 1 s  
 23-06-2025 14:20:25



d

(B)

Figure 6: Total Deformation of polyester material

The analysis result for polyester material. The figure 5 shows the stress generated in the model when a load of 19.5 KN was applied. The maximum stress observed was  $7.0911 \times 10^6$  Pa. In figure 6 the Total deformation was 0.00030607 m.

The compilation of all the above results has been tabulated below

Table 2: von-misses stress and deformation result of the two different materials

MATERIAL	VON-MISSES STRESS (Pa)	TOTAL DEFORMATION (m)
POLYCARBONATE	$7.1753 \times 10^6$	0.00040706
POLYESTER	$7.0911 \times 10^6$	0.00030607

### 3D Printed Helmet using Polycarbonate Material



**Figure 7: Additive Manufacturing (FDM) of 3D Printed Helmet**

#### CONCLUSION

Static structure analysis is carried out on the existing designed Constructional helmet by using Analysis software and the results of two different materials, the highest stress observed was for Polycarbonate the lowest was for polyester and the deformation that we observed was highest in Polycarbonate and lowest in polyester. From the above condition, we can state that the materials which were imparted to a force of 19.5 KN was to just check on to the performance of the materials and their total deformation, the important aspect for a helmet is its deformation against the applied load. From the above observation, we can say that polycarbonate material amongst the two tested materials implies to be a better suitability for 3D printing of helmets.

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