

# Design and Analysis of Industrial Helmet

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## ABSTRACT

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 industry as a result 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 filling of material, uneven pressure distribution and blow holes. The aim of the project is to increase the strength of industrial helmet by making the modify material in existing one.

In order to achieve the objective of the project, the work is carried out in three stages.

In the first stage a parametric model is designed by using 3D modeling module in Pro-Engineer software. After designing the helmet, mould flow analysis is carried out on helmet by using plastic advisor which is a module in pro/E. Mould flow analysis is used for finding material filling, pressure distribution, air traps, and weld lines during the injection molding process at constant pressure and different temperature ranges.

In the second stage, after completion of the mould flow analysis impact analysis is done on industrial helmet by using COSMOS software for the three different type materials from different heights.

## I. INTRODUCTION

### 1.1 Introduction to Helmet

A helmet is a form of protective gear worn on the head to protect it from Injuries. Ceremonial or symbolic helmets (e.g., English policeman's helmet) without protective function are sometimes used. The oldest known use of helmets was by Assyrian soldiers in 900BC, who wore thick leather or bronze helmets to protect the head from blunt object and sword blows and arrow strikes in combat. Soldiers still wear helmets, now often made from lightweight plastic materials.

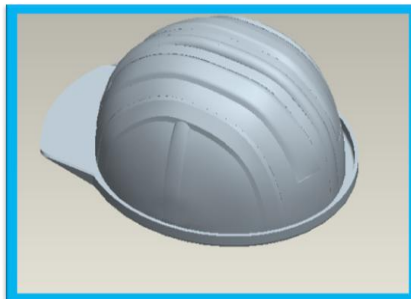


Figure 1.1 original model of industrial helmet

In civilian life, helmets are used for recreational activities and sports (e.g., jockeys in horse racing, American football, ice hockey, cricket, and rock climbing); dangerous work activities (e.g., construction, mining, riot police); and transportation. (e.g., Motorcycle helmets and bicycle helmets). Since the 1990s, most helmets are made from resin or plastic, which may be reinforced with fibers such as aramids.

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. Anatomical helmets adapted to the inner head structure were invented by neurosurgeons at the end of the 20th century.

Helmets used for different purposes have different designs. For example, a bicycle helmet must protect against blunt impact forces from the wearer's head striking the road. A helmet designed for rock climbing must protect against heavy impact, and against objects such as small rocks and climbing equipment falling from above. Practical concerns also dictate helmet design: a bicycling helmet should be aerodynamic in shape and well ventilated, while a rock climbing helmet must be lightweight and small so that it does not interfere with climbing.

Some helmets have other protective elements attached to them, such as a face visors or goggles or a face cage, and ear plugs and other forms of protective headgear, and a communications system. Sports helmets may have an integrated metal face protector (face cage).

## II. LITERATURE SURVEY

The literature towards the design methodologies, analysis techniques proposed by different authors is collected and presented in the subsequent paragraphs.

### **Franklin, Glen A.**

The purpose of this study was to identify the impact of motorcycle helmet use on patient outcomes and cost of hospitalization, in a state with a mandatory helmet law.

Patients admitted after motorcycle crashes from July 1996 to October 2000 were reviewed, including demographics, Injury Severity Score, length of stay, injuries, outcome, helmet use, hospital cost data, and insurance information. Statistical analysis was performed comparing helmeted to un helmeted patients using analysis of variance, Student's test, and regression analysis.

Admitted 216 patients, 174 wore helmets and 42 did not. Injury Severity Score correlated with both length of stay and cost of hospitalization. Mortality was not significantly different in either group. Failure to wear a helmet significantly increased incidence of head injuries (Student's *t* test,  $p < 0.02$ ), but not other injuries. Helmet use decreased mean cost of hospitalization by more than \$6,000 per patient.

Failure to wear a helmet adds to the financial burden created by motorcycle-related injuries. Therefore, individuals who do not wear helmets should pay higher insurance premiums.

### **G M Ginsberg and D S Silverberg**

Legislation requiring bicyclists to wear helmets in Israel will, over a helmet's 5-year duration (assuming 85% compliancy, 83.2% helmet efficiency for morbidity, and 70% helmet efficiency for mortality), save approximately 57 lives and result in approximately 2544 fewer hospitalizations; 13,355 and 26,634 fewer emergency room and ambulatory visits, respectively; and 832 and 115 fewer short-term and long-term rehabilitation cases, respectively. Total benefits (\$60.7 million) from reductions in health service use (\$44.2 million), work absences (\$7.5 million), and mortality (\$8.9 million) would exceed program costs (\$20.1 million), resulting in a benefit-cost ratio of 3.01:1.

### **Syrotuik, Daniel G. Reid, David C.**

There is lack of consensus among pre-hospital personnel (athletic therapists, paramedics, sport physiotherapists) concerning specific aspects of initial care and assessment of injured athletes presenting signs and symptoms of a cervical spine injury (CSI).

In instances of serious injury involving the head and/or spine, complicated by altered levels of consciousness, protective equipment such as helmets and shoulder pads may provide a hindrance to prompt, safe, and efficient management. Specifically, there is disagreement concerning the need or advisability of removing protective head gear, as in the case of football and hockey athletes. Using the technique of fluoroscopy, the cervical spine displacement of 21 male football and hockey athletes was determined while wearing protective shoulder pads and protective head equipment at the following times (a) during helmet removal, (b) during cervical collar application, and (c) as the helmetless head was allowed to rest.

### Mohan J. Edirisinghe, Heidi M. Shaw and Katherine L. Tomkins

The yield stress of seven A16.SG alumina suspensions was estimated using shear stress-shear rate data measured at the processing temperature. Five of these were processed using a high molecular weight polypropylene binder system but each have a different %vol. of ceramic. The two other formulations contain a low molecular weight alcohol as the major binder. The relative viscosities of the A16.SG alumina-polypropylene compositions were used in an extended form of the Eilers equation to evaluate  $V_{\max}$ , the maximum volume fraction of ceramic. The relative viscosities of three other alumina powders processed using the same polypropylene binder system were also investigated using the same equation in order to assess the effect of particle characteristics on  $V_{\max}$ .

## III. PLASTICS

A material consisting of very large molecules characterized by light weight, high corrosion resistance, high strength-to-weight ratios, and low melting points. Most plastics are easily shaped or formed.

### 3.1 Thermoplastic:

A thermoplastic, or thermo softening plastic, is a polymer that becomes pliable or moldable above a specific temperature, and returns to a solid state upon cooling.<sup>[1][2]</sup> Most thermoplastics have a high molecular weight. The polymer chains associate through intermolecular, which permit thermoplastics to be remolded because the intermolecular interactions increase upon cooling and restore the bulk properties. In this way, thermoplastics differ from thermosetting polymers, which form irreversible bonds during the curing process. Thermo sets often do not melt, but break down and do not reform upon cooling

#### 3.1.1 Types of Thermoplastic:

Acetal  
Acrylics  
Acrylonitrile-Butadiene-Styrene  
Nylon  
Polyamide- imide etc

### 3.2 Acrylonitrile butadiene styrene (ABS)

ABS is a common thermoplastic. Its glass transition temperature is approximately 105 °C (221 °F).<sup>[1]</sup> ABS is amorphous and therefore has no true melting point.

ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 5 to 30% butadiene and 40 to 60% styrene. The result is a long chain of poly butadiene criss-crossed with shorter chains of poly(styrene-co-acrylonitrile). The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. The styrene gives the plastic a shiny, impervious surface. The butadiene, a rubbery substance, provides resilience even at low temperatures. For the majority of applications, ABS can be used between -20 and 80 °C (-4 and 176 °F) as its mechanical properties vary with temperature.<sup>[2]</sup> The properties are created by rubber toughening, where fine particles of elastomer are distributed throughout the rigid matrix.

### 3.3 Impact grade Acrylonitrile butadiene styrene (ABS)

Medium high Impact grade ABS is a common thermoplastic. Its glass transition temperature is approximately 105 °C (221 °F).<sup>[1]</sup> ABS is amorphous and therefore has no true melting point.

ABS is a terpolymer made by polymerizing styrene and acrylonitrile in the presence of polybutadiene. The proportions can vary from 15 to 35% acrylonitrile, 25 to 50% butadiene and 30 to 50% styrene. The result is a long chain of poly butadiene criss-crossed with shorter chains of poly(styrene-co-acrylonitrile). The nitrile groups from neighboring chains, being polar, attract each other and bind the chains together, making ABS stronger than pure polystyrene. If increasing of butadiene the impact grade ABS plastic more stronger than the ABS plastic. The styrene gives the plastic a shiny, impervious surface. The butadiene, a rubbery substance, provides resilience even at low temperatures. For the majority of applications, ABS can be used between -25 and 90 °C (-3 and 196 °F) as its mechanical properties vary with temperature.<sup>[2]</sup> The properties are created by rubber toughening, where fine particles of elastomer are distributed throughout the rigid matrix

### 3.4 Nylon 4-6 (polyamide):

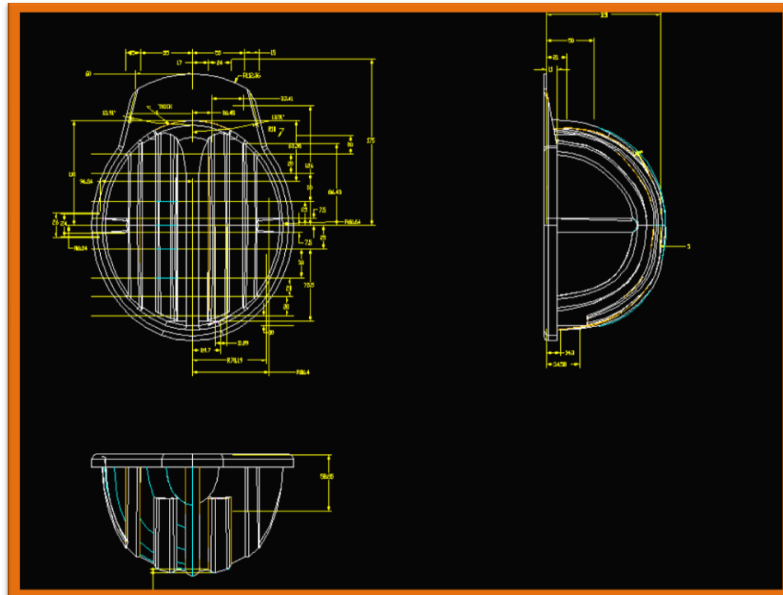
The name "nylons" refers to the group of plastics known as polyamides. Nylons are typified by amide groups (CONH) and encompass a range of material types (e.g. Nylon 6,6; Nylon 6,12; Nylon 4,6; Nylon 6; Nylon 12 etc.), providing an extremely broad range of available properties. Nylon is used in the production of film and fiber, but is also available as a moulding compound.

Nylon is formed by two methods. Dual numbers arise from the first, a condensation reaction between diamines and dibasic acids produces a nylon salt. The first number of the nylon type refers to the number of carbon atoms in the diamine, the second number is the quantity in the acid(e.g. nylon 6,12)

The second process involves opening up a monomer containing both amine and acid groups known as a lactam ring. The nylon identity is based on the number of atoms in the lactam monomer (e.g. nylon 4-6 or nylon 12 etc).

#### IV. MODELING AND MOULD FLOW ANALYSIS OF HELMET

Figure 4.1 2D Diagram of the industrial helmet



##### 4.1 Design and manufacturing procedure of helmet

By using the fundamental abilities of the software with regards to the single data source Principle, it provides a rich set of tools in the manufacturing environment in the form of tooling design and simulated CNC machining and output. Tooling options cover specialty tools for molding, die-casting and progressive tooling design.

##### 4.2 Different Modules in Pro/Engineer

1. Part Design
2. Assembly
3. Drawing
4. Sheet metal
5. Mould Design
6. Manufacturing

##### 4.3 Model of Industrial Helmet

Industrial helmet is model by using Pro/E software, Figure 4.2, Figure 4.3 & Figure 4.4 gives the detailed explanation of the helmet modeled in Pro/E software

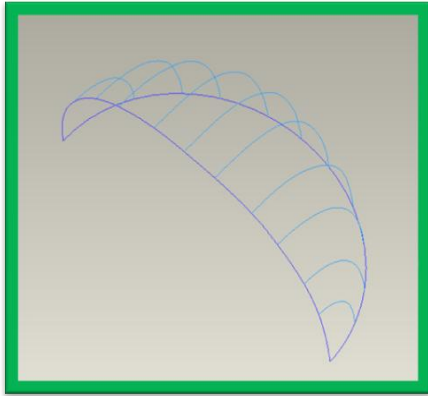


Figure 4.2 First Wire Frame Model

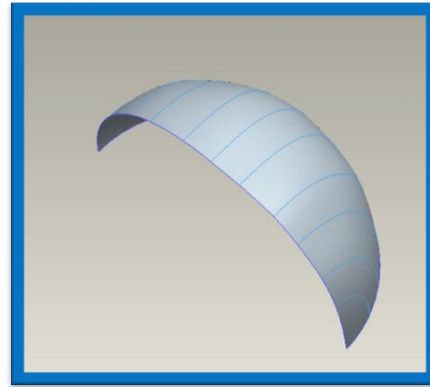


Figure 4.3 Surface Part

#### 4.4 Plastic flow analysis

The Flow Analysis summary page gives an overview of the model's analysis, including information about actual injection time and pressure and whether weld lines and air traps are present. In addition, the dialog uses the Confidence of Fill result to assess the mould ability of the part. Figure 3.4 gives the information about the plastic flow analysis

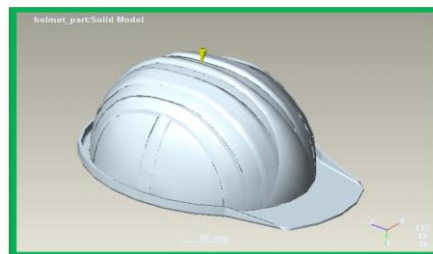


Figure 4.4 Solid model of the Helmet

#### 4.5 Fill Time

This result shows the flow path of the plastic through the part by plotting contours which join regions filling at the same time. These contours are displayed in a range of colors from red, to indicate the first region to fill, through to blue to indicate the last region to fill. A short shot is a part of the model that did not fill, and will be displayed as translucent. By plotting these contours in time sequence, the impression is given of plastic actually flowing into the mould. Figure 3.5 explains the fill time required for the helmet mould.

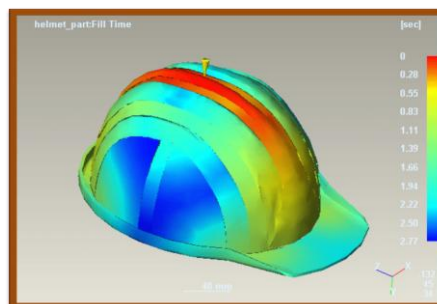


Figure 4.5 Fill time of Helmet

#### 4.6 Confidence of Fill

The confidence of fill result displays the probability of a region within the cavity filling with plastic at conventional injection molding conditions. This result is derived from the pressure and temperature results. Figure 3.6 explains the confidence fill

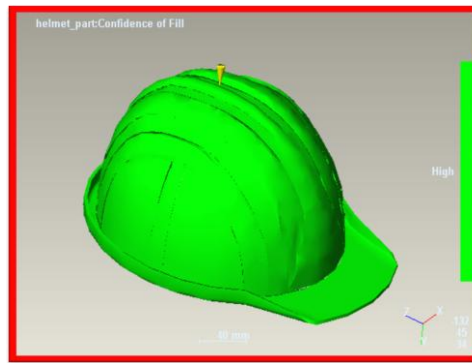


Figure 4.6 Confidence of fill of helmet

**4.7 Quality Analysis**

The Quality display is derived from combinations of the five results listed below. These five results are each divided into ranges - unacceptable (red), acceptable (yellow) and preferred (green). The five results are:

- a) flow front temperature
- b) pressure drop
- c) cooling time
- d) shear rate
- e) shear stress

For each area of the cavity, the five results are evaluated. If all five results in an area are acceptable, the area is green. If there is at least one unacceptable result, the area is red. If there are both acceptable and preferred results, the area is yellow.

**1. An area of the Quality result is green if all of these cases are true:**

The flow front temperature (T) is between the minimum (T <sub>min</sub> ) and maximum (T <sub>max</sub> ) recommended temperatures for the material in the material database.	$T_{min} < T < T_{max}$
The pressure drop (P <sub>drop</sub> ) is in the range between 0% and 80% of the maximum injection pressure (P <sub>max</sub> ), as set in the Processing Conditions Tab of the Molding Parameters dialog.	$P_{drop} < (0.8P_{max})$
The cooling time (t) is less than 1.5 times the average cooling time for the part (t <sub>av</sub> )	$t < 1.5t_{av}$

**2. One of these conditions is true: An area of the Quality result is yellow if none of the red conditions is true, and at least.**

The flow front temperature (T) is between the minimum (T <sub>min</sub> ), recommended temperature for the material and a value 5°C above the maximum (T <sub>max</sub> ), recommended temperature for the material.	$T_{min} < T < (T_{max} + 5^{\circ}C)$
The pressure drop (P <sub>drop</sub> ) lies in the range between 80% and 100% of the maximum injection pressure (P <sub>max</sub> ), as set in Processing Conditions Tab of the Molding Parameters dialog.	$(0.8P_{max}) < P_{drop} < P_{max}$
The cooling time (t) is between 1.5 and 5 times the average cooling time for the part.	$1.5t_{av} < t < 5t_{av}$

**3. An area of the Quality result is red if at least one of these cases is true:**

The flow front temperature (T) is more than 5°C above the maximum Maximum recommended temperature for material (T <sub>max</sub> )	$T > (T_{max} + 5^{\circ}C)$
The pressure drop (P <sub>drop</sub> ) is greater than or equal to the maximum injection pressure (P <sub>max</sub> ), as set in Processing Conditions Tab of the Molding Parameters dialog.	$P_{drop} \geq P_{max}$
The cooling time (t) is more than 5 times above the average cooling time for the part (t <sub>av</sub> ).	$t > 5t_{av}$

**4.8 Important information about mould flow analysis**

In this chapter mould flow analysis of helmets can be studied and also plastic flow analysis, filling time of helmets, pressure drop in helmet, injection pressure in helmet, flow front temperature and quality of helmet can be analyzed. By using this process manufacture of industrial helmet can be done without any failures.

The analysis results herein are believed to be reliable but are not to be construed as providing a warranty, including any warranty of merchantability or fitness for purpose, or representation for which Mould flow Corporation assumes legal responsibility. Users should undertake sufficient verification and testing to determine the suitability for their own particular purpose of any information presented herein. Nothing herein is to be taken as permission, inducement, or recommendation by Mould flow Corporation to practice any patented invention without a license or in any way infringe upon the intellectual property rights of any other party.

## V. ANALYSIS OF THE HELMET BY USING COSMOS SOFTWARE

### 5.1 Analysis Steps

Complete analysis study by performing the following steps:

- a) Create a study defining its analysis type and options.
- b) If needed, define parameters of your study.

Parameters could be a model dimension, a material property, a force value, or any other entity that you want to investigate its impact on the design

### 5.2 Impact analysis of Nylon 4-6 plastic when dropped from 2000m height

Properties of Nylon 4-6

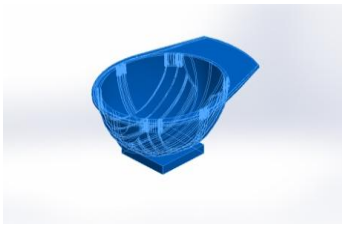
Model Reference	Properties
	<p><b>Name:</b> Default (4)  <b>Model type:</b> Linear Elastic Isotropic  <b>Default failure criterion:</b> Max von Mises Stress  <b>Yield strength:</b> 2.5e+008 N/m<sup>2</sup>  <b>Tensile strength:</b> 3e+007 N/m<sup>2</sup>  <b>Elastic modulus:</b> 1.6e+010 N/m<sup>2</sup>  <b>Poisson's ratio:</b> 0.394  <b>Mass density:</b> 1400 kg/m<sup>3</sup>  <b>Shear modulus:</b> 3.189e+008 N/m<sup>2</sup></p>

Table 5.1 volumetric properties of helmet

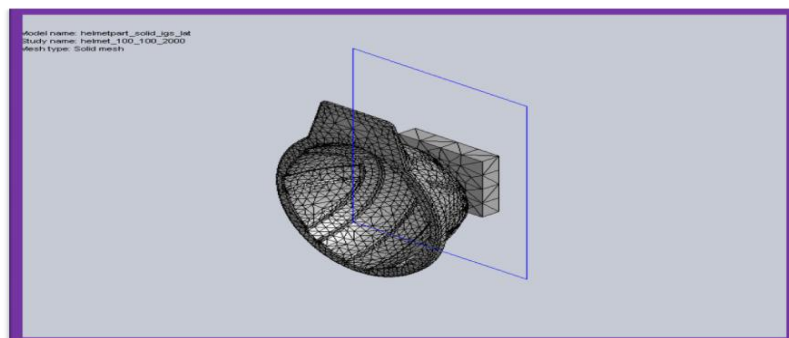
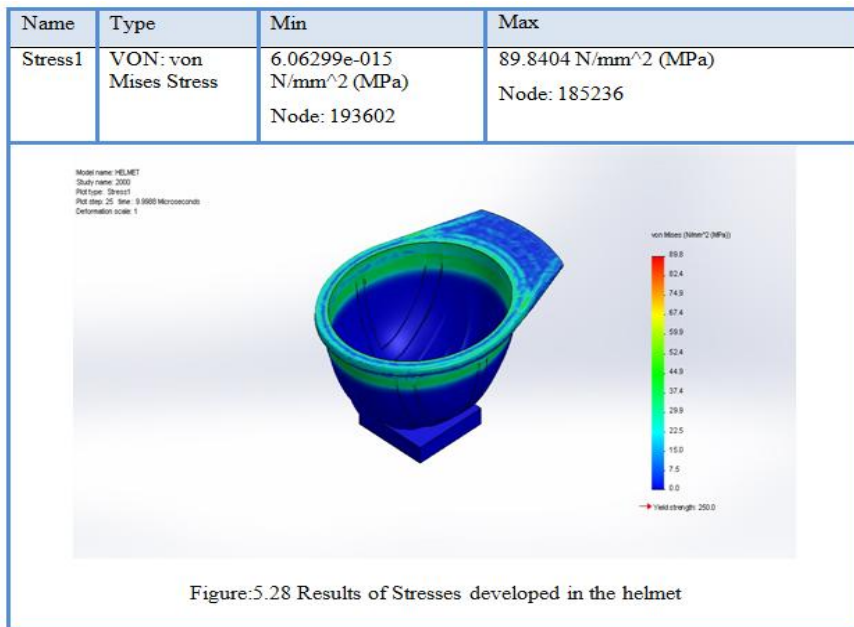


Fig: solid mesh of helmet

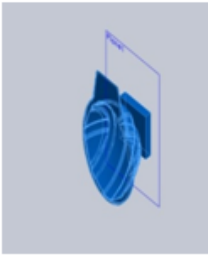


**5.9.4 Results of Stresses developed in the helmet dropped from 2000mm height**



**Discussion:** In the given above Figure 5.28 the blue color indicates the minimum level of strain and the red color indicates the maximum level of strain on helmet.

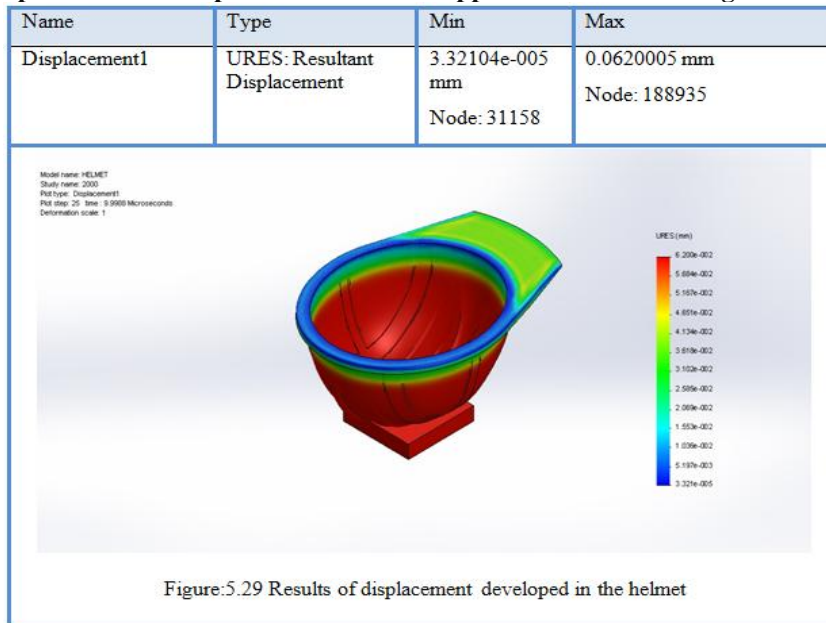
**5.9.4 Results of displacement developed in the helmet dropped from 2000mm height**

Document Name and Reference	Treated As	Volumetric Properties	Document Modified
Boss-Extrude2 	Solid Body	Mass:0.67312 kg Volume:0.000480804 m <sup>3</sup> Density:1400 kg/m <sup>3</sup> Weight:6.5965 N	D:\helmet\helmetpart_solid_igs_1at.SLDPRT

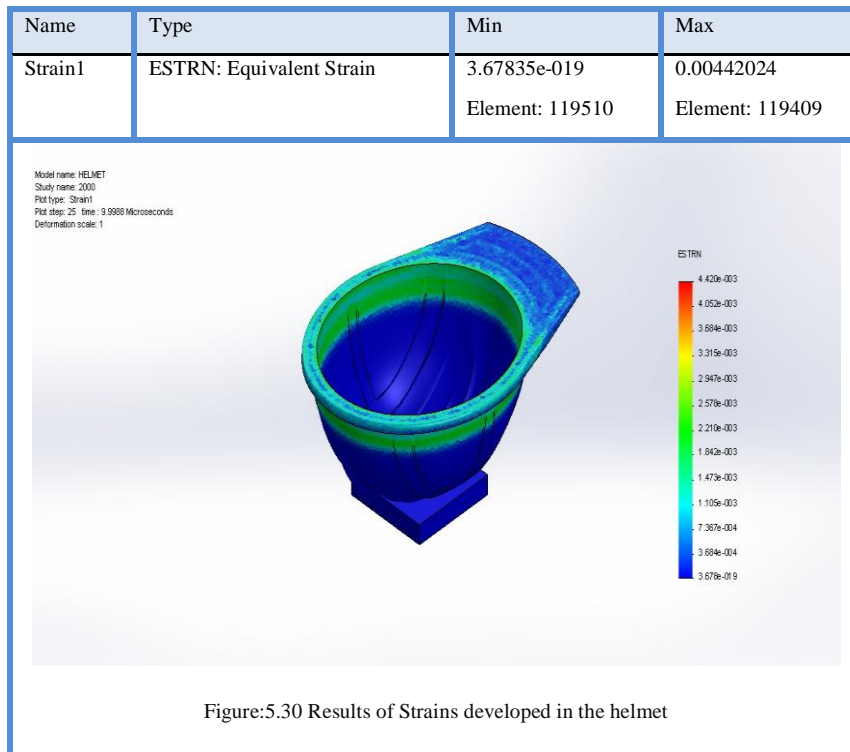
5.3 volumetric properties



5.9.5 Results of Displacement developed in the helmet dropped from 2000mm height.



5.9.5 Results of Strain developed in the helmet dropped from 2000mm height.



**Discussion:** In the given above Figure 5.30 the blue color indicates the minimum level of strain and the red color indicates the maximum level of strain on helmet.

## VI. RESULT ANALYSIS

Impact analysis is carried out on the existing designed helmets by using COSMOS software and the results are tabulated as following

### 6.1.1 ABS Plastic

DISTANCES (mm)	STRESS (N/mm <sup>2</sup> )	DISPLACEMENT (mm)	STRAIN	FOS
2000	17.1164	0.0309706	0.00746974	1.89
3000	21.1292	0.0382015	0.00922569	1.52
4000	23.8155	0.044087	0.0104911	1.25

### 6.1.2 Impact ABS Plastic

DISTANCES (mm)	STRESS (N/mm <sup>2</sup> )	DISPLACEMENT (mm)	STRAIN	FOS
2000	23.6628	0.0310221	0.00710183	1.90
3000	29.2154	0.0382672	0.00877044	1.54
4000	33.3442	0.0440759	0.0100622	1.35

### 6.1.2 Impact ABS Plastic

DISTANCES (mm)	STRESS (N/MM <sup>2</sup> )	DISPLACEMENT (MM)	STRAIN	FOS
2000mm	89.8	6.200e <sup>-2</sup>	4.420e <sup>-3</sup>	2.78
3000mm	97.98	4.027e <sup>-2</sup>	2.653e <sup>-2</sup>	2.55
4000mm	113.7	4.667e <sup>-2</sup>	5.355e <sup>-3</sup>	2.22

Stress produced in Nylon 4-6 plastic helmet is more than stresses produced in impact ABS plastic and ABS plastic helmet for different heights. It indicates that the resistance against the load per unit area, factor of safety is more, and with standing capacity of Nylon 4-6 plastic is more.

From the results it is proved that displacement produced in Nylon 4-6 plastic helmet is more than displacement produced in ABS plastic and impact ABS plastic helmet for different heights. It shows that the displacement of helmet cannot be altered to high and the impact of load on helmet is less.

Volumetric Strain produced in Nylon 4-6 plastic helmet is less than strain produced in ABS plastic and impact ABS plastic helmet for different heights, which gives more rigidity to the human neck from impact loads.

In this chapter, it is found that the Nylon 4-6 plastic is good instead of ABS plastic and impact ABS plastic helmet by using based on the above results.

## ACKNOWLEDGEMENT

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