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Analysis on a Two Wheeler Helmet using PTC Creo and Ansys Software for Carbon Fiber, ABS & GFRP Materials

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Abstract:- Helmet plays an essential role in reducing the rate of accidents. Motorcyclists are more prone to crash injuries than car drivers because motorcycles are unenclosed, leaving the rider vulnerable to contact hard road surfaces. There are many types of helmets depend upon the field where it is using like riding, sports, etc. The objective of the work deals with the design and analysis of the helmet under specified boundary conditions and loadings for the three different materials namely, Carbon Fiber, Acrylonitrile Butadiene Styrene (ABS) and Glass Fiber Reinforced Polyester resin (GFRP). We are deigning the module in PTC Creo and compare the impact resistance of the three materials using Ansys and suggesting the best material for better performance. This type of impact resistance analysis is likely to carry out to determine the best suitable material for the given conditions.

***Keywords**:- Carbon Fiber, Acrylonitrile Butadiene Styrene (ABS) and Glass Fiber Reinforced Polyester resin (GFRP), Impact Resistance.*

I. INTRODUCTION

Head injuries due to motorcycle accident cause a great deal of concern because it may lead to death and permanent disability. Several analyses and experiments on the motorcycle helmet have been performed. Vetter and Vanderby (1987) developed a non linear finite element model for the static analysis of helmet. Gilchrist and Mills (1994) performed impact analysis of a motorcycle helmet by using an equivalent model of mass, spring, and damper. Yetham et al (1994) carried out a finite element parametric study of impact response of the helmet. However, the accuracy of their model was limited because used coarse mesh. Recentlt, Kostopouls et al (2002) performed impact analysis of a helmet-head form system using the finite element code LS-DYNA3D.

Head injury is the most common cause of severe injuries in motorcycle accidents. Compared with cars, motorcycles are especially dangerous. Per km traveled, the number of deaths on motorcycles is about 14 times the number in cars. Motorcycles often have excessive performance capabilities, including especially rapid acceleration and high top speed. They're less stable than cars in emergency braking and less visible. Motorcyclists are more prone to crash injuries than car drivers because motorcycles are unenclosed, leaving the rider vulnerable to contact hard road surfaces. This is why wearing a helmet is so important.

II. MATERIALS USED

Types of synthetic fiber used to make some helmets:

- Carbon Fiber
- Acrylonitrile Butadiene Styrene (ABS)
- Glass Fiber Reinforced Polyester resin (GFRP)

In former times lightweight non-metallic protecting materials and strong transparent materials for visors were not available. Most helmets are made from resin or plastic, which may be reinforced with fibers as the above mentioned ones.

III. DESIGN AND ANALYSIS OF HELMET

The present work explains the behaviour of the helmet made of different materials virtually under static as well as dynamic loading. The model of helmet is prepared in PTC Creo software; meshed using Hypermesh and ANSYS as a FEM tool to study the behaviour of the helmet under different loads. Analysis is performed with different materials i.e Carbon Fiber, ABS and GFRP in three different directions to predict the suitable material for making the helmet. A set of estimated results are found out by using the analyzing software.

For designing a helmet model, the standard designing parameters are followed. The British, American standards as well as the IS are preferred mostly.

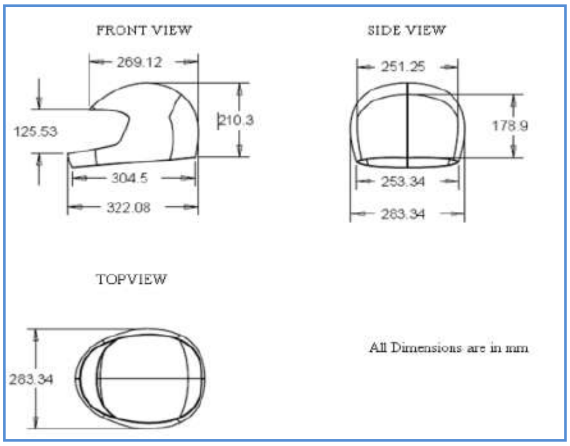

Fig 1:- Designing Dimensions

A. Circumference of the helmet

Table 1. shows the various sizes of the helmets used in all the countries. In this work the medium sized helmet is considered for analysis.

Size	XXS	XS	S	M	L	XL	XXL
Circumference (cm)	53	54	55-56	57-58	59	60-61	62

Table 1. Head circumference

B. Modeling using PTC Creo

PTC Creo, formerly known as ProE is a 3D CAD, CAM, CAE and associative solid modelling application.

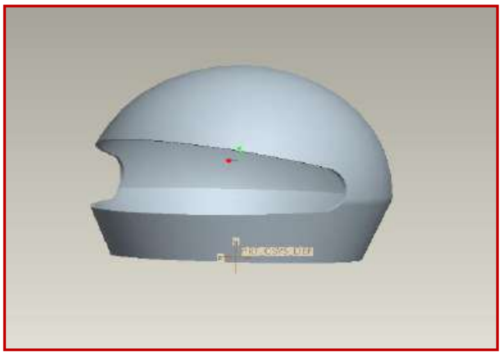

Fig 2:- Sketch of Helmet Body

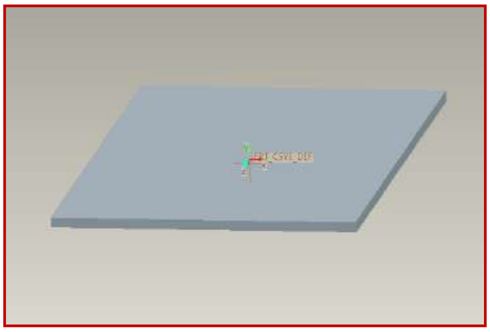

Fig 3:- Sketch of Anvil

Fig 4:- Assemble of Helmet Body and Anvil

C. Meshing using Hyper Mesh

Altair Hypermesh is a market-leading, multi-disciplinary finite element pre-processor which manages the generation of the largest, most complex models, starting with the import of CAD geometry to exporting ready-to-run solver file.

- *Meshed Model of Helmet*

In this meshed model, SHELL 63 is used as element type.

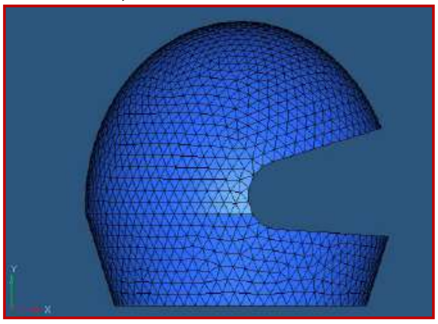

Fig 5:- Meshed model of helmet

- *Meshed Assembly of Helmet and Anvil*

In this meshed model, SHELL 163 is used as element type for both helmet and anvil.

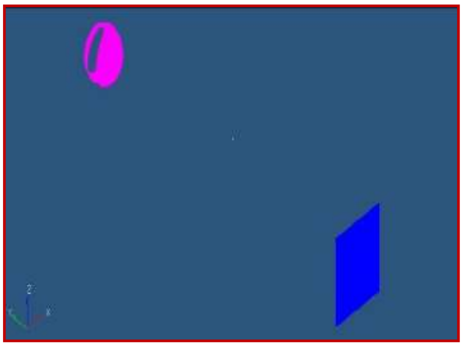

Fig 6:- Meshed Assembly of helmet and anvil

IV. DROP TEST

It involves dropping an object from some height in a gravitational field onto a flat, rigid surface by neglecting surface friction. The basic procedure outlined here assumes that the object has a zero initial velocity, and the object is being dropped onto a target that lies in a plane which is normal to the direction of the acceleration due to gravity.

A. Drop Test at a Velocity of 8.5 m/sec

Figure 7. shows drop test of helmet before hits the anvil at 8.5 m/s

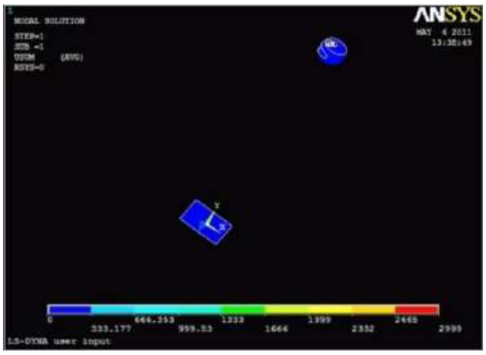

Fig 7:- Helmet before hitting the anvil

Figure 8. Shows drop test helmet after hitting the anvil at 8.5 m/s

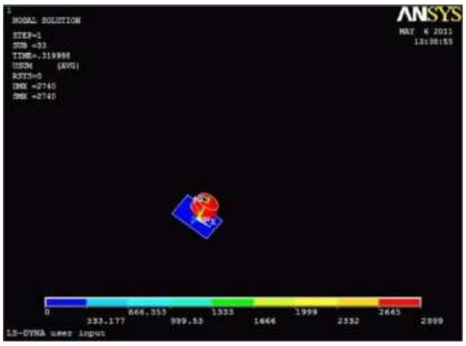

Fig 8:- Helmet after hitting the anvil

Figure 9. Shows the maximum stress value of the helmet after hitting the anvil.

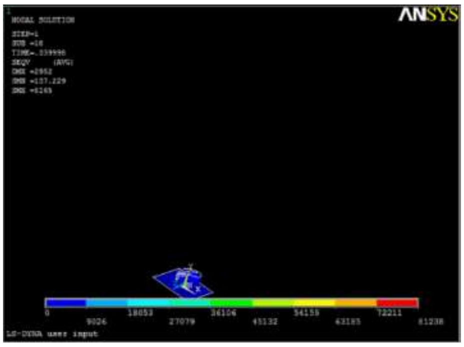

Fig 9:- helmet in contact with anvil

Figure 10. Shows the deformed shape of helmet after hitting the anvil at 8.5 m/sec.

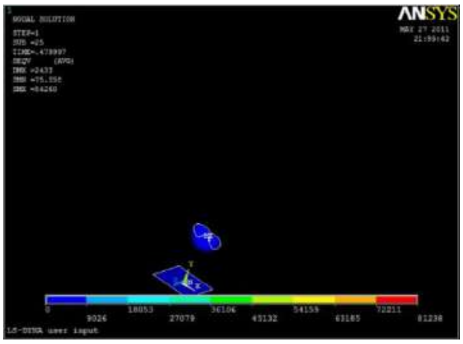

Fig 10:- Deformed shape of helmet after hitting the anvil

B. Drop Test at a Velocity of 9.5 m/sec

Figure 11. Shows drop test of helmet before hits the anvil at 9.5 m/s.

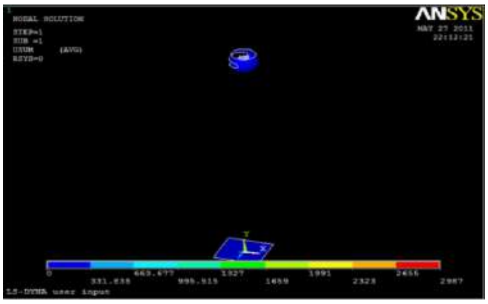

Fig 11:- Helmet before hitting anvil

Figure 12. Shows drop test helmet after hitting the anvil at 9.5 m/s.

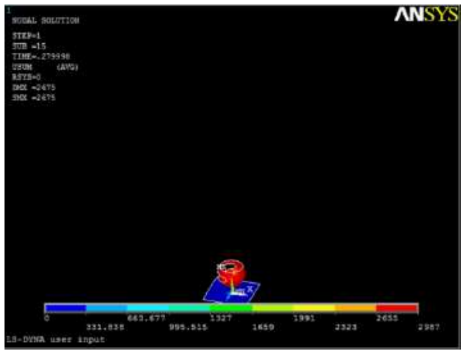

Fig 12:- Helmet after hitting anvil

Figure 13. Shows the maximum stress value helmet after hitting the anvil.

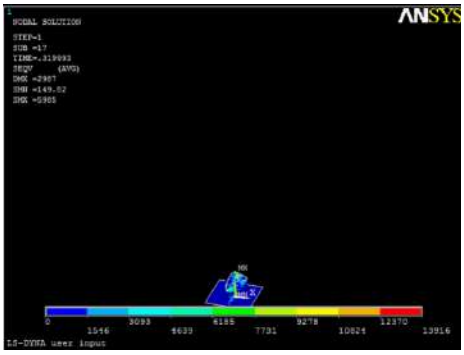

Fig 13:- helmet in contact with anvil

Figure 14. Shows the deformed shape of the helmet model at 9.5 m/sec.

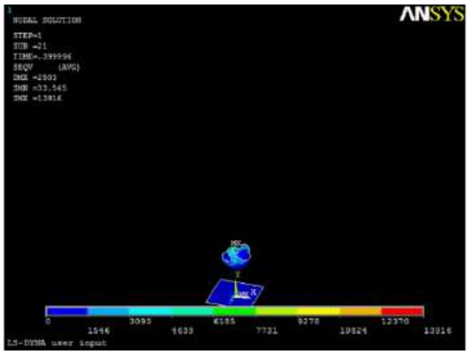

Fig 14:- Deformed shape of helmet after hitting the anvil

Velocity (m/s)	Maximum stress (MPa)
8.5	5165
9.5	5985

Table 2. Drop Test Results

From the drop test analysis results velocity is directly proportional to maximum stress.

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V. STRUCTURAL ANALYSIS

In this work structural analysis carried out by giving load on different portions (Top, Rear, Side, Chin and Forehead) of helmet and the deflection, stresses were analyzed for different outer shell materials (Carbon Fiber, ABS, GFRP).

A. Load applied on different portions

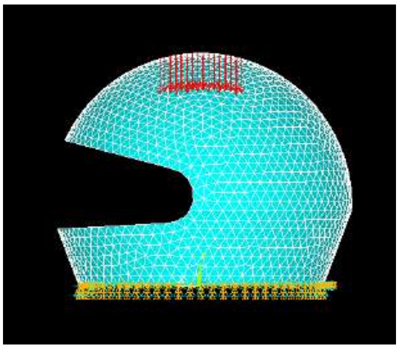

Fig 15:- Load applied on Top portion

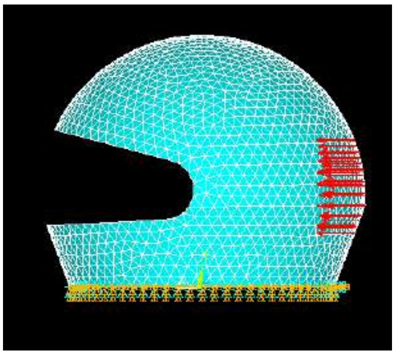

Fig 16:- Load applied on Rear portion

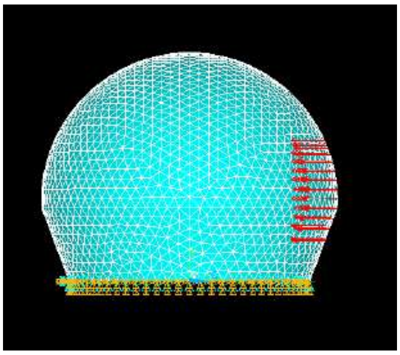

Fig 17:- Load applied on Side portion

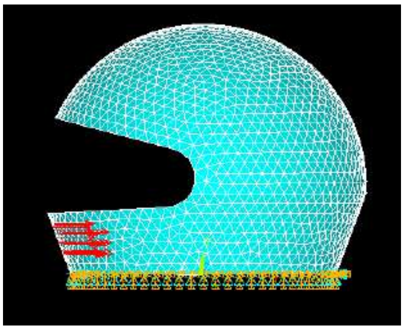

Fig 18:- Load applied on Chin portion

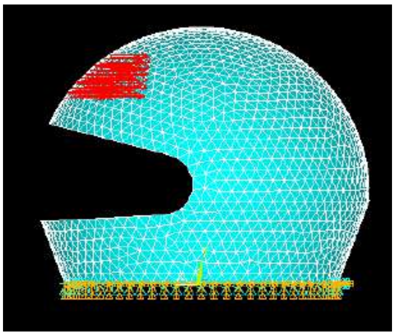

Fig 19:- Load applied on Fore Head portion

VI. RESULTS AND DISCUSSIONS

A. For Carbon Fiber Material

The following figures show the deflection and stress distribution of helmet for different load values as Carbon Fiber is a outer shell material.

- *Load on Top surface*

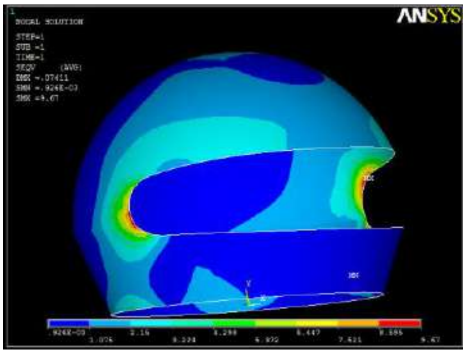

Fig 20:- Stress Distribution at 350 N

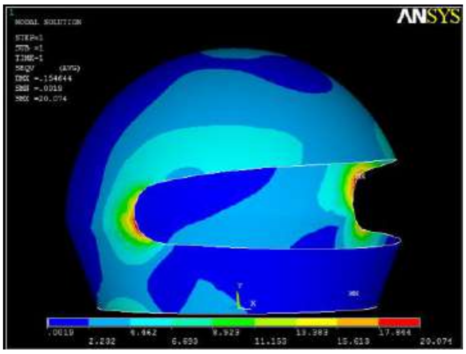

Fig 21:- Stress Distribution at 700 N

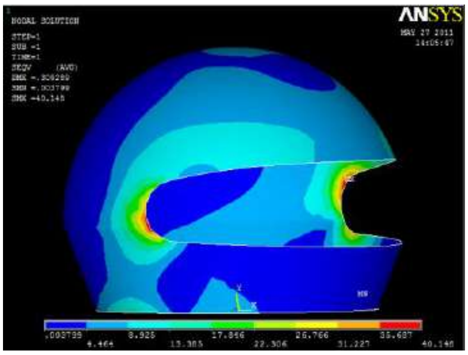

Fig 22:- Stress Distribution at 1050 N

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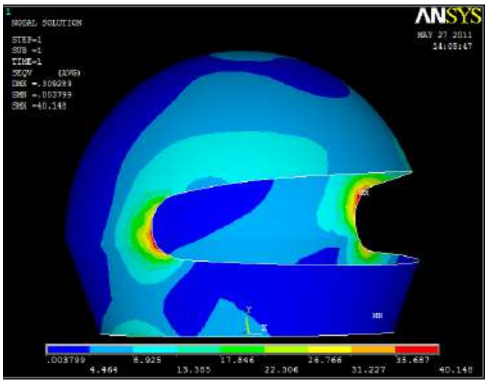
Fig 23:- Stress Distribution at 1400 N

* *Load on Rear surface*

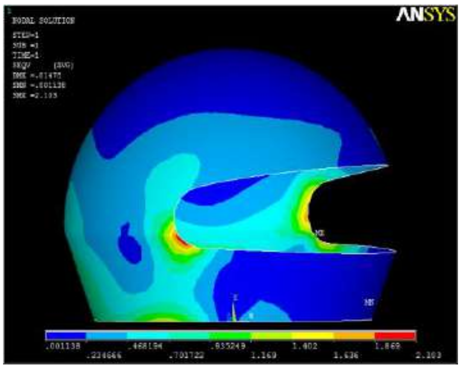
Fig 24:- Stress distribution at 350 N

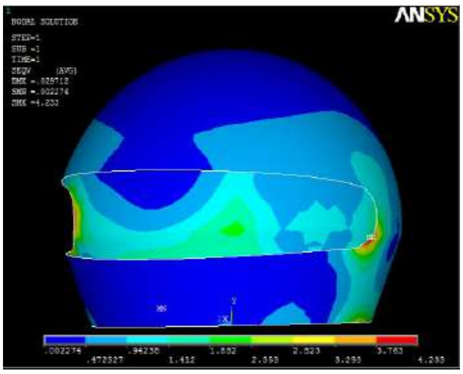
Fig 25:- Stress distribution at 700 N

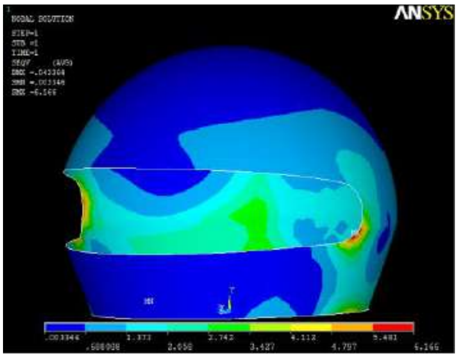
Fig 26:- Stress distribution at 1050 N

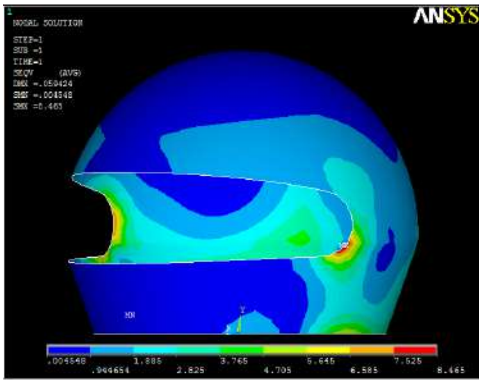
Fig 27:- Stress distribution at 1400 N

* *Load on Side surface*

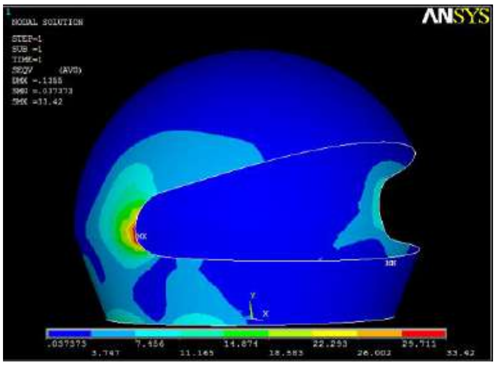
Fig 28:- Stress distribution at 350 N

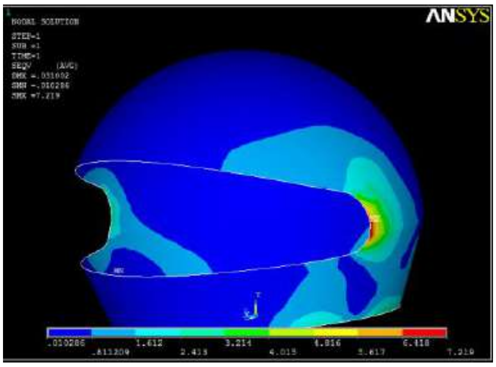
Fig 29:- Stress distribution at 700 N

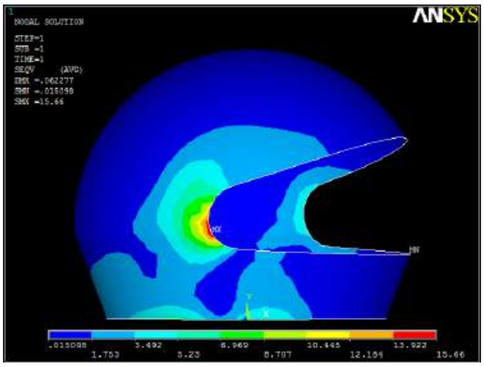
Fig 30:- Stress distribution at 1050 N

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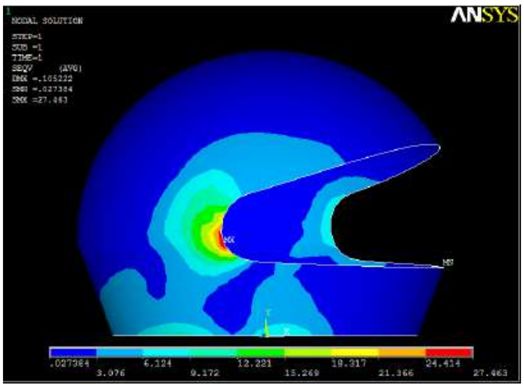

Fig 31:- Stress distribution at 1400 N

* *Load on Chin surface*

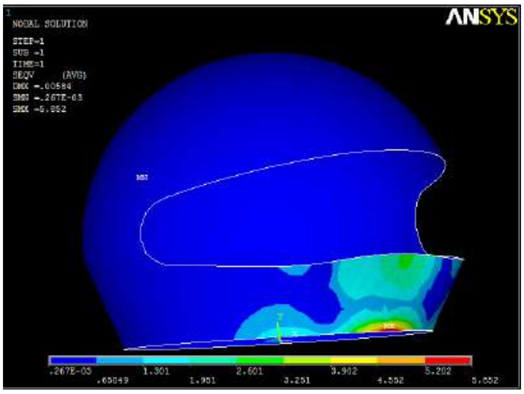

Fig 32:- Stress distribution at 350 N

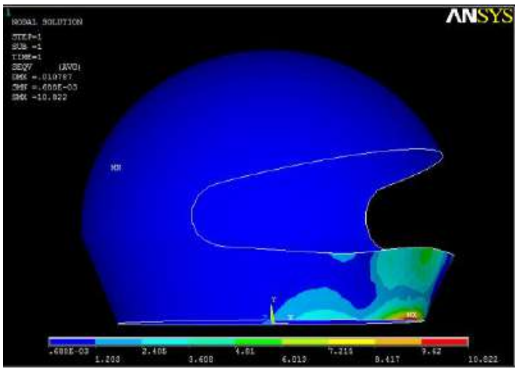

Fig 33:- Stress distribution at 700 N

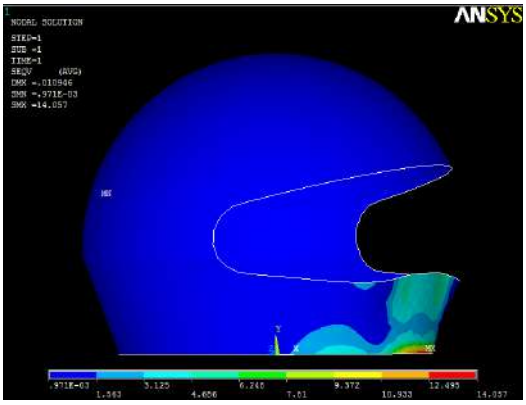

Fig 34:- stress distribution at 1050 N

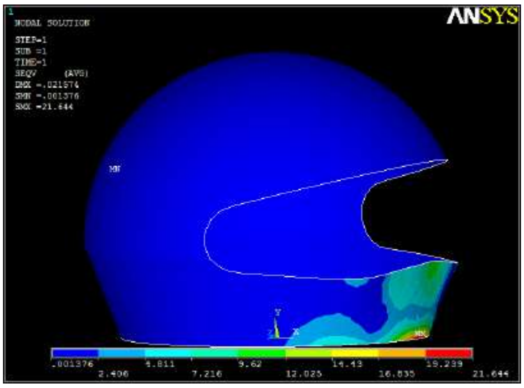

Fig 35:- stress distribution at 1400 N

* *Load on Forehead surface*

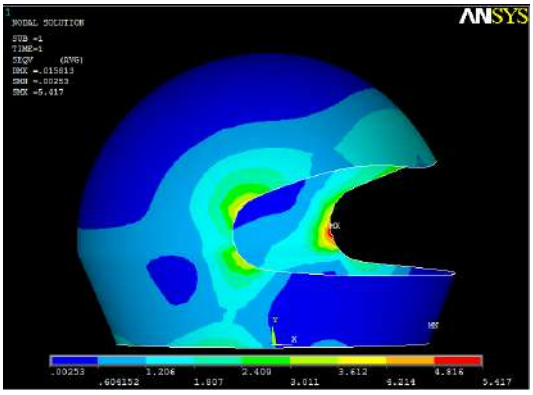

Fig 36:- stress distribution at 350 N

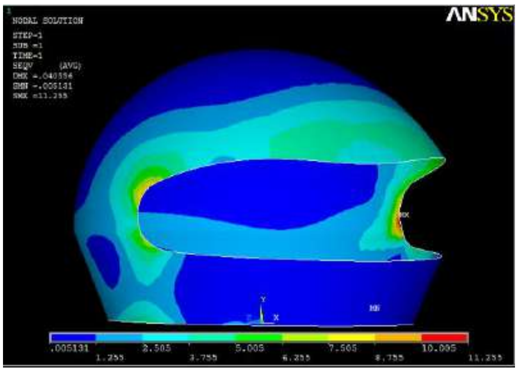

Fig 37:- stress distribution at 700 N

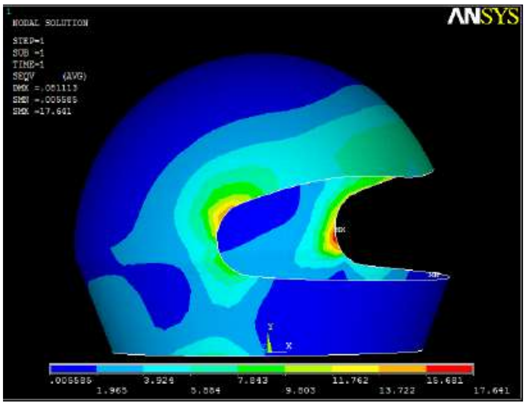

Fig 38:- Stress distribution at 1050 N

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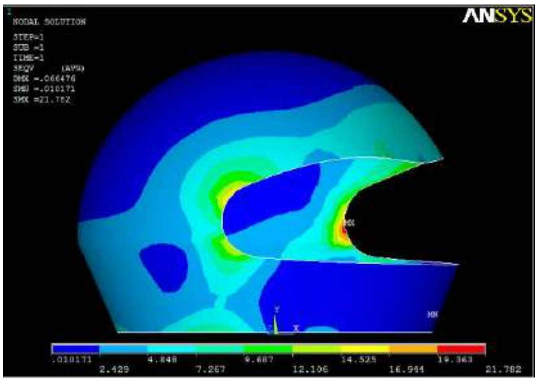

Fig 39:- stress distribution at 1400 N

B. For Acrylonitrile Butadiene Styrene (ABS) Material

The following figures show the deflection and stress distribution of helmet for different load values as ABS is a outer shell material.

- *Load on Top surface*

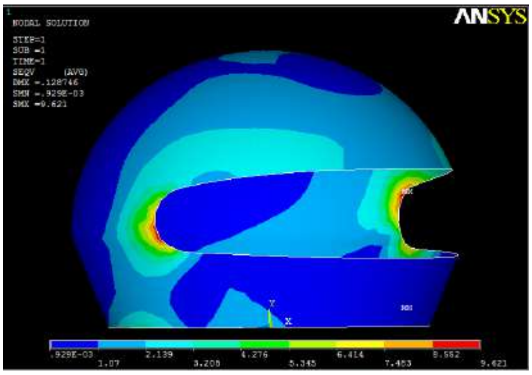

Fig 40:- stress distribution at 350 N

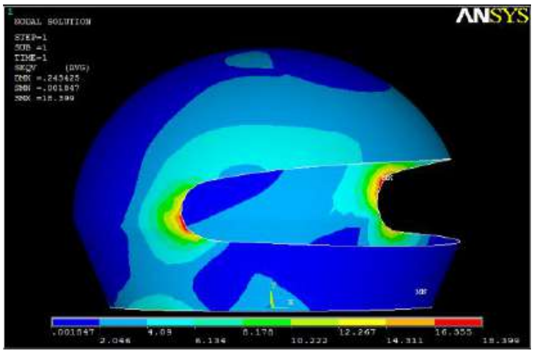

Fig 41:- stress distribution at 700 N

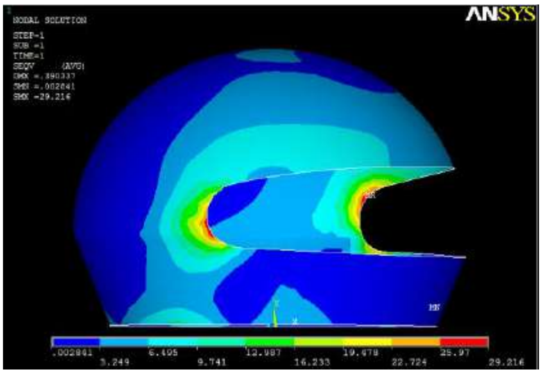

Fig 42:- stress distribution at 1050 N

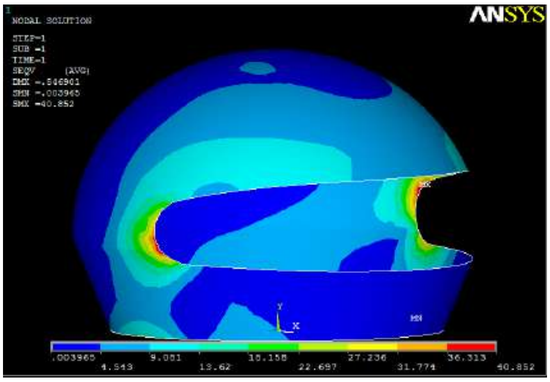

Fig 43:- Stress distribution at 1400 N

- *Loads on Rear surface*

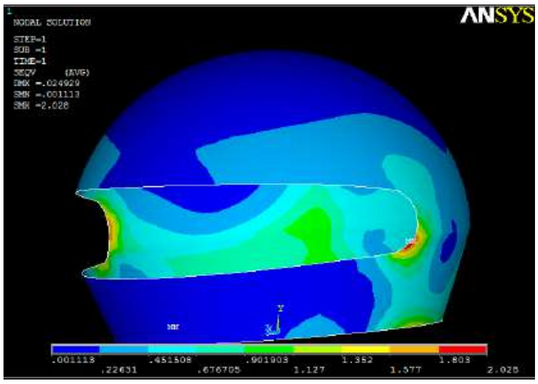

Fig 44:- Stress distribution at 350 N

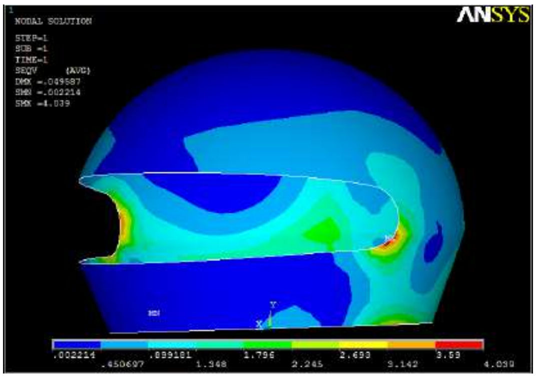

Fig 45:- Stress distribution at 700 N

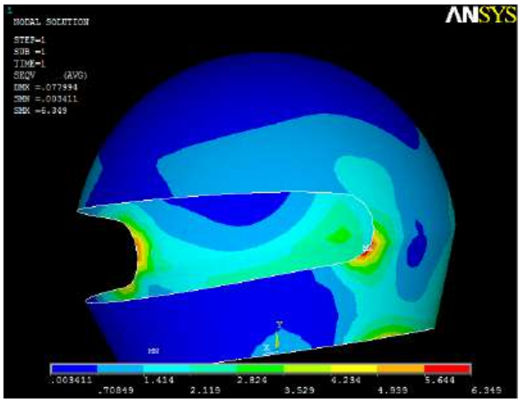

Fig 46:- Stress distribution at 1050 N

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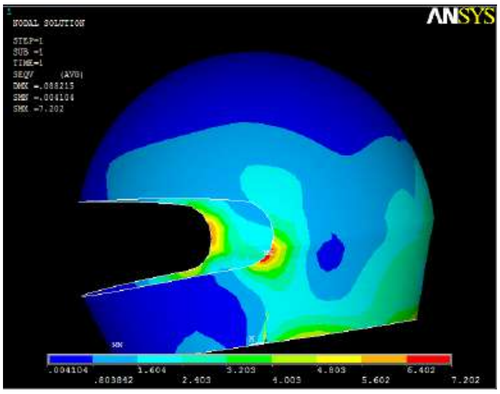

Fig 47:- Stress distribution at 1400 N

* *Loads on Side surface*

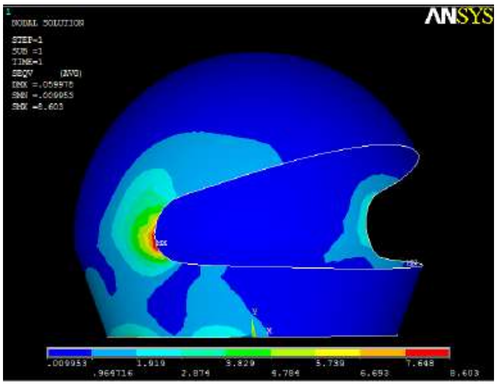

Fig 48:- Stress distribution at 350 N

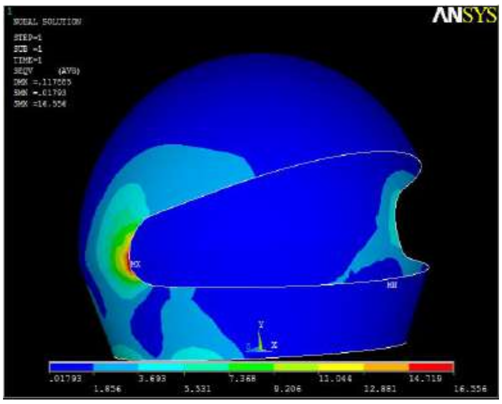

Fig 49:- Stress distribution at 700 N

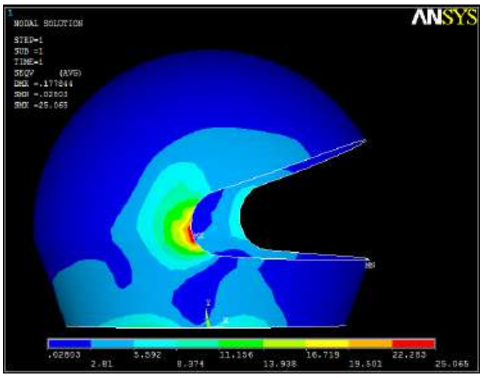

Fig 50:- Stress distribution at 1050N

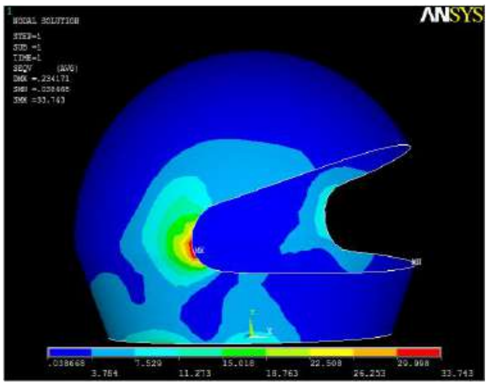

Fig 51:- Stress distribution at 1400 N

* *Loads on Chin surface*

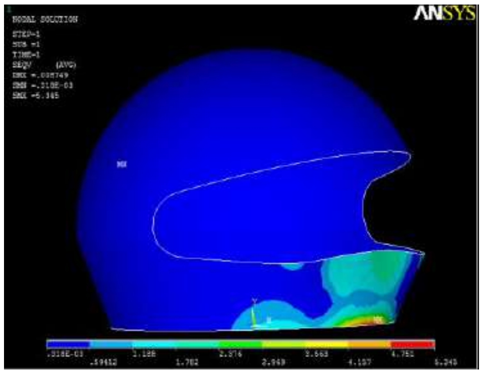

Fig 52:- Stress distribution at 350 N

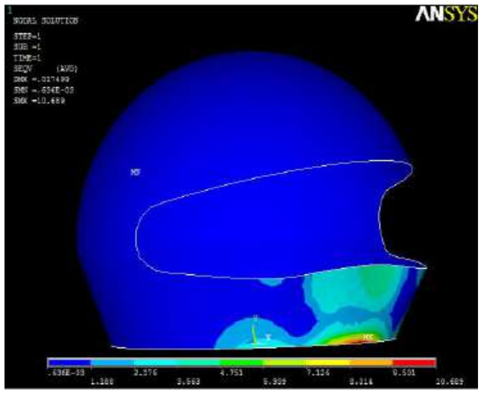

Fig 53:- Stress distribution at 700 N

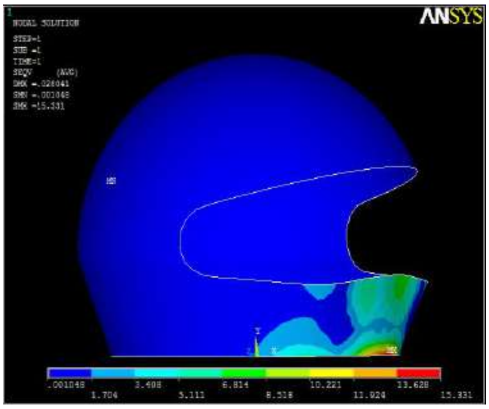

Fig 54:- Stress distribution at 1050 N

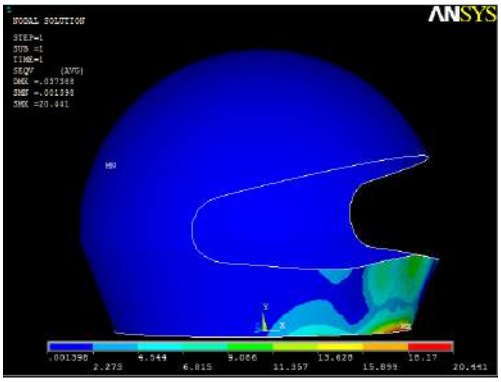

Fig 55:- Stress distribution at 1400 N

* *Loads on Forehead surface*

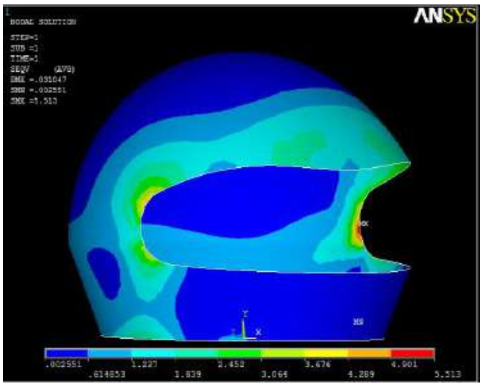

Fig 56:- Stress distribution at 350 N

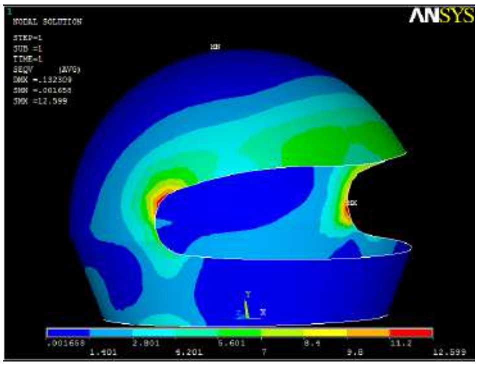

Fig 57:- Stress distribution at 700 N

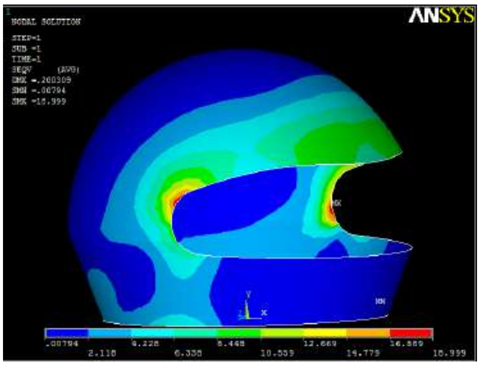

Fig 58:- Stress distribution at 1050 N

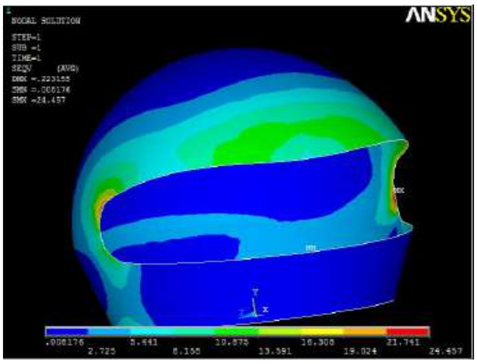

Fig 59:- Stress distribution at 1400 N

C. For Glass Fiber Reinforced Polyester resin (GFRP) Material

The following figures show the deflection and stress distribution of helmet for different load values as GFRP is a outer shell material.

* *Loads on Top surface*

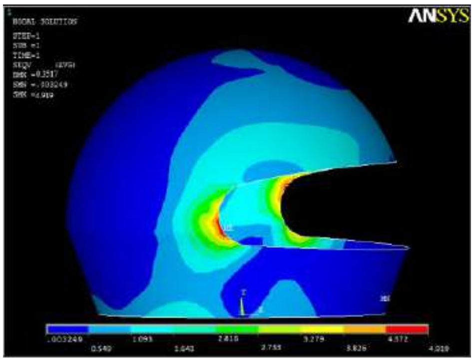

Fig 60:- Stress distribution at 350 N

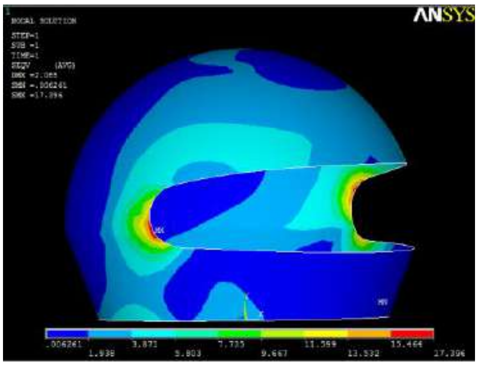

Fig 61:- Stress distribution at 700 N

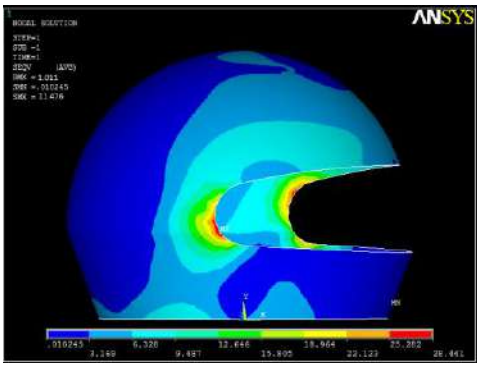

Fig 62:- Stress distribution at 1050 N

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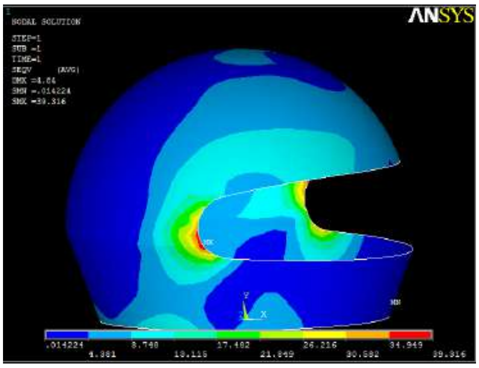

Fig 63:- Stress distribution at 1400 N

- *Loads on Rear surface*

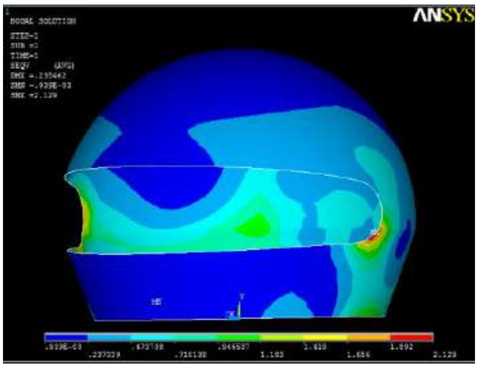

Fig 64:- Stress distribution at 350 N

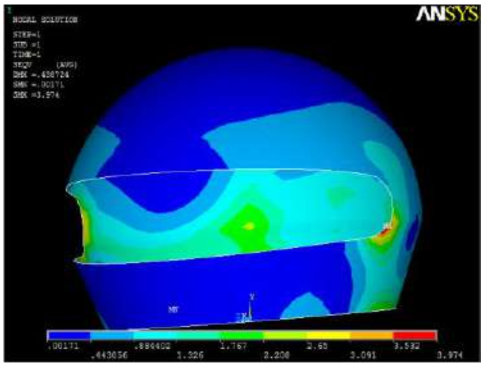

Fig 65:- Stress distribution at 700 N

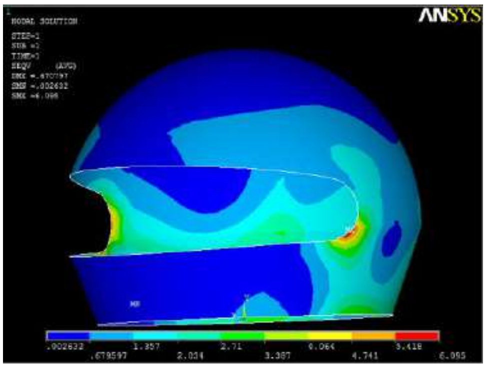

Fig 66:- Stress distribution at 1050 N

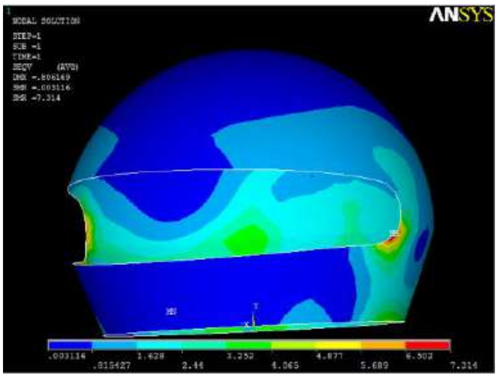

Fig 67:- Stress distribution at 1400 N

- *Loads on Side surface*

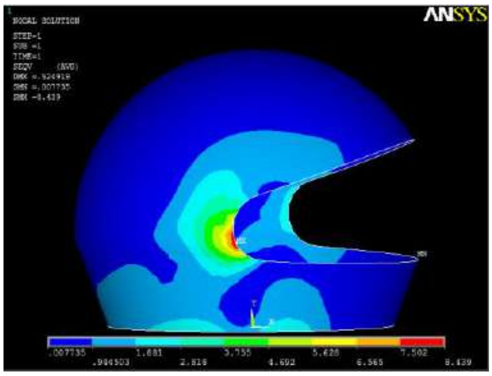

Fig 68:- Stress distribution at 350 N

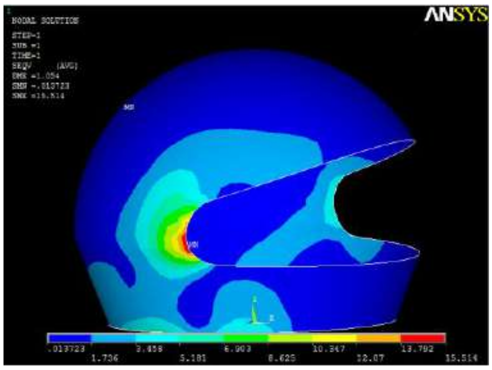

Fig 69:- Stress distribution at 700 N

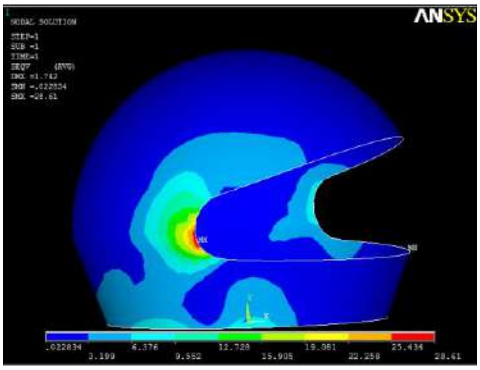

Fig 70:- Stress distribution at 1050 N

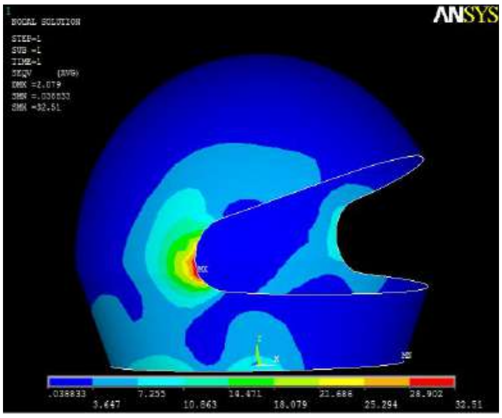

Fig 71:- Stress distribution at 1400 N

* *Loads on Chin surface*

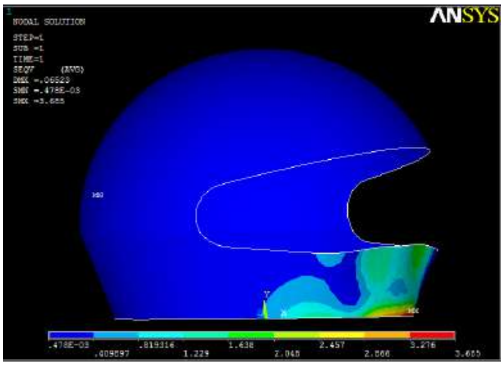

Fig 72:- Stress distribution at 350 N

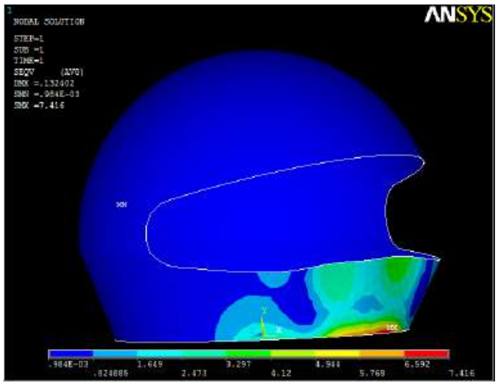

Fig 73:- Stress distribution at 700 N

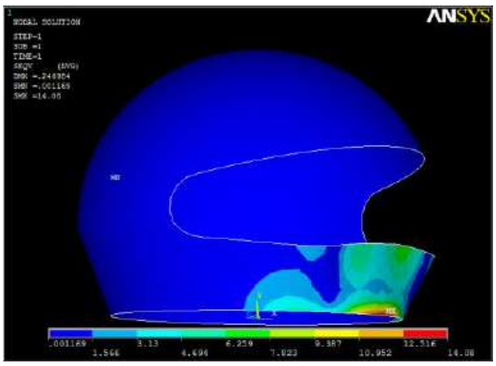

Fig 74:- Stress distribution at 1050 N

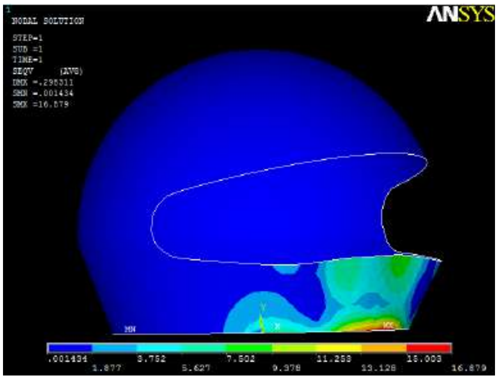

Fig 75:- Stress distribution at 1400 N

* *Loads on Forehead surface*

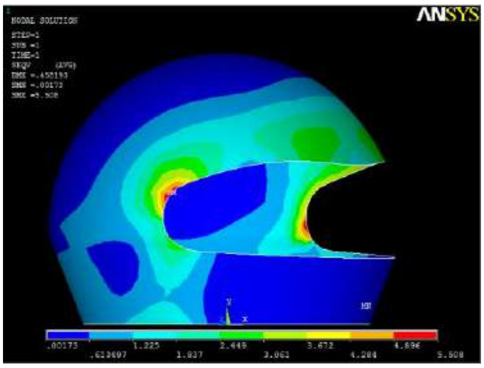

Fig 76:- Stress distribution at 350 N

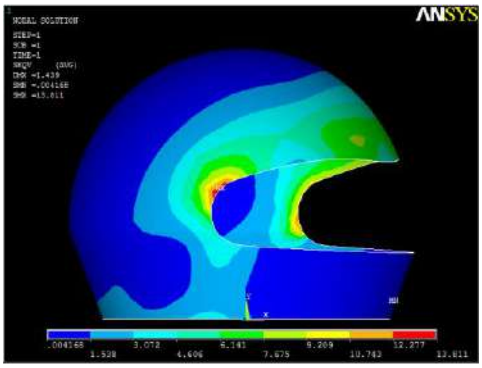

Fig 77:- stress distribution at 700 N

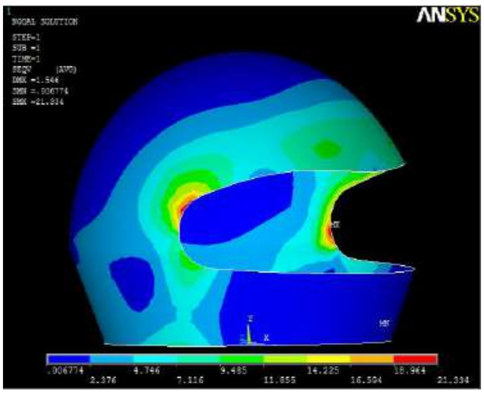

Fig 78:- Stress distribution at 1050 N

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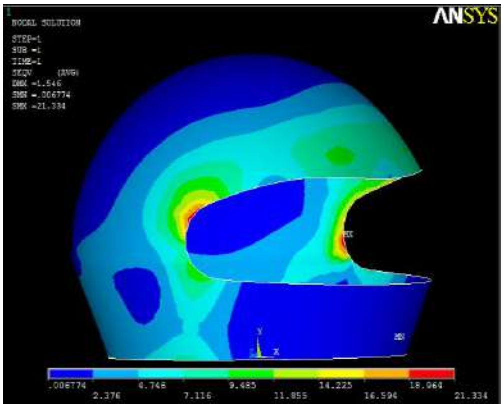

Fig 79:- Stress distribution at 1400 N

D. Comparing between Maximum Stress and Deflection for Different Materials on Different Surfaces of Helmet

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	9.67	20.074	29.88	40.148
ABS	9.621	18.399	29.02	40
GFRP	9.019	17.396	28.441	39.316

Table 3. Maximum stress (MPa) of helmet when load applied on the top surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	0.0741	0.154	0.23	0.309
ABS	0.128	0.243	0.39	0.5469
GFRP	1.084	2.085	3.466	4.84

Table 4. Maximum deflection (m) for helmet when load applied on the top surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	2.103	4.233	6.166	8.645
ABS	2.03	4.03	6.03	7.2
GFRP	2.129	3.974	6.09	7.314

Table 5. Maximum stress (MPa) for helmet when applied on the rear surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	0.0147	0.0297	0.0433	0.0594
ABS	0.0249	0.049	0.0779	0.0881
GFRP	0.2354	0.438	0.6707	0.806

Table 6. Maximum deflection (m) for helmet when applied on the rear surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	7.219	15.66	27.643	33.42
ABS	8.063	16.556	25.065	33
GFRP	8.439	15.514	28.61	32.5

Table 7. Maximum stress (MPa) for helmet when applied on the side surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	0.031	0.133	0.2	0.2231
ABS	0.0599	0.117	0.177	0.234
GFRP	0.5249	1.054	1.742	2.079

Table 8. Maximum deflection (m) for helmet when applied on the side surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	5.852	10.822	14.057	21.644
ABS	5.345	10.682	15.331	20.441
GFRP	3.685	7.416	14.08	16.879

Table 9. Maximum stress (MPa) for helmet when applied on the chin surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	0.00584	0.0107	0.0109	0.0215
ABS	0.008	0.0175	0.028	0.0379
GFRP	0.0652	0.132	0.246	0.298

Table 10. Maximum deflection (m) for helmet when applied on the chin surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	5.417	11.255	17.641	21.782
ABS	5.513	12.599	16.899	20.457
GFRP	5.508	13.811	16.653	19.334

Table 11. Maximum stress (MPa) when applied load on the forehead surface

Shell Material	*Load (N)*			
	350N	700N	1050N	1400N
Carbon Fiber	0.00584	0.0107	0.01094	0.0215
ABS	0.0310	0.1323	0.2	0.2231
GFRP	0.4581	1.373	1.439	1.546

Table 12. Maximum deflection (m) when applied load on the forehead surface

From the results for deflection variation under static analysis done on the top, rear, side, chin and Forehead surface of the helmet. It indicates the variation of maximum deflection values under different loading conditions. It can be concluded from the table that different materials behave differently for varying conditions of loading and also CARBON FIBER posseses good characteristics under different loading conditions.

VII. CONCLUSION & FUTURE SCOPE

In this work the drop test analysis of motorcycle helmet and static analysis of helmet was done for different materials at different load values in various positions.

The conclusions drawn from this work are stated below

- The drop test of carbon fiber helmet shows the stress values for 8.5 m/s and 9.5 m/s velocities
- The static analysis shows the stress and deflection values of different materials

From the results it's observed that the Carbon Fiber with stand more stresses and it gives less deflection for different load conditions. It's felt that Carbon Fiber is suitable material for a helmet outer shell.

It's also suggested in future the drop test can be done for various materials at different velocities. Also it is suggested that by considering the human head form model inside the helmet we can analyze the helmet as well as human head form.

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