Performance Analysis of Motor Cycle Helmet under Static and Dynamic Loading

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Each year nearly nine hundred persons die in head injuries and over fifty thousand persons are severally injured due to non wearing of helmets . In motor cycle accidents, the human head is exposed to loads exceeding several times the loading capacities of its natural protection. In this work, an attempt has been made for analyzing the helmet with all the standard data. The simulation software 'ANSYS' is used to analyze the helmet with different conditions such as bottom fixed-load on top surface, bottom fixed–load on top line, side fixed–load on opposite surface, side fixed–load on opposite line and dynamic analysis. The maximum force of 19.5 kN is applied on the helmet to study the model in static and dynamic conditions. The simulation has been carried out for the static condition for the parameters like total deformation, strain energy, von Mises stress for different cases. The dynamic analysis has been performed for the parameter like total deformation and equivalent elastic strain. The result shows that this values are concentrated in the retention portion of the helmet. These results has been compared with the standard experimental data proposed by the BIS and well within the acceptable limit.

Keywords: Helmet, deformation, strain energy, equivalent elastic strain.

1.   Introduction

Helmet can protect vehicle riders from severe injuries during traffic accidents. Also, serious motor cycle accidents have increased in the last two decades. To design a functional helmet, it is important to analyze the structure of helmets. The main helmet components are the foam linear and the shell. Basically, the function of the foam is to absorb most of the impact energy, while the function of the shell is to resist penetration of any foreign object from touching the head and resulting in direct skull damage, and to distribute the impact load on a wider foam area thus increasing the foam linear energy absorption capacity.

The force resistance test is the main criteria for shell thickness determination and, in fact, resulting in a helmet with a thicker shell and consequently a weight of about 6 to 8 times as compared to the foam liner. If a thicker shell is chosen, the strength will increase, unfortunately, as well as cost and weight or an alternative material should be considered. For analysis its better result helmet design and material property has been tested and compared with standard.

2.   Theoretical background

An understanding of the ways in which the helmeted head is loaded during motor cycle accidents and knowledge of the causes of head injuries is very helpful to improve helmet protection. The helmet must be designed to provide the user with the most lightweight, form fitting system, while meeting other system performance requirements. This can be achieved through a complete analysis of the system requirements. Helmet has been used as protective equipment in order to sealed human head from impact induced injuries such as in traffic accident, sports, construction work ,military and some other human activities. Hence, the structure and protective capacity of the helmet are altered in high energy impact. This helmet material and design have been improved from time to time mainly in the presence of prevailing threats.

3.   Literature review

Several studies have been conducted to evaluate the protective performance of helmets during direct head impact, with constant–rate compression and drop–impact tests which are typically used to investigate the protective contribution of individual helmet components [1] [2] [3] and [4]. The effectiveness of mandated motorcycle helmet use in Taiwan by applying logit modeling approach and before-and-after comparisons [5]. The helmet design variations in terms of different variables other than headform linear acceleration and suggested that the model had optimized cost, weight and helmet size [6]. The biomechanical characteristics of head impact with both metal form and ABS helmets. He suggested that the metal form shell is performed well compared with ABS helmet [7]. The rotational and linear acceleration of a Hybrid II headform, representing a motorcyclist's head, in such impacts, considering the effects of friction at the head/helmet and helmet/road interfaces by Finite element analysis [8]. The simulation models of helmet and human head to study the impacts on a protected and unprotected head in a typical motorcycle related collisions [9]. The simulation method to determine the velocity of air flow in the helmet models with Pressure and stresses in the brain [10]. Head

injuries by Finite element simulation [11]. During a long bicycle time trial or during the cycling portion of a triathlon, 80 to 90 percent of the power developed by the athlete is used to overcome aerodynamic drag [14]. Many of these events are won or lost by only seconds. Small reductions in overall aerodynamic drag can easily save seconds in any of these events, giving the athlete a decisive advantage [15]. In the chapters the helmets must provide crash protection, adequate ventilation, and reduced aerodynamic drag. In air at typical cycling speeds the Reynolds number for an aerodynamic helmet is in the range of 300000 to 500000. Reynolds numbers in this range show that the aerodynamic properties will be dominated by inertial effects [16]. Experimental study of bird strike tests on aluminium foam based double sandwich panels. They predicted the failure of structural components with aluminium foam in bird–strike events through a numerical model [12]. Investigated in a triple layer dielectric systems in which the reflection at the main contact surface is decreased due to the interference of the reflected light from each interface, so that the refractive index n(x) is an unknown piecewise constant function [13]. The results from various sector indicate the very high percentage injuries can be prevented by using helmet. Even though people wear helmet, due to its inadequate quality, the neck pain was developed and glare in the visor are high. Hence it is essential to produce standard helmet with proper aero-dynamic shape to reduce the neck pain of the rider in the long journey paraded with anti–glare in the visor. The attempt has been made to design and analysis of aerodynamic shape helmet model by using "Pro–E" software.

4.   Materials and methods

When a helmet is subjected to a load or force act on the helmet it will get deformed. Various factors on the helmet is to be analyzed that is to say deformation, strain energy, equivalent stress or von Mises stress and equivalent strain. It is very important to analyze the behaviour of helmet both in static and dynamics condition. The impact energy depends on the drop mass and drop height the different standard use different impact energy. The chin guard is an area of the helmet that requires particular attention, because a high proportion of the fatalities with head injuries sustained a fracture of the base of the skull, caused by a direct impact through the chin guard to the facial skull.

4.1.   *Helmet CAD modeling*

The CPSC standard dimensions helmet has been created in modeling software "Pro–engineering" and then it is imported to "ANSYS" software for analyzing. The Fig. 1 shows the various dimension of the parts in the helmet.

4.2.   *Static analysis of helmet*

The maximum permissible limit of 19.5 kN (as per BIS standard) impact force is considered for this analysis. The simulation plots are given for case – 1.

The following the different conditions are considered for this study:
(a) Bottom fixed and load on top surface (Case 1)
(b) Bottom fixed and load on top line (Case 2)
(c) Side fixed and load on opposite area (Case 3)
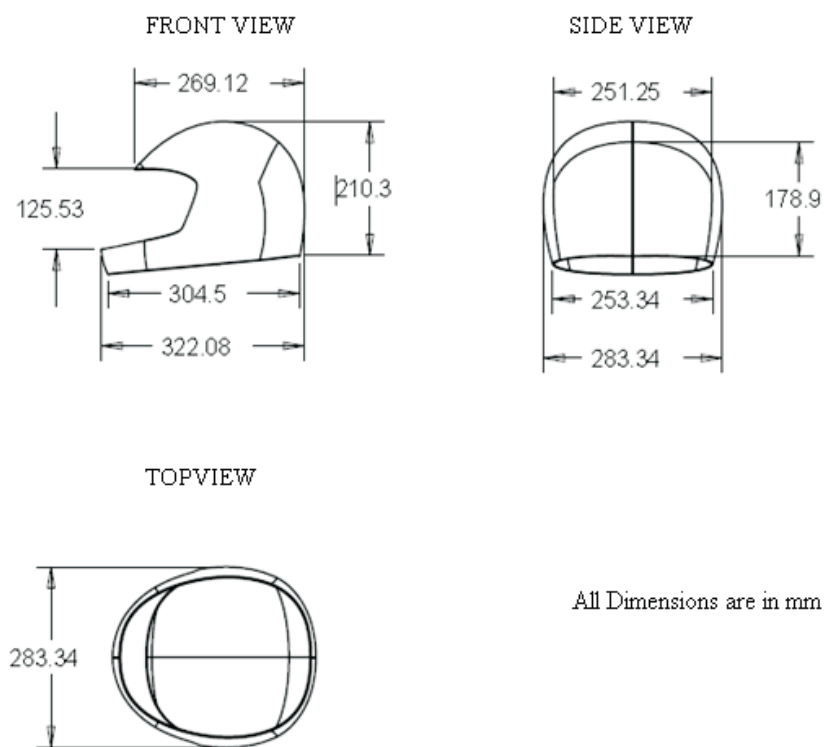(d) Side fixed and load on opposite line (Case 4)

FRONT VIEW

SIDE VIEW

269.12

251.25

210.3

178.9

125.53

304.5

253.34

322.08

283.34

TOPVIEW

283.34

All Dimensions are in mm

Figure 1 Standard dimension of various parts in helmet

Figure 2 Helmet CAD model

4.2.1. *Bottom fixed and load on top area 19.5 kN (Case 1)*

In this figure bottom has been fixed and the load has been applied on the top surface of the helmet – this is because in practice helmet is fixed with our neck so it is considered as bottom fixed. If motorcyclist falls on the road, mainly load is performed on top and both right and left sides of the helmet only. So for the first case load has been applied on the top sides and various results of the stress, strain energy, total deformation has been taken and that is boundary conditions, equivalent elastic strain, equivalent stress, strain energy, total deformation has been taken and analyzed.
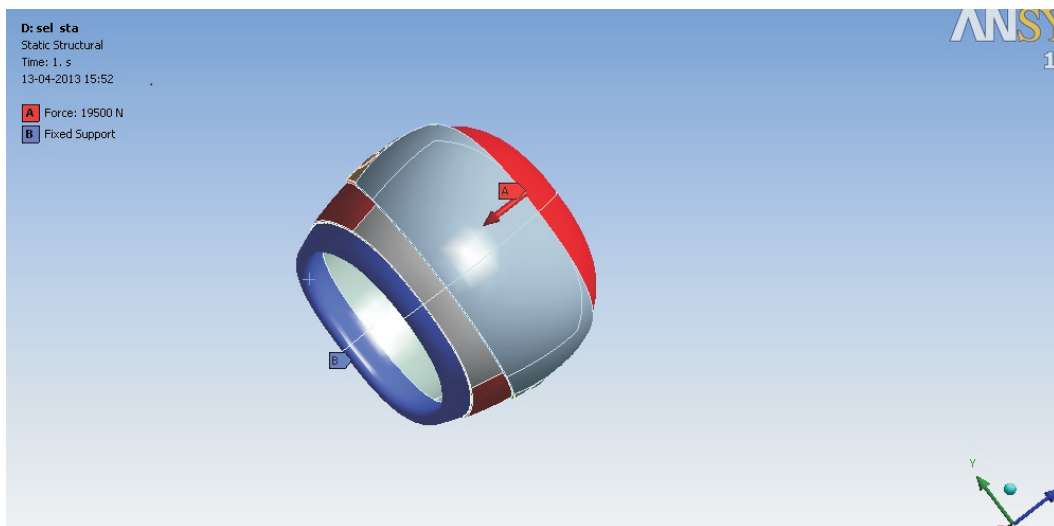

Figure 3 Boundary conditions (Case 1)

Fig. 3 shows the boundary condition of helmet in static condition. The bottom surface of the helmet is fixed in all directions. Load is applied on the top area of helmet.

Fig. 4 shows the equivalent Von Mises stress of the helmet. The maximum stress distribution is on the visor holder side and the value is 1.2232×10^9 N/m^2.

Fig. 5 shows the strain energy distribution of helmet. The maximum strain energy distribution is on the forehead of the helmet and the value is 10.647 J.

Fig. 6 shows the total deformation of the helmet. The maximum deformation is occurred on the inside part of the foam and the value of 0.00147 m.
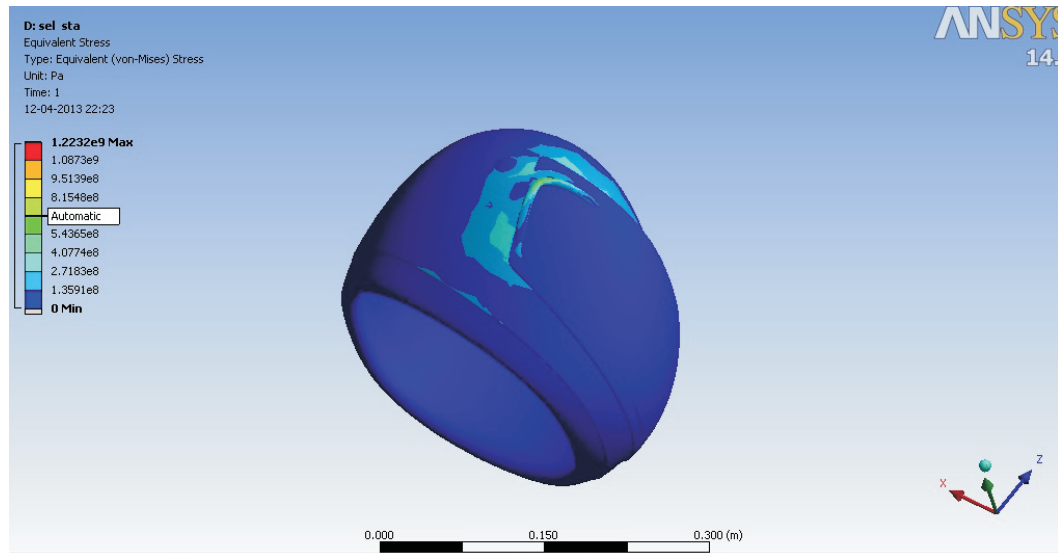
Figure 4 Equivalent Von Mises stress (Case 1)
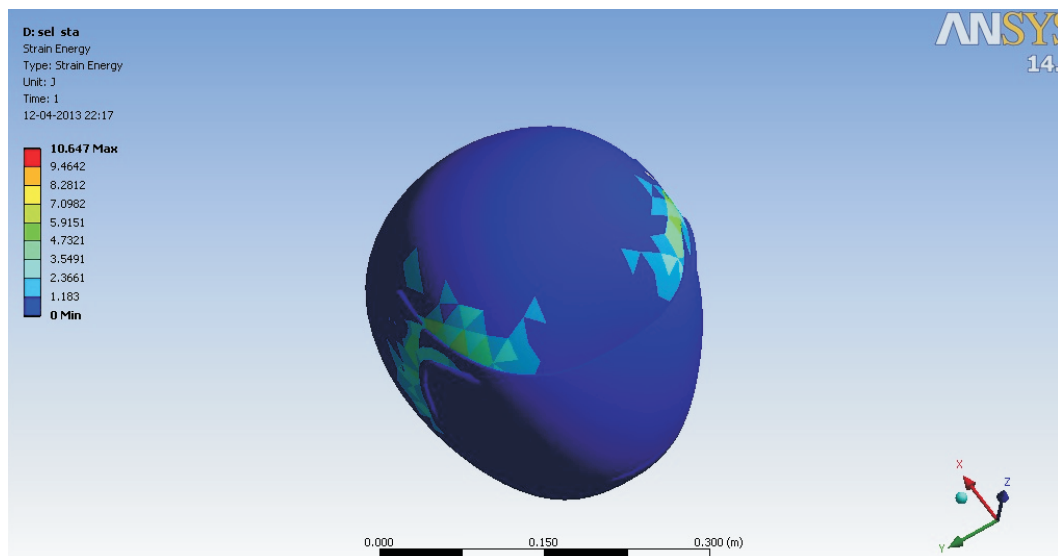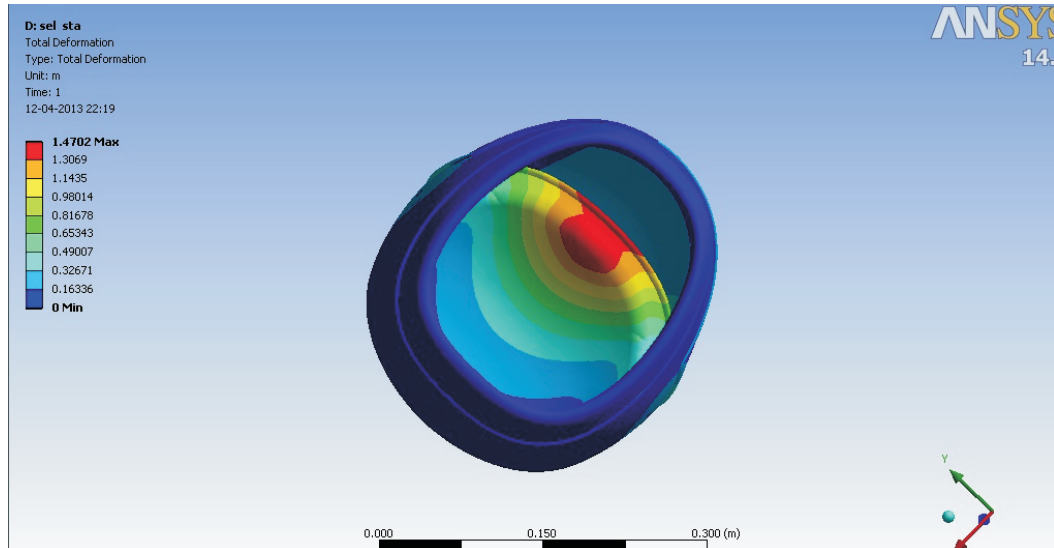

Figure 5 Strain energy (Case 1)

Figure 6 Total deformation (Case 1)

4.3.   *Dynamic analysis of helmet*

For the dynamic analysis the helmet is fixed in between two testing steel plates. The Upper plate (movable) has a weight of 19.5 kN (BIS recommended) and bottom plate (Rigid) has also 19.5 kN . The movable upper plate is put over the helmet with the height of 3 meters.

Fig. 7 shows the boundary condition of helmet in the dynamic condition. Bottom plate is fixed on the helmet and top plate is a movable one. Load is applied on the top plate of load 19.5 kN.
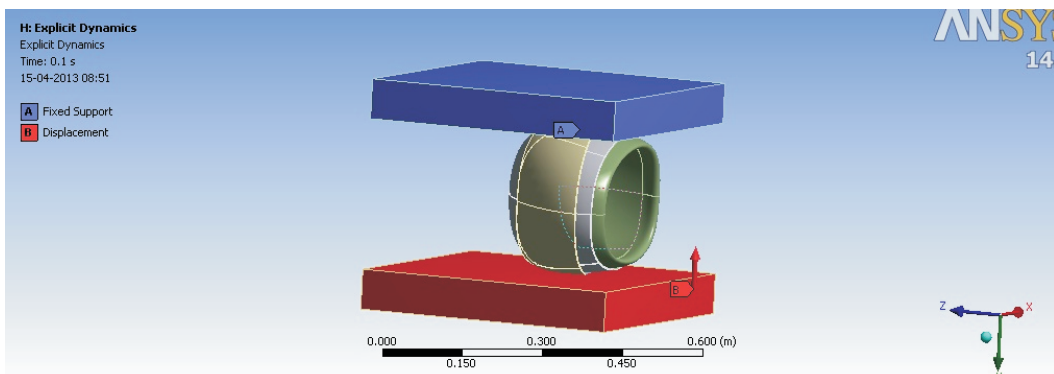

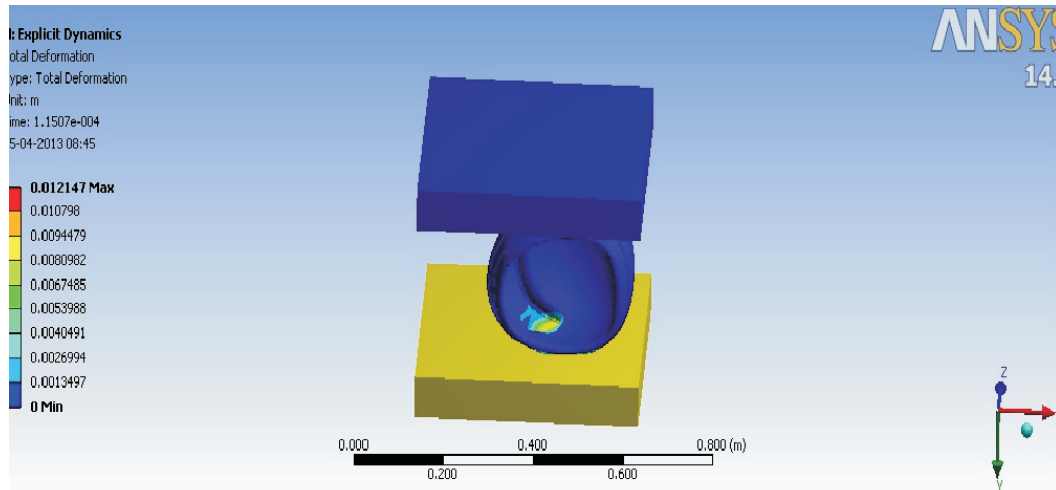**Figure 7** Boundary condition (Dynamic)

Figure 8 Total deformation (Dynamic)

Fig. 8 shows the total deformation of the helmet. The maximum deformation is occurred on the visor part of the helmet and the value is 0.012147 m.
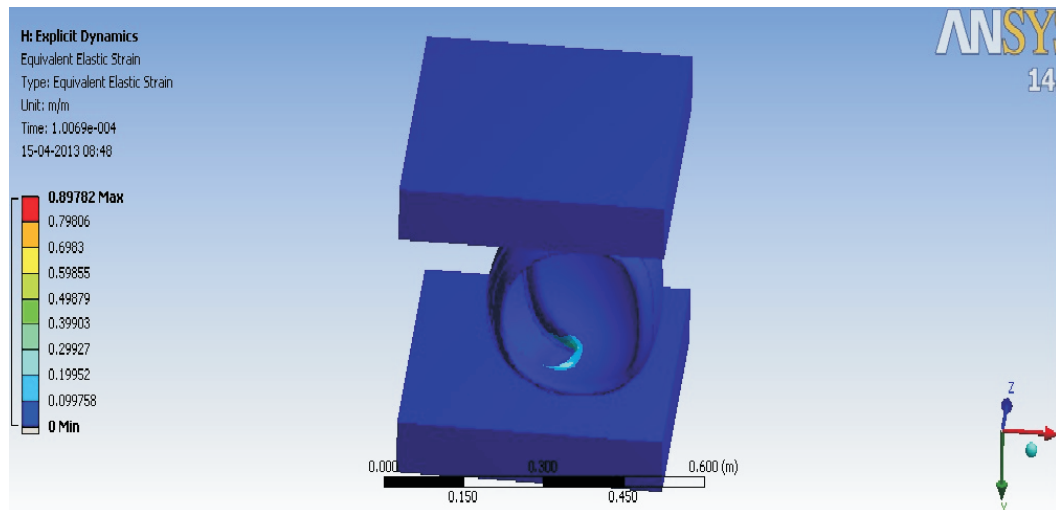

Figure 9 Equivalent strain (Dynamic)

Fig. 9 shows the equivalent strain of the helmet. The maximum strain is occurred on the visor part of the helmet and the value is 0.89 m.

5. Results and discussion

The injuries to the head can take various forms such as lacerations of the skin, bone fracture, intracranial injury and brain injury. The forces required to cause a particular injury are variable and very little quantitative information exists about the magnitude of force, stress or strain that will cause a particular injury. However, some experimental measurements on cadavers provide information about forces and pressures for coup and contra coup injuries to the brain. The results of various cases are shown in Tab. 1

Table 1 Simulation results of all cases

S.No	Cases	Boundary conditions	Total Deformation (mm)	Strain Energy (J)	Equivalent (von Mises) stress (Pa)
1	Case 1	Bottom fixed and load on top area 19.5 kN	1.4702	10.647	1.223×10^9
2	Case 2	Bottom fixed and load on top line19.5 kN	3.5061	48.279	2.340×10^9
3	Case 3	Side fixed and load on opposite area 19.5 kN	6.2263	111.94	2.084×10^9
4	Case 4	Side fixed and load on opposite line 19.5 kN	1.4702	10.647	1.222×10^9

The comparison results of all the four cases has been estimated in the above Tab. 1. This shows the simulation results for static condition of helmet. The output values are compared.

5.1. *Results of static analysis*

Table 2 Results of static condition

S.No	Analysis Condition	Parameter	Finite element analysis results	Result from experiment(BIS standard)
1	Static	Total deformation	6.2263 mm	6mm to 24 mm
2	Static	Strain energy	111.94 in joules	138 in joules

From Tab. 2 results of all the cases has been compared with standard data it concludes that all data are within the acceptable limit.
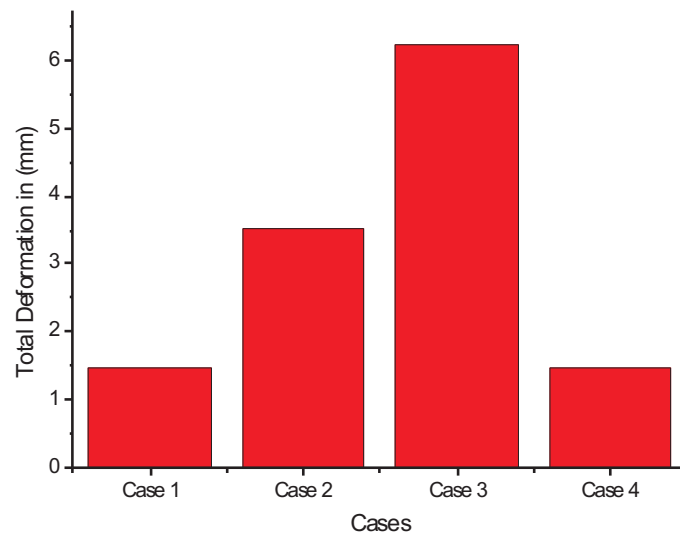
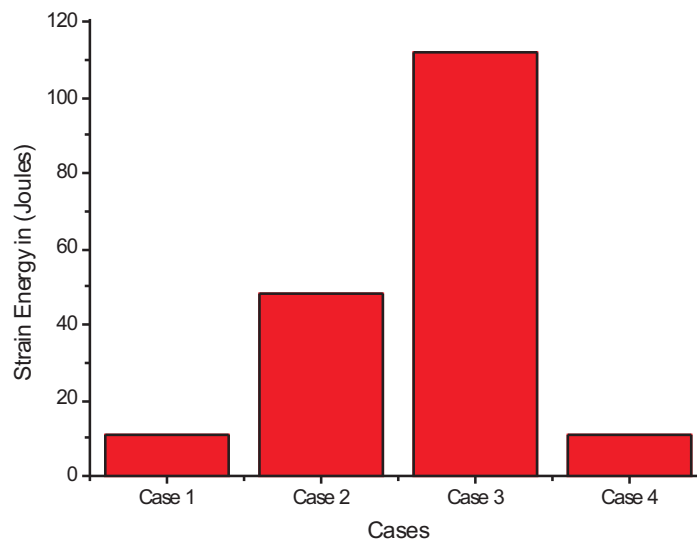**Figure 10** Deformation of all cases

Figure 11 Strain energy of all cases

Fig. 10 deformation of all cases are plotted above, which shows that case – 1 and 4 has less deformation so energy transfer to the head is high, which cause serious injuries.

Fig. 11 shows the strain energy graph, that case – 1 and 4 has absorbed less strain energy that is maximum force is transmitted to head.

5.2. *Result of dynamic analysis*

Table 3 Result of dynamic condition

S.No	Analysis Condition	Parameter	Finite element analysis results	Result from experiment (BIS standard)
1	Dynamic	Total deformation	12.147 mm	6 mm to 24 mm

From Tab. 3 results of dynamic analysis has been compared with standard data it concludes that the total deformation is within the acceptable limit.

6. Conclusion

The design and analysis of helmet has been carried out in "ANSYS" for static and dynamic conditions. The study has been made for different cases. The results from the various cases shows that chin (retention system) side of the helmet (Case 1 and 4) has undergone less strain energy and deformation. In this case the rider meet an accident, the head injury is very serious. So special attention should be needed in chin side of the helmet to reduce serious injuries.

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