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Analysis of Motor Cycle Helmet under Static and Dynamic Loading

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Abstract**—**Each year nearly nine hundred persons die in head injuries and over fifty thousand persons are severely injured due to non wearing of helmets. In motor cycle accidents, the human head is exposed to heavy impact loading against 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 these values are concentrated in the retention portion of the helmet. These results have 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.

I. INTRODUCTION

HELMET can protect vehicle riders from severe injuries during traffic accidents. Also, serious of motor cycle accidents has increased in the last two decades. To design a functional helmet, it is important to analyzing the structure of helmet. The main components of the helmet are foam linear and a shell. Basically, the function of the foam is to absorb impact load, while the function of the shell is to resist the penetration of any foreign object touches into a head and 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. The thicker shell increases the weight of helmet about 6 to 8 times as compared with the foam liner. If a thicker shell is chosen, the strength will increase, as well as the cost and weight of the helmet is also increase.

II. THEORETICAL BACKGROUND

Helmet has been used as protective equipment in order to seal human head from impact induced injuries due to in traffic accidents, sports, construction works, military and some other human activities. An understanding in the way, which the helmet worn head is also injured in the most of the road accident, the helmet must be designed to protect the user from the head injuries. This can be achieved by a complete analysis of helmet with all the system requirements. Hence, the structural and protective capacity of the helmet is analyzed in the high impact sources. The helmet material and design can be improved from time to time mainly in the presence of prevailing threats.

III. LITERATURE REVIEW

Many 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]-[4]. In [5] the effectiveness of mandated motorcycle helmet use in Taiwan was studied by applying logit modeling approach and before-and-after comparisons.

In [6] the helmet design variations in terms of different variables other than headform linear acceleration and suggested that the model was optimize cost, weight and helmet size. In [7] the biomechanical characteristics of head impact with both metal foam and ABS helmets and suggested that the metal form shell is performing well compared with ABS helmet. In [8] 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. In [9] the simulation models of helmet and human head are studied and analyzed the impacts on a protected and unprotected head in a typical motorcycle related collisions. In [10] the simulation method is used to determine the velocity of air flow in the helmet models with Pressure and stresses in the brain are investigated. In [11] the head injuries by Finite element simulation are discussed. In [12] an experimental bird strike tests on aluminum foam based double sandwich panels and predicted that the failure of structural components with aluminum foam in bird-strike events through a numerical model. The results from various sectors indicate the very high percentage injuries can be prevented by using helmet. Even

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though people wearing helmet, due to its inadequate quality the head injuries are high because of most of the helmets are fails to the standard. Hence it is essential to design a standard helmet with suitable materials. The attempt has been made to analysis the helmet using 'ANSYS' software [13] under static and dynamic conditions.

IV. Materials and Methods

When a helmet is subjected to a load or force act on the helmet it will get deformed. The following parameters are considered for analyzing the helmet such as deformation, strain energy, equivalent stress or von-Mises stress and equivalent strain. It is very important to analyze the behavior of helmet both in static and dynamic condition. In the static analysis the various parameters like stress, strain energy, total deformation are studied and identified the critical loading cases which causes heavy injury to the rider. In the dynamic analysis the total deformation in the helmet is estimated and compared with the standard experimental data. The impact energy subjected to the helmet 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.

A. Helmet CAD modeling

The CPSC standard dimensions helmet has been created in modeling software 'Pro-Engineer' and then it is imported to 'ANSYS' software for analysis. Fig. 1 shows the various dimensions of the parts in the helmet.

B. Static Analysis of Helmet

The maximum permissible limit of 19.5 kN (as per BIS standard) impact load is applied for this analysis. The following are the different conditions considered for this study. The solid model of the helmet is shown in Fig. 2.

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)

In Fig. 3 bottom was fixed and the load was applied on the top surface of the helmet. 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 applied 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 parameters like stress, strain energy, total deformation obtained from the analysis were discussed.

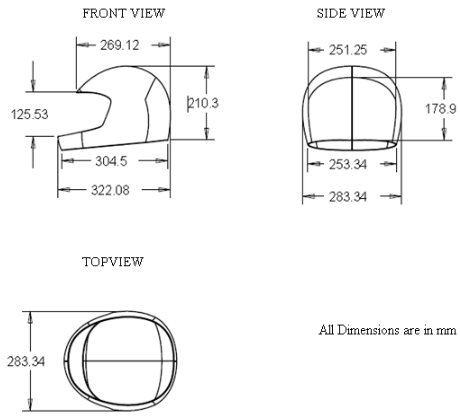

Fig. 1 Standard dimensions of various parts in helmet

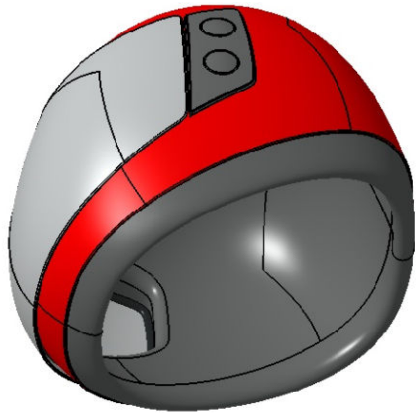

Fig. 2 Helmet CAD model

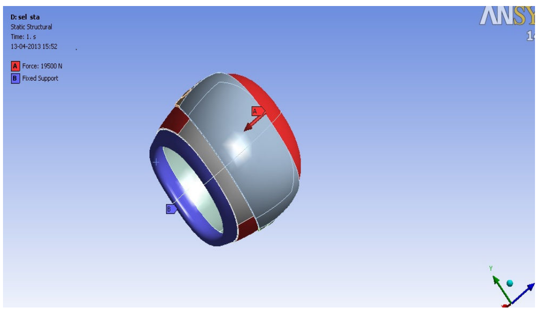

Fig. 3 Boundary conditions (Case 1)

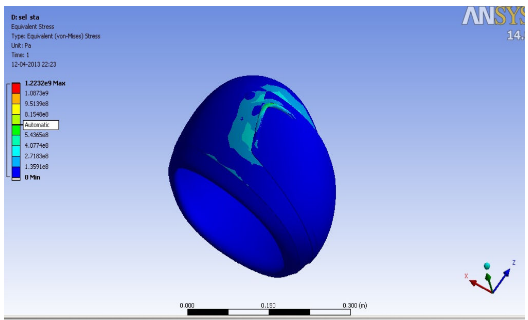

Fig. 4 Equivalent Von-Mises stress (Case 1)

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 x 10^9 N/m^2.

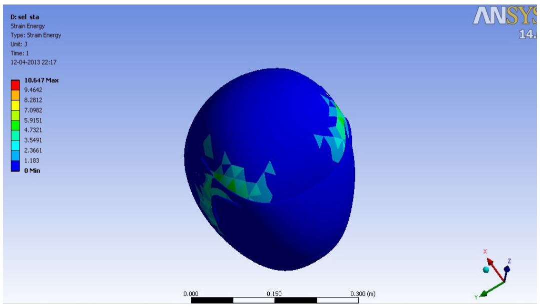

Fig. 5 Strain energy (Case 1)

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.

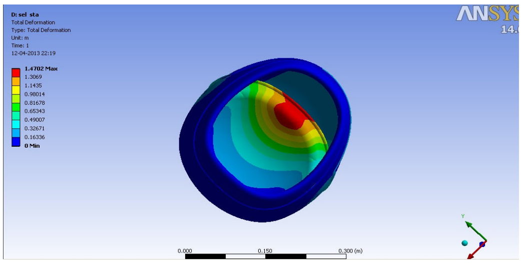

Fig. 6 Total deformation (Case 1)

Fig. 6 shows the total deformation of the helmet. The maximum deformation is occurs on the inside part of the foam and the value of 0.00147m.

C. 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 of 19.5 kN is applied on the top plate for the analysis.

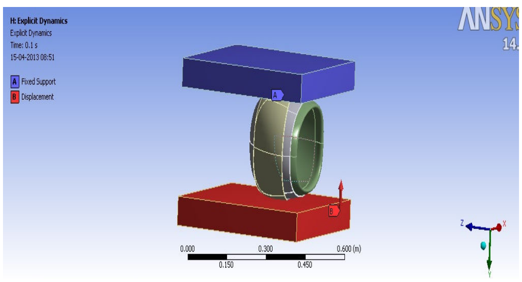

Fig. 7 Boundary condition (Dynamic)

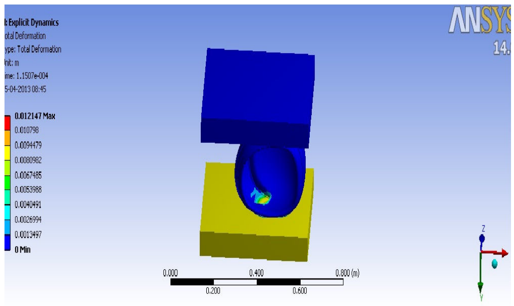

Fig. 8 Total deformation (Dynamic)

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 0.012147m.

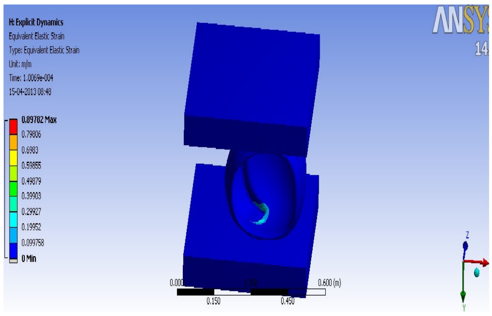

Fig. 9 Equivalent strain (Dynamic)

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 0.89m.

V. 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 cadaver provide information about forces and pressures for coup and contra coup injuries to the brain. The results of various cases are shown in Table I

TABLE I
SIMULATION RESULTS OF ALL CASES

S. No.	Cases	Total Deformation (mm)	Strain Energy (Joules)	Equivalent von-Mises stress (Pa)
1	Case 1	1.4702	10.647	1.223 x 10^9
2	Case 2	3.5061	48.279	2.340 x 10^9
3	Case 3	6.2263	111.94	2.084 x 10^9
4	Case 4	1.4702	10.647	1.222 x 10^9

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

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A. Results of Static Analysis

TABLE II
RESULTS OF STATIC CONDITION

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

From Table II results of all the cases have been compared with standard data it concludes that all data are within the acceptable limit.

Fig. 10 deformation of all cases are plotted, 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.

The critical cases have been identified from the analysis. The rider meet an accident in the case - 1 and 4 loading conditions, the heavy injury will be caused for the rider. So, the more attention should be given for these cases.

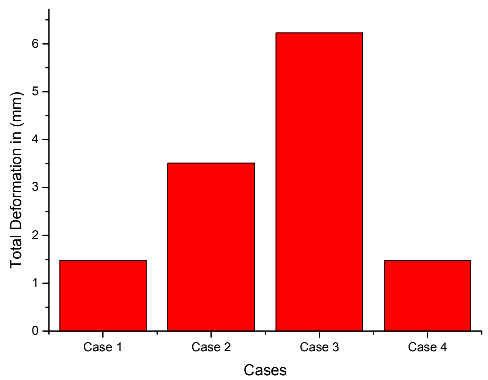

Fig. 10 Deformation of all cases

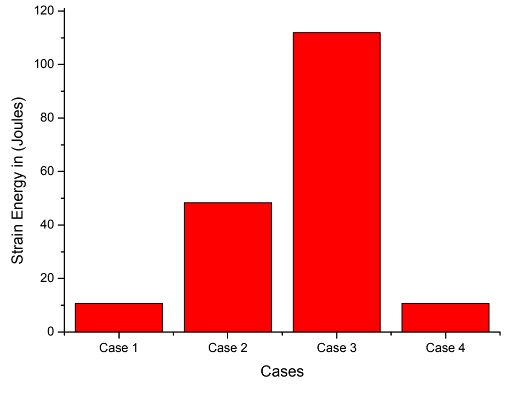

Fig. 11 Strain energy of all cases

B. Result of Dynamic Analysis

TABLE III
RESULT OF DYNAMIC CONDITION

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

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

VI. 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 show 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 is needed in chin side of the helmet to reduce serious injuries for the rider.

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