A MAJOR PROJECT REPORT

ON

SAFETY ASSESSMENT OF MOTORCYCLE HELMET USING FINITE ELEMENT ANALYSIS

SUBMITTED TO

RAJIV GANDHI PROUDYOGIKI VISHWAVIDYALAYA, BHOPAL

IN PARTIAL FULFILLMENT FOR THE AWARD OF THE DEGREE

OF

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

GUIDED BY:

MR. RIZWAN SHEIKH

ASSOCIATE PROFESSOR

SUBMITTED BY:

ROHIT KUMRAWAT (0808ME141085)

VARUN AGRAWAL (0808ME141108)

DEPARTMENT OF MECHANICAL ENGINEERING
IPS ACADEMY
INSTITUTE OF ENGINEERING & SCIENCE INDORE

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DECLARATION

We hereby declare that the project entitled "SAFETY ASSESSMENT OF MOTORCYCLE HELMET USING FINITE ELEMENT ANALYSIS" submitted for the Bachelor of Engineering (Mechanical Engineering) degree is our original work and the project has not formed the basis for the award previously of any other degree, diploma, fellowship or any other similar titles.

Signature of the Students

Place: INDORE

Date:

DEPARTMENT OF MECHANICAL ENGINEERING
IPS ACADEMY
INSTITUTE OF ENGINEERING & SCIENCE INDORE

DEPARTMENT OF MECHANICAL ENGINEERING
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CERTIFICATE

This is to certify that the project titled "SAFETY ASSESSMENT OF MOTORCYCLE HELMET USING FINITE ELEMENT ANALYSIS" is the bona-fide work carried out by Rohit Kumrawat & Varun Agrawal, students of B. E. (Mechanical Engineering) of IPS Academy, Institute of Engineering and Science, Indore (M.P.) affiliated to RGPV Bhopal, M.P.(India) during the academic year 2017-18, in partial fulfillment of the requirements for the award of the degree of Bachelor of Engineering (Mechanical Engineering) and that the project has not formed the basis for the award previously of any other degree, diploma, fellowship or any other similar title.

Internal Examiner **External Examiner**

DEPARTMENT OF MECHANICAL ENGINEERING
IPS ACADEMY
INSTITUTE OF ENGINEERING & SCIENCE INDORE

RECOMMENDATION

It is recommended that the major project work on "SAFETY ASSESSMENT OF MOTORCYCLE HELMET USING FINITE ELEMENT ANALYSIS" submitted by Mr. Rohit Kumrawat & Mr. Varun Agrawal for the partial fulfillment of major project work for Rajiv Gandhi Proudyogiki Vishwavidyalaya, Bhopal (M.P.).

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ACKNOWLEDGEMENT

No task is single man’s effort. Any job in this world however trivial or tough cannot be accomplished without the assistance of others. An assignment puts the knowledge and experience of an individual to litmus test. There is always a sense of gratitude that one likes to express towards the persons who helped to change an effort in a success.

We express our ardent and earnest gratitude to our project guide Mr. Rizwan Sheikh (Associate Professor, Department of Mechanical Engineering) for the keen interest, inspiring guidance, continuous encouragement, valuable suggestions and constructive criticism throughout the pursuance of this report.

We are thankful to our Head of Department, Professor Dr. Sanjay Jain and all the faculty members of our department for giving us the opportunity to undertake the study.

Last but not the least it would be unfair if we don’t express our indebtedness to our parents and all our friends for their active cooperation which was of great help during the course of our project.

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ABSTRACT

The helmet is protective equipment which is used for the different purposes like by two-wheeler riders, during construction of a building, driving sports cars, etc. for the protection of the head from the injury caused by impact during an accident. There are various standards and their norms for deciding the safety level of different kinds of the helmet. In this research work, a motorcycle helmet was designed and then analyzed according to the norms of the standard DOT FMVSS 218. The impact and penetration tests were performed on the helmet assembly as per the safety requirements of this standard. In this work, the helmet was designed using a CAD software CREO Parametric 3.0 and the meshing on the helmet assembly was completed on the CAE software HyperMesh 13. The dynamic testing was performed on the LS-DYNA which is a product of LSTC. To enhance and ensure the impact capacity of the helmet, two different cases based on the thickness of the foam padding in the helmet were simulated. And finally, the case which passed all the tests as per the standard had been suggested. This research work can also assist in the optimization of the helmet by suggesting the different models which would optimize the cost, weight, and helmet size.

KEYWORDS: Motorcycle Helmet; FMVSS 218; CAD; CAE; Safety

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LIST OF ABBREVIATIONS

ABS - Acrylonitrile Butadiene Styrene

AIS - Abbreviated Injury Scale

AS/NZS - Australian/New Zealand Standard

ASTM - American Society for Testing and Materials

BIS - Bureau of Indian Standards

CAD - Computer-Aided Design

CAE - Computer-Aided Engineering

CPSC - Consumer Product Safety Commission

DOT - Department of Transportation

ECE - Economic Commission for Europe

EN - European Norms

EPS - Expanded Polystyrene

FEA - Finite Element Analysis

FE - Finite Element

FMVSS - Federal Motor Vehicle Safety Standard

FRC - Fiber Reinforced Composite

HDPE - High Density Polyethylene

HIC - Head Injury Criterion

IMechE - Institution of Mechanical Engineering

LSTC - Livemore Software Technology Corporation

MTBI - Mild Traumatic Brain Injury

NHTSA - National Highway Traffic Safety Administration

PAS - Product Approval Specifications

PVC - Polyvinyl Chloride

TBI - Traumatic Brain Injury

TRL - Transport Research Laboratory

Chapter 1

INTRODUCTION

Each year thousands of people die due to head injuries and are severely injured due to non-wearing of helmet. In the motorcycle accidents, human head is directly exposed to that amount of load which exceeds several times the load capacity of normal human head.

Helmet can protect riders from severe injuries. The main components of the helmet are foam and shell. The function of foam is to absorb the 70-80% of entire impact energy, while the function of the shell is to absorb the remaining impact energy and protect the head from the penetration of the foreign objects and to distribute the impact load on the wider foam area which results in the increase in the foam linear energy absorption capacity.

Although helmet can protect from severe head injuries, its inadequate quality leads to the various injuries such as permanent neck pain and serious traumatic brain injury (TBI) and also has high glare in the visor. In order to decrease these effects various measures can be taken like increase in the thickness of the shell and foam or change the stiffness of both the components which can increase the strength of the helmet but it also leads to the increase in the weight and cost of the helmet.

The helmet must be designed in such a way that it should be of light weight, optimum cost, best form fitting system, and meet the other system requirements. The best way to achieve all these requirements and protect the rider from the fatal injuries is to design a safe helmet according to the particular standard or regulation.

The safety of the helmet can be measured in different forms like calculation of the head acceleration during impact or by reducing the Head Injury Criterion (HIC).

The experimental setup of testing the helmet is very costly. It can be analyzed by using Finite Element Analysis which is also known as Matrix Structural Analysis as it uses the matrix algebra to solve the system of simultaneous equations. In FEA, the complex structures are divided into finite elements which are connected by the nodes. By using different boundary conditions, different parameters like stresses, displacements, temperature distribution, acceleration, etc. can be calculated and the comparison can be made between the results.

Department of Transportation (DOT) Federal Motor Vehicle Safety Standards (FMVSS) 218, formed in 1974, developed and enforced by National Highway Traffic Safety Administration (NHTSA), is a well-accepted regulation whose purpose is to reduce fatalities and injuries resulting from the traffic accidents. This standard applies to all the helmets intended for use by motorcyclists and other motor vehicle users.

1.1 Project Overview

In this project, we worked on the dynamic testing of motorcycle helmet using finite element analysis. In this work, the helmet was designed using a CAD software CREO Parametric 3.0 and the meshing on the helmet assembly was completed on the CAE software HyperMesh 13. The dynamic testing was performed on the LS-DYNA which is a product of LSTC.

We analyzed the impact and penetration tests on the motorcycle helmet according to the DOT FMVSS 2018. The testing conditions according to this standard are:-

The speed of the helmet assembly in case of impact attenuation testing with hemispherical anvil is 5.2 m/s and in case of the flat anvil is 6.0 m/s. In case of penetration testing, the mass of the conical impactor is 3 kg.

The requirements of the testing are that in impact testing, the peak acceleration should not exceed 400g and in penetration testing, the striker should not contact the surface of the test headform.

To enhance and ensure the impact capacity of the helmet, two different cases based on the thickness of the foam padding in the helmet were simulated. And finally, the case which passed all the tests as per the standard had been suggested.

Chapter 2

LITERATURE REVIEW

2.1 Existing Research Work

By Chang, Ho, et al. (2003) –

They presented a report on helmet design method by considering the criteria of designing as the reduction of the risk of mild traumatic brain injury (MTBI), comfort, stability and fit. The helmet design optimization and its solution were explained.

By Mills and Gilchrist (2008) –

Finite Element Analysis (FEA) was performed for bicycle helmets making oblique impacts with a road surface, to evaluate the linear and rotational accelerations of the headform. Helmet rotation on the helmet was considered, modeling the helmet and retention strap interactions with the headform. The effects of frictional parameters on the response were explored, and parameters selected to reproduce experimental results. Predictions were made for two helmets, for a range of impact locations and tangential velocities. The design method for the peak headform linear acceleration was confirmed; it was hardly affected by the tangential component of the impact velocity. The peak headform rotational acceleration was investigated as a function of the helmet geometry, impact sites and velocities and the contributing mechanisms established.

By Pinnoji, Bourde, et al. (2008)-

New motorcycle helmets are designed with metal foam shell and their impact behaviour has been studied. Impact experiments have been performed on a first set of prototype helmets with metal foam shell at standard impact locations. Numerical simulations are performed and the predicted headform acceleration is validated with experimental data. The biomechanical characteristics of head impact were studied with both metal foam and ABS helmets. The helmet with metal foam shell performed reasonably well compared to ABS helmet. The authors aimed towards the reduction in weight of helmet without compromising with its impact capacity. The helmet weight was found to be 30% less as compared to ABS helmet.

By Mills, Wilkes, et al. (2009)-

In this research work, a study is performed on full-face helmets which often make oblique impacts with road surfaces. Finite Element Analysis was used to predict 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. And the results of simulations of the oblique impact test in British Standard BS 6658 were validated by comparison with published data. This showed that COST 327 experimental data was largely determined by the friction coefficient (0.55) between the helmet shell and abrasive paper, and hardly affected by that between the head and helmet. Slip was predicted at the shell/paper interface throughout the impact, due to the high angular inertia of the helmet, and the normal force remaining below 3.5 KN. Simulations of more severe motorcycle helmet impacts explored the effects of impact site and direction, impact velocity components, and the helmet fit. In these impacts, the higher velocity component normal to the road caused high frictional forces on the helmet shell, eventually causing it to roll on the road. The peak headform rotational accelerations, at some impact sites, were potentially injurious. It concluded that the most effective method of reducing head rotational acceleration could be a reduction in the linear acceleration limit of the helmet standards.

By Rueda and Gilchrist (2012)-

Computer methods can assist in understanding the behavior of the individual components of a helmet, beyond merely the headform output as is usually done in a laboratory environment or for test-house certification purposes. This design study uses a method that we have previously used to analyze the effects of helmet liner material properties. While the helmet liner is of vital importance for energy absorption, other design modifications can also serve to improve its performance. The equestrian helmet model previously developed and analyzed by the authors was used in this study. The helmet shell and geometric factors, such as a gap between the liner and shell, ventilation holes and ridges on the helmet liner were studied to observe their influence on helmet performance. By studying helmet design variations in terms of different variables other than headform linear acceleration, it is possible to determine which helmet configurations perform better, why they perform the way they do and how efficiently they perform.

By Gandhi, Kumaravelan, et al. (2014)-

This study deals with the analysis of motorcycle helmet by analyzing it using standard data. The different conditions under which the helmet was analyzed in 'ANSYS' software are 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 was applied on the helmet to study the model in static and dynamic conditions. The various parameters considered were total deformation, strain energy, and von Mises stress for different cases in the static conditions. Finally, the results were compared with the standard experimental data proposed by the BIS.

The inadequate quality of the helmet leads to the development of serious neck pain and high glare in the visor. Hence, it is essential to produce standard helmet with proper aerodynamic shape to reduce the neck pain with anti-glare in the visor. They designed the helmet in 'PRO-E' software according to the standard dimensions proposed by 'Consumer Product Safety Commission (CPSC)'. They concluded that the special attention is needed in chin side of the helmet to reduce serious injuries. The chin (retention system) had undergone less strain energy and deformation which lead to a serious head injury during an accident.

By Sadaq, Junaidi, et al. (2014)-

A motorcycle helmet is the best protective head gear for the prevention of head injuries caused by different carnial impact. A finite element model based on realistic geometric features of a motorcycle helmet is established, and explicit finite element, COSMOS, is employed to simulate dynamic responses at different impact velocities. Peak acceleration and Head Injury Criterion values derived from the head form are used to assess the protective performance of the helmet. In this present work motor cycle helmet is designed and modelled in 3D modelling software Pro/Engineer. The impact analysis is performed on the helmet when colliding to a target at different speeds of 50 Km/hr, 60 Km/hr and 70 km/hr that faces the helmet on the front, right and back directions using COSMOS software. The materials used for the helmet is ABS and PVC. The PVC material helmet performed well as compared to ABS helmet when compared on the basis of stresses but ABS material helmet was better than ABS helmet in terms of strain and deformation.

By Sikri, Shishodia, et al. (2014)-

Helmets are widely used by two wheelers for protecting against impact during road accidents. Helmets reduce the impact force and thereby stresses in the brain to a great extent. To encourage people to wear helmets, the impact protection capability has to be combined with light weight of helmet. The helmet consists of two major parts depending on the main role, outer shell and liner foam. Outer shell constitutes about 70-80% of the total weight of the helmet, while in literature, simulations shows that outer shell absorbs only 10-30% of the impact energy. So, the aim of present study is to investigate if a helmet without an outer shell or with an alternate light weight outer shell could provide same protection as conventional helmets. Acceleration of the headform and impact force on the helmet was measured. The helmet weight was reduced by the use of polypropylene foam, foam thickness was reduced in case of polycarbonate shell, and EPS liner foam has only excellent first impact performance helmets.

By Connor, Meng, et al. (2016)-

It is a review which was given under the European Training Network for Advanced Designs in Safety. Initially, it gives the evolution of all the safety standards for the helmet safety adopted in different countries. The standards which are dominant in Europe and US are discussed in this report (review) like ECE 22.05, DOT FMVSS 218 and Snell M2015 for motorcycles, EN 1078, CPSC 1203 AS/NZS 2063 and Snell for bicycles and EN1077, ASTM F2040 and Snell RS98 for snow sports helmet. VG 01.040 2014, PAS 015:2011, EN 14572:2005, ASTM F1163-15 and Snell E2016 for equestrian helmets.

It explains all the tests like impact test, penetration test, retention test, roll off test, rigidity test, friction test, and chin bar test which are based on above standards and which are needed to be performed on various helmets mentioned above. The explanation of all the type of headforms used according to the different standards to perform all the tests is also mentioned in this review. It also explains the test procedure of all the above mentioned tests. The pass/fail criteria and head injury criterion (HIC) are different according to the different standards.

The boundary conditions of all standards which are applied during the testing of helmet are also explained properly. It majorly explains that which tests are needed to be performed according to the different standards on the particular type of helmet. The comparison of the pass/fail criteria of different standards on a particular helmet is also given.

By Jacob, Faria, et al. (2016)-

This report describes the results of the research project focused on helmet protection under impact on it. Three kinds of helmets were considered – construction helmet, motorcycle helmet, and bicycle helmet. The aim of this project is to check the amount of stress absorbed by the skull and brain during the impact, as well as evaluate the maximum capacity of helmet protection. The analysis consists of dynamic simulation of an impact in the helmet using Finite Element Analysis (FEA). The models were meshed using HYPERMESH and after the modeling phase, the analyses were made using ABAQUS (a computer aided engineering program) that shows the stresses and displacements experienced by whole system: helmet, skull, and brain. This report also compares the effect of different materials like ABS and HDPE on the helmet. They considered different numerical values for different parameters like velocity and height for the impact test on all the three helmets. The results obtained from the analysis were displayed on charts that show the effect of the helmet based on different boundary conditions such as object height for the hard hat, and the rider speed for the bicycle and motorcycle helmets. For the motorcycle helmet they concluded that the Carbon Fiber and Kevlar exhibit similar values of results and avoided deadly injuries. And for the more accurate results, one can increase the refinement and quality of meshing.

By Thomas, Dr. Suresh, et al. (2017)-

In this work impact analysis is carried out in the Composite Helmet by Using FRC and Glass Fiber. In this recent world the fiber strengthened composite materials are synthesized using glass fiber as reinforcements together with matrix, which have attracted the attention of researchers due to their low density with high specific mechanical strengths, convenience, and renewability. The current work efforts to make a development in the current existing helmet manufacturing procedure and materials used to have better mechanical properties as well as to enhance the compatibility between fibers and the matrix. The composites are ready with the unsaturated polyester matrix and fibers such as, reinforced composite materials and glass fiber using hand lay-up method with suitable proportions to result in helmet shell construction. The fabricated helmet are planned to estimate its mechanical properties such as tensile strength, impact strength and compression strength. The simulation was performed on ANSYS. The results indicate that the use of fiber composite is viable for helmet application.

By Mellor and StClair, Paper 05-0329-

It deals with the study of helmet and about the mechanisms of various injuries caused due to the failure of the helmet. In this study, it is stated that the helmet consists of a light weight carbon composites shell fitted with an optimized energy absorbing liner and a low friction sacrificial outer surface. The principle objectives in this research are ultra-stiff shell structure and optimized liner and low friction outer surface.

The advanced helmet is designed to reduce both linear and rotational acceleration loadings to the head. In order to quantify the benefits of the advanced helmet, the impact response was measured during a range of impact conditions. The results were related to the AIS scale using correlation coefficients developed by TRL from an accident replication programme. It was shown that the advanced helmet could reduce injury risk by up to 20% for AIS 6 injuries and up to 70% for AIS 5 and AIS 4 injuries. The performance of the helmet during less severe impacts (corresponding to AIS 3, 2 and 1) was designed to be equivalent to current helmet designs. The helmet was designed such that it has the capability to reduce AIS 6 injuries to AIS 4 and AIS 5 and 4 injuries to AIS 3.

By Sambamoorthy and Halder-

They simulated the FEA modeling of the different foams available in LS-DYNA and the results, Head Injury Criterion (HIC) and acceleration curves were compared with the physical test results.

Federal Motor Vehicle Safety Standard No. 218-

This standard establishes minimum performance requirements for helmets designed for use by motorcyclists and other motor vehicle users. This standard applies to all helmets designed for use by motorcyclists and other motor vehicle users. The procedure explains the basic geometry of the helmet and various types of standard headforms. It also includes standard dimensions of the headforms and weights of helmet assembly according to the different headforms. This regulation explains various requirements or the boundary conditions of various tests like impact attenuation test and penetration test which are to be performed on the helmet. The standard also includes information about configuration and projections in the helmet.

The explanation of the testing procedure of all the tests according to the different temperature conditions like ambient conditions (21 degrees C), low temperature (-10 degrees C), high temperature (50 degrees C), and water immersion (25 degrees C) is also given which are generally employed for the experimental testing.

It features the entire testing conditions which are to be maintained while performing all the tests like site selection on the helmet for impact test or penetration test.

2.2 Proposed Research Work

In this research work, we performed the dynamic testing of motorcycle helmet using finite element analysis (FEA). The impact and penetration tests on the helmet were performed according to the regulation "Department of Transportation, Federal Motor Vehicle Safety Standards 218 (DOT FMVSS 218)".

Initially, the testing of the helmet was performed using foam of less thickness. Its testing results were compared with the regulation requirements. Later, the same tests were performed with the foam of higher thickness and the same comparison was made.

Generally, the shell of the helmet constitutes around 70% of the entire helmet weight and remaining is of foam. In this work, we aimed towards the designing of the light weight helmet with the major weight in the foam. We used the thin shell made of low density and low stiffness material (in place of generally used material) for the helmet shell and the high density and high stiffness material (compared to expanded polystyrene) for the foam. This change led to the weight of shell to be only 25% of the entire helmet and that of foam to be the remaining weight.

Chapter 3

SYSTEM ANALYSIS AND DESIGN

3.1 Basic Definitions

Basic plane means a plane through the centers of the right and left external ear openings and the lower edge of the eye sockets of a reference headform or test headform.

Helmet positioning index means the distance in inches, as specified by the manufacturer, from the lowest point of the brow opening at the lateral midpoint of the helmet to the basic plane of a reference headform, when the helmet is firmly and properly positioned on the reference headform.

Midsagittal plane means a longitudinal plane through the apex of a reference headform or test headform that is perpendicular to the basic plane.

Reference headform means a measuring device contoured to the dimensions of one of the three headforms with surface markings indicating the locations of the basic, mid-sagittal, and reference planes, and the centers of the external ear openings.

Reference plane means a plane above and parallel to the basic plane on a reference headform or test headform at the certain distance.

Retention system means the complete assembly by which the helmet is retained in position on the head during use.

Test headform means a test device contoured to the dimensions of one of the three headforms with surface markings indicating the locations of the basic, mid-sagittal, and reference planes.

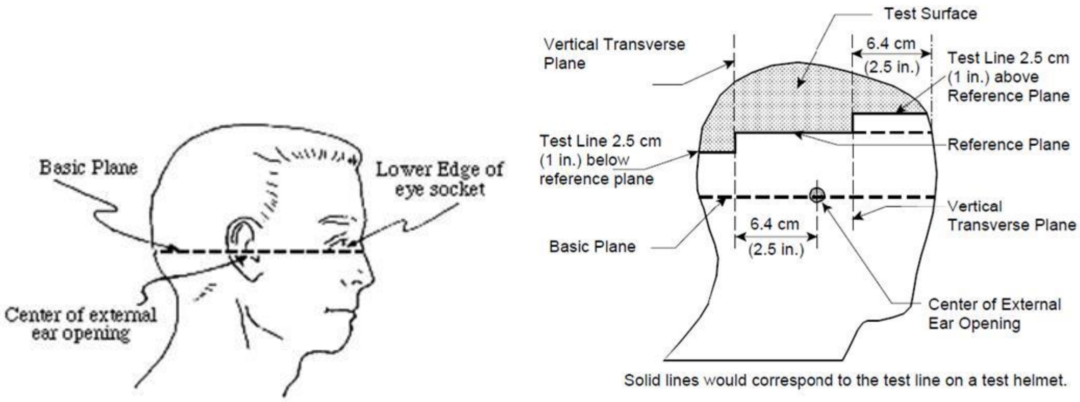

Figure 1 Basic Plane and Test Line

3.2 Modeling

In this study, a full face motorcycle helmet had been designed and then tested as per the norms of FMVSS 218. Before the helmet design, a medium headform had been selected for the testing as per the standard and designed in the CAD software CREO Parametric 3.0. Detailed dimensions of the headform are given in figure 2.

Greater than 6-3/4, but less than or equal to 7-1/2 (European Size 60) - MEDIUM

This headform is selected because it resembles with the structure or shape of head of maximum human beings.

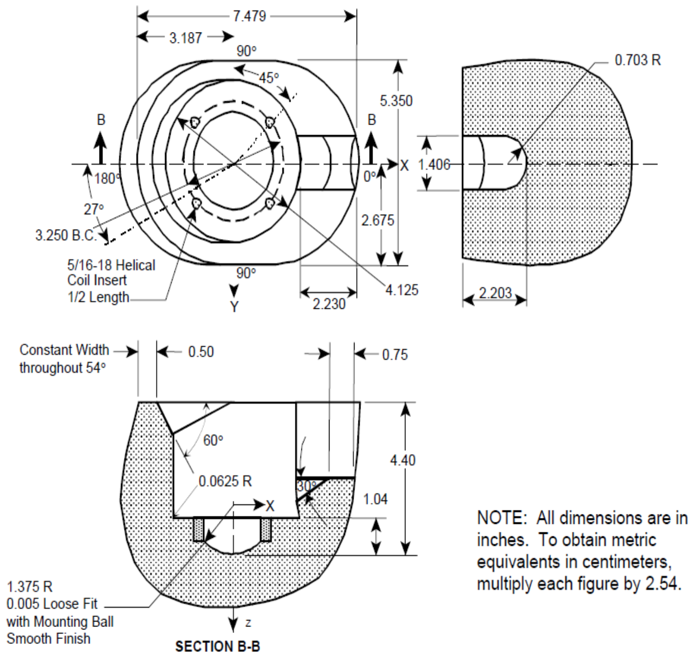

Figure 2 Dimensions of the Medium Headform

The CPSC (Consumer Product Safety Committee) standard dimensions helmet had been designed in CREO Parametric 3.0. The 3D CAD model of the motorcycle helmet is shown in figure 3.

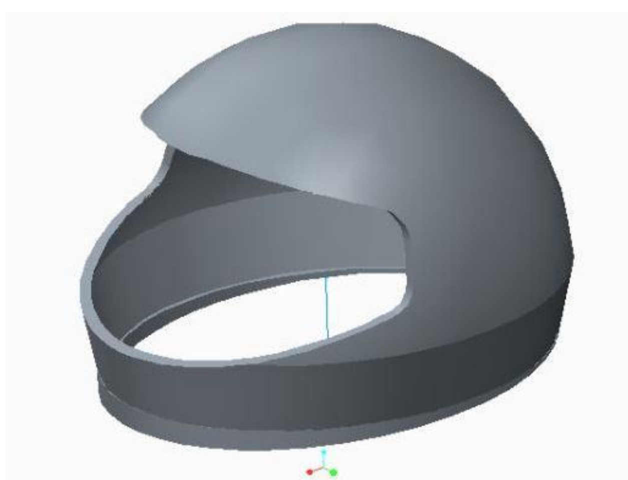

Figure 3 CAD Model of Helmet

3.3 Meshing

CAE software HyperMesh 13 was used to generate the mesh on the helmet assembly. Tetra elements were developed on the headform. FE model of headform is shown in figure 4.

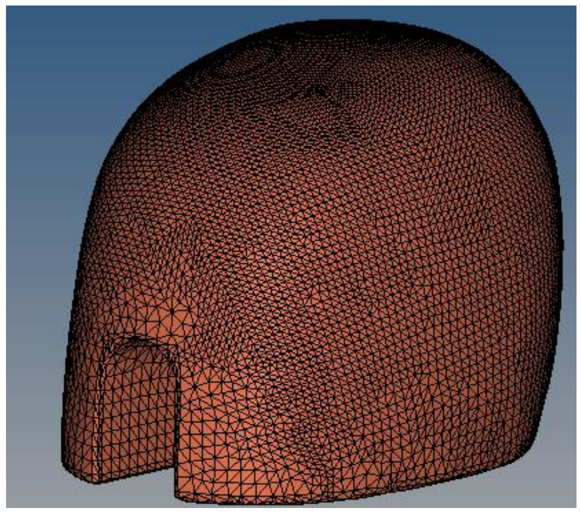

Figure 4 FE Model of Headform

Detailed FE model of the helmet shell and foam padding is shown in figure 5.

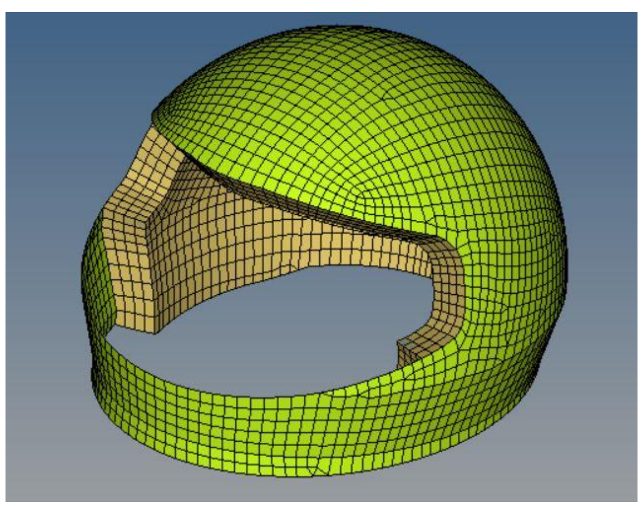

Figure 5 FE Model of Helmet

3.4 Helmet Components and Material Properties

A 1.5mm helmet shell had been given the material properties of the fiberglass reinforced polymer. Foam padding of 25mm thickness was used as the main impact energy absorbing component and the properties of polyurethane foam were used. The headform used is generally made of magnesium alloy (K-1A) and its properties were retrieved from matweb.

3.5 Test Setup

The headform had been fitted in the helmet with the minimum distance from the padding so as to avoid the penetration of the elements in the model. The helmet assembly is shown in figure 6.

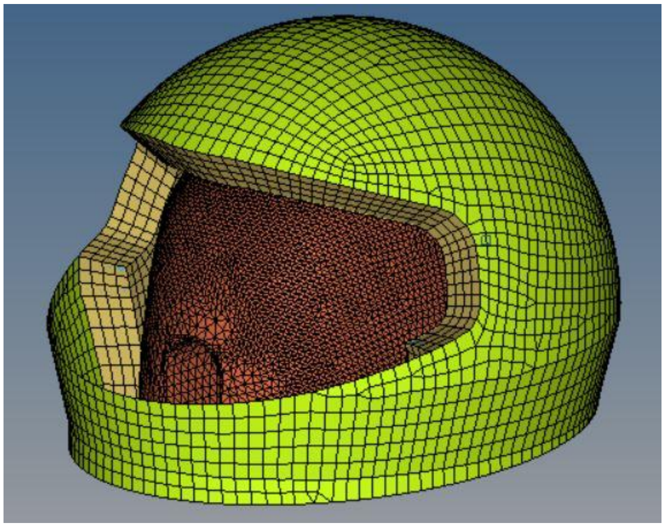

Figure 6 FE Model of Helmet Assembly

The test setup for the impact attenuation testing as per the FMVSS 218 is shown in figure 7 and figure 8 and the same was used in the software for the simulation.

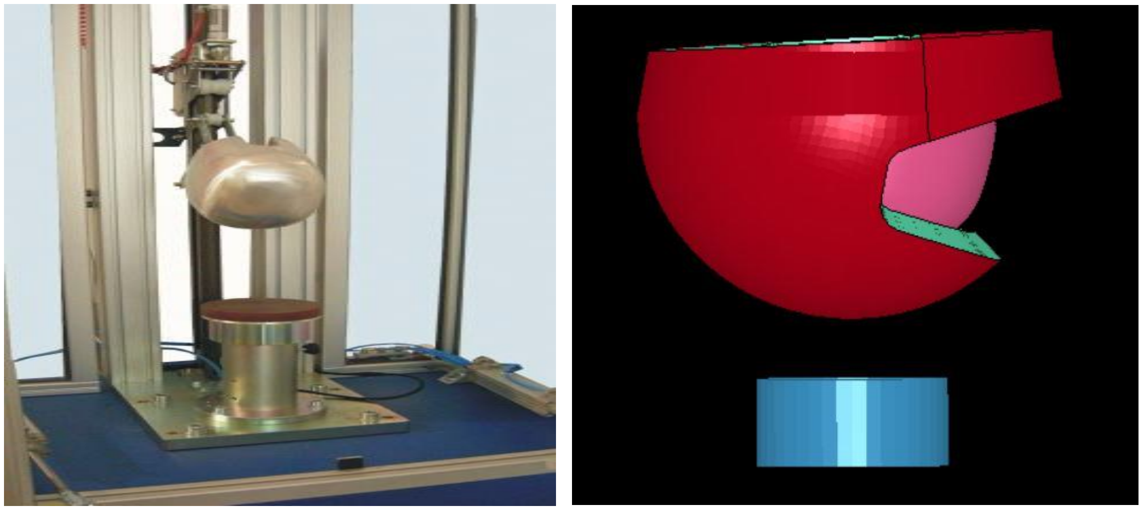

Figure 7 Test Setup for Flat Anvil

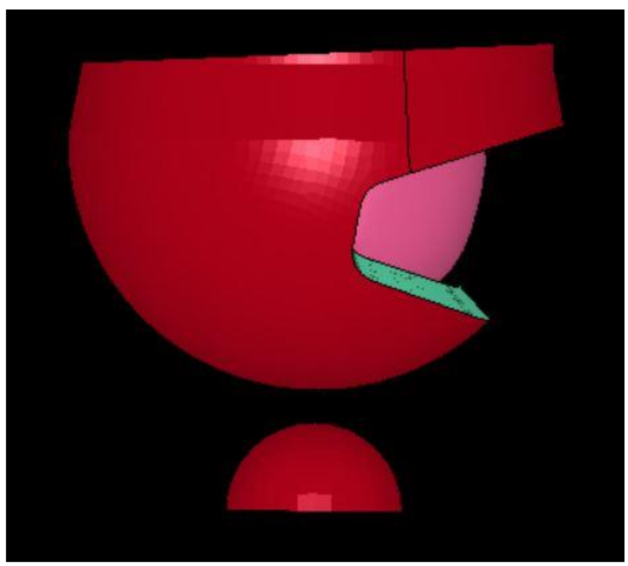

Figure 8 Test Setup for Hemispherical Anvil

Similarly, the penetration test setup is shown in figure 9.

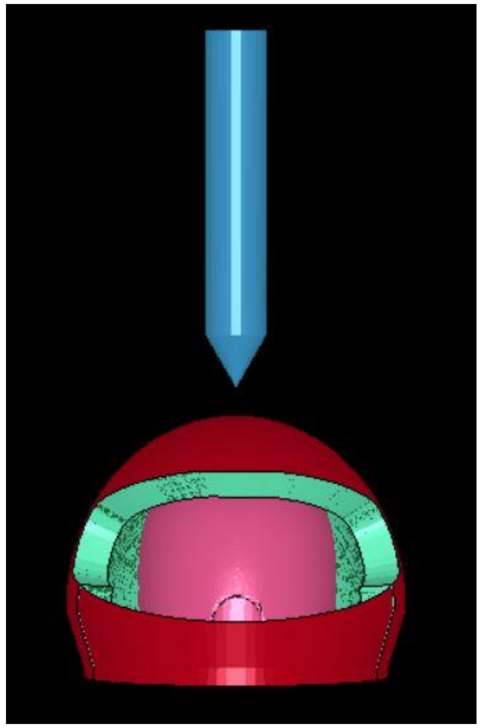

Figure 9 Test Setup for Penetration Testing

The helmet assembly had given the speed of 6.0 m/s in case of the flat anvil and 5.2 m/s in case of the hemispherical anvil. In case of penetration testing, the conical impactor had given the speed of 7.67 m/s. The accelerometer was used in the FE model to get the results with high accuracy.

3.6 Analyses

The analyses were made with the different foam padding thickness. This was performed because as the thickness of the foam padding increases, the peak head acceleration decreases in case of impact.

Initially, the helmet assembly was tested on the flat anvil with the 20mm thick foam padding. Figure 10 shows cross-sectional view of the helmet assembly of this testing. The peak head acceleration was found to be greater than 400g.

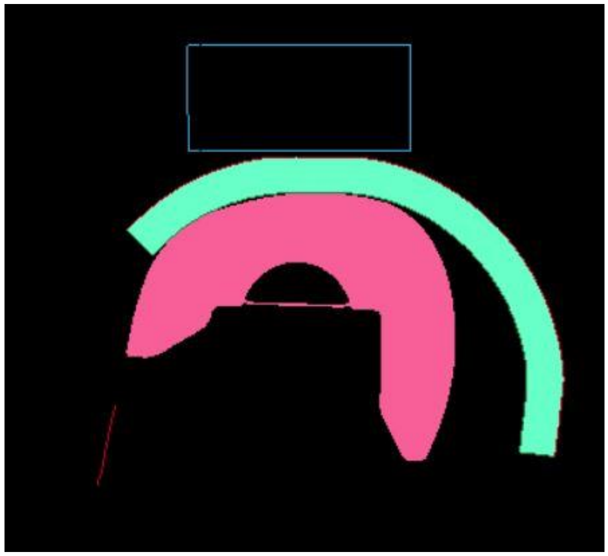

Figure 10 Cross Section of Helmet Assembly and Helmet Deformation with 20mm thick foam

Figure 11 shows the testing of the helmet assembly on the flat anvil with the 25mm thick foam padding. The peak acceleration was found to be less than 400g.

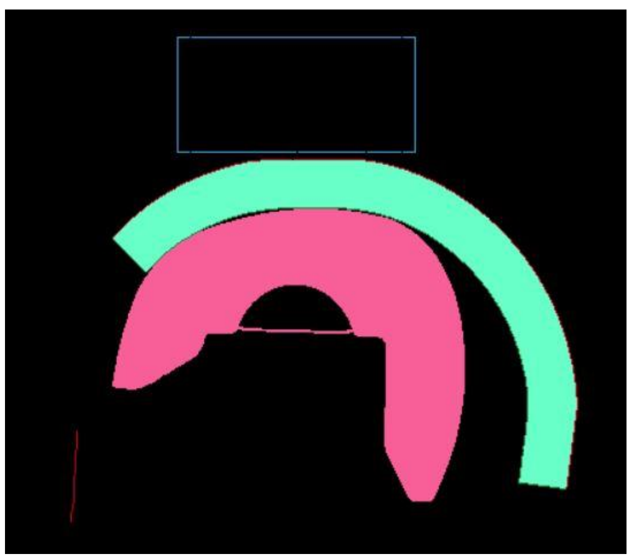

Figure 11 Cross Section of Helmet Assembly with Helmet Deformation with 25mm thick foam

Figure 12 shows the testing of the helmet assembly on the hemispherical anvil with 25mm thick foam padding.

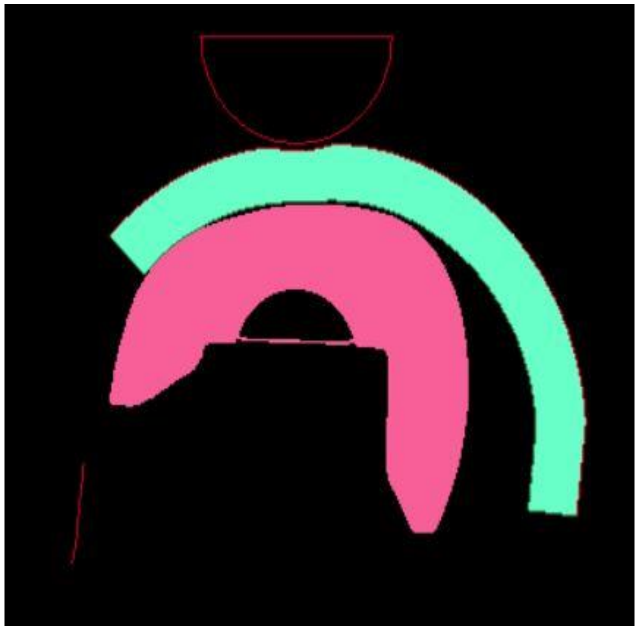

Figure 12 Cross Section of Helmet Assembly and Helmet deformation in case of Hemispherical Anvil

Figure 13 shows the penetration testing of the helmet assembly.

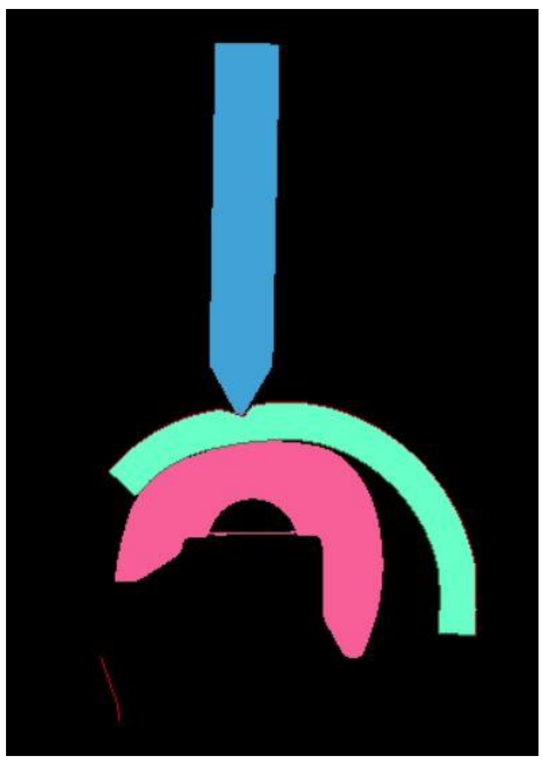

Figure 13 Cross Section of Helmet Assembly and Helmet Deformation in case of Penetration Testing

Chapter 4

RESULTS

Figure 14 shows the graph of acceleration (mm/ms^2) and time (ms) for the impact of helmet assembly with the flat anvil in case of 20mm foam thickness. The peak acceleration was found to be greater than 400g.

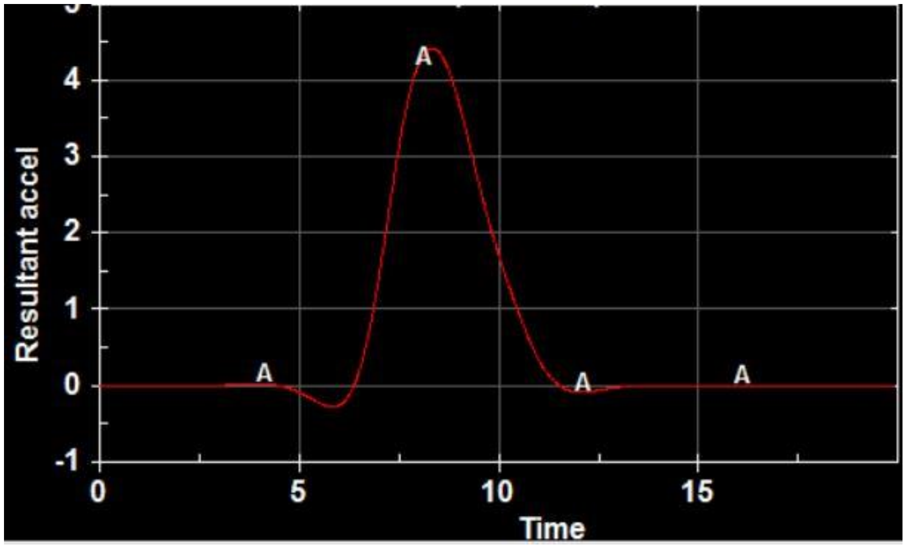

Figure 14 Acceleration-Time Graph in case of 20mm foam thickness for flat anvil impact

In case of 25mm foam thickness, the peak acceleration of the helmet assembly was found to be less than 400g in case of impact with a flat anvil. Figure 15 shows this result.

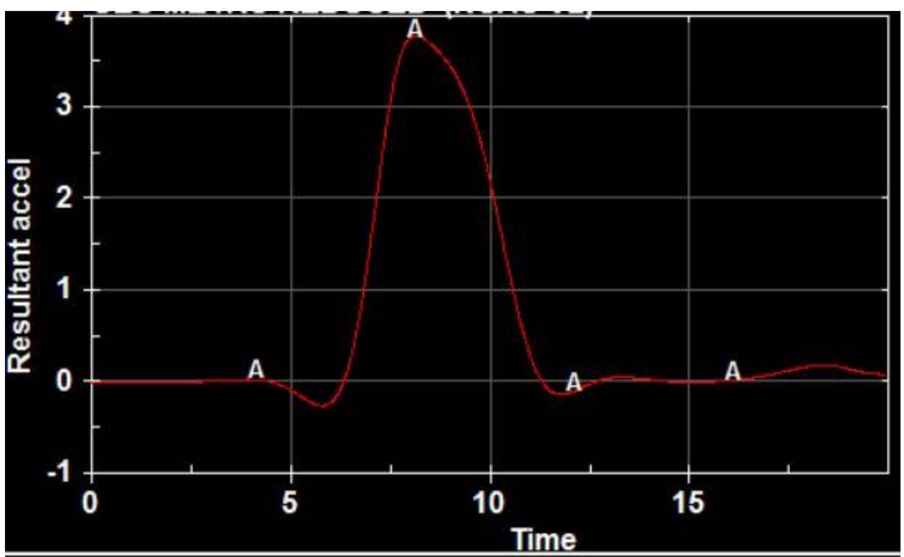

Figure 15 Acceleration-Time Graph in case of 25mm foam thickness for flat anvil impact

In the impact of helmet assembly with the hemispherical anvil in case of 25mm foam thickness, the peak acceleration was found to be very less than 400g (figure 16).

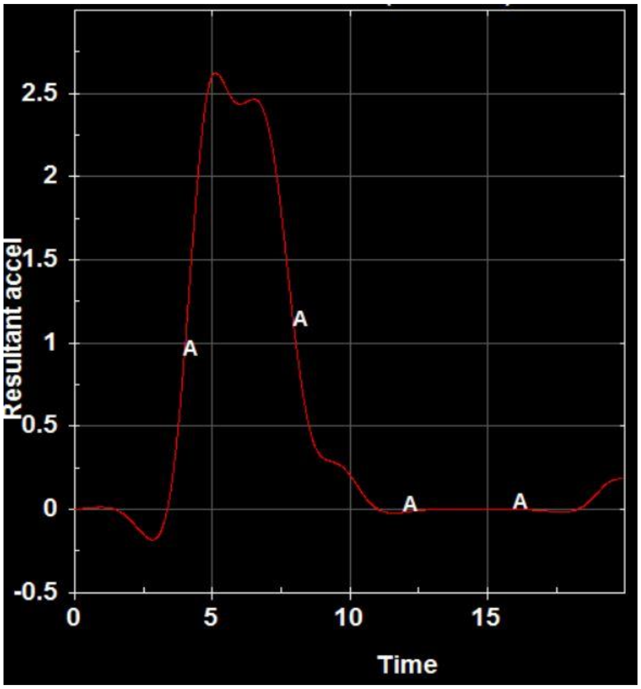

Figure 16 Acceleration-Time Graph for 25mm foam thickness for Hemispherical Anvil Impact

The penetration testing results are shown in figure 13 itself in which the striker has no contact with the surface of headform.

CASE	PEAK ACCELERATION
Flat Anvil with 20mm foam thickness	450.798g
Flat Anvil with 25mm foam thickness	385.919g
Hemispherical Anvil with 25mm foam thickness	268.212g
In case of penetration testing, striker had no contact with the surface of headform.	

Figure 17 Table of Results

Chapter 5

CONCLUSION

In this research work on full-face motorcycle helmet, the testing had been performed by using HyperWorks and LS-DYNA and as per the norms of regulation DOT FMVSS 218. The different tests were simulated to ensure the impact capacity of the helmet.

The foam thickness played a very important role in the peak headform acceleration. When the testing of motorcycle helmet was performed on flat anvil with less foam thickness then it failed to pass the test criterion.

When the foam thickness was increased, and the helmet was tested on flat anvil, hemispherical anvil, and the conical impactor, the helmet passed all the tests and met the safety requirements of the regulation.

Therefore, in this helmet the mass of helmet shell is very less and that of foam is more.

This motorcycle helmet will be able to reduce number of injuries occur due to the failure or breakdown of helmet during crash.

Chapter 6

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