Indian Journal of Science and Technology, *Vol 9(34), DOI: 10.17485/ijst/2016/v9i34/100989, September 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Application of Reverse Engineering and Impact Analysis of Motor Cycle Helmet

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Abstract

Background/Objectives: A motor cycle helmet can prevent head injury from accident. This paper mainly concentrates on impact analysis of motorcycle helmet in different positions. **Method/Analysis:** The analysis of motor cycle helmet is divided into two stages. First stage includes the reverse engineering of Helmet and in the second stage; the virtual prototype of the helmet was analyzed by using LS-Dyna. This paper gives a clear detail about impact analysis of helmet in different positions such as Front, rear and top. It also discusses about impact force in frontal and non-frontal accidents. A Finite Element analysis was done on helmet head using LS-Dyna. The helmet head was impinged on rigid wall in all directions i.e. front, side, top and rear and the corresponding results were observed. **Findings:** The resultant force on head was observed for impacts from all directions. The variation of resultant force on head with respect to outer shell thickness was observed. **Applications/Improvements:** The results obtained can be used to redesign the helmet and increase the safety of rider.

Keywords: Impact Analysis, Motorcycle Helmet, Non-Frontal Impacts, Reverse Engineering, Safety

1. Introduction

The primary goal of a motorcycle helmet is to provide protection to head against impact during an accident. It must provide protection against frontal, non-frontal and skidding accidents. The main components of helmet are outer shell and foam. During impact most of the energy is absorbed by foam and outer shell. Generally, Acrylonitrile Butadiene Styrene (ABS) is used as outer shell material and Expanded Polystyrene (EPS) is used as foam material. To compare frontal and non-frontal accidents the helmeted head is impacted from all directions with different velocities. The parameter thickness of outer shell is varied. A used helmet is used to get outer dimensions.

Following are the few types of motorcycle helmets that are generally used by riders.

- Full face helmet- This type of helmet covers entire head including rear skull and front of chin. Such helmets have an opening in front across eyes and nose. This opening is covered by a transparent plastic face shield known as visor. The visor has facility to rotate up and down. These helmets are found to be most protective compared to other types. Though some wearers dislike due to increased heat, poor vision, lack of wind and reduced hearing. A full face helmet is shown in Figure 1.
- Open face helmet- An open face helmet covers ears, cheeks and back of head. The lower chin bar is not present in this type. It is less protection than full face since the chin bar is absent. Bugs, dust and wind can cause discomfort to the rider. Hence riders need to wear sunglasses or goggles additional to helmet for eye protection. Many open face helmets include or have a facility of face shield which is more effective than goggles. An open face helmet is shown in Figure 2.

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Figure 1. Full face helmet.

Figure 2. Open face helmet.

- Flip up helmet- The flip up helmet is a combination of full face helmet and open face helmet. It is also called as convertible or flip face helmet. It is similar to full face helmet when full assembled and closed. The chin bar provided in this helmet is pivoted upwards or may be removed with a special lever to access face as in open face helmet. A flip up helmet is shown in Figure 3.

Figure 3. Flip up helmet.

- Off road helmet- This type of helmet is similar to full face helmet except it has elongated chin bar and extra visor. This visor is opaque and keeps sun out of the eyes of rider. It is mostly used by motocross riders; hence it is also called as motocross helmet. This helmet has enough space inside so that the rider can wear goggles and allow air to flow inside. The chin bar has an opening with a filter to avoid dust particles. An off road helmet is shown in Figure 4.

Figure 4. Off road helmet.

- Half helmet- A half helmet is similar to open face helmet except it covers only head. It is least protective helmet than other type. The shape of half helmet is similar to a bowl. A half helmet is shown in Figure 5.

Figure 5. Half helmet.

Many research papers are published regarding impact analysis of helmets. In[1] presented a paper on ventilation of helmets using metal foam. Impact analysis was performed to study the effects of ventilation groove provided on modified design. The provision of groove on helmet did not have much effect on the dynamic performance of helmets and the maximum pressure were in not sensitive to groove. The modified design had 60% weight reduction compared to non-groove ABS shell helmet. In[2] published another paper which shows that the impact dynamics of metal foam shells for motorcycle helmets. Head injury criteria and stresses on brain were evaluated for metal foams and ABS shell helmets. The results showed that the use of metal foams in outer shell has reduced impact forces on brain and 73% reduction in mass was observed compared to ABS. In[3] presented helmet performances improved in accordance with biomechanical criteria. The results showed that the risk of injuries is very high even if the helmet passes the standard. They proposed a new method of improving the helmet in case of impact by focusing on outer shell characteristics and by assessing the head injury risk with human head finite element model. A paper published[4] describes the effect of frontal loading impact on helmeted head. The human head was impacted on rigid wall with and without helmet. The results showed the use of helmet reduces the stress on brain in frontal accidents.

2. Proposed Methodology

2.1 Step1: Reverse Engineering

Reverse engineering was applied to model the motorcycle helmet. The outer surface of the motorcycle helmet was scanned using a 3D scanner. The cloud surface was used to model the helmet using CATIA V5. The scanned outer surface is shown in Figure 6. The CAD model consists of outer shell and foam. Generally the thickness of outer shell and foam are 4mm and 18mm. The CAD model is shown in Figure 7.

Figure 6. Scanned surface of helmet.

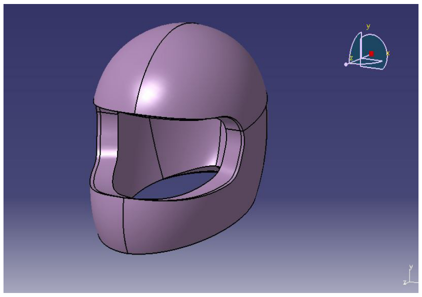

Figure 7. CAD model of helmet.

2.2 Step 2: Discretization

The meshed outer shell model consists of 366 elements and 403 nodes. The meshed foam models consist of 732 elements and 1209 nodes. The head model consists of 124 elements and 270 nodes. Quad mesh is used to mesh the models. The meshed model of helmet and head is shown in Figure 8 and Figure 9. The average thickness of outer shell and foam measured in India is 4 mm and 18 mm. The outer shell is meshed with 4 noded shell elements.

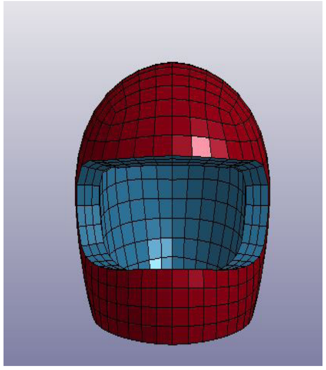

Figure 8. Meshed model of helmet.

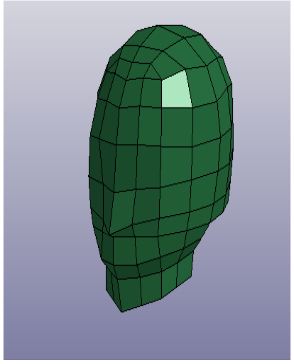

Figure 9. Dummy head model.

2.3 Step 3: Impact Analysis

The impact analysis is performed in LS-DYNA[5]. The helmeted head is impacted with a wall from all sides with a velocity 7m/s as per Indian drop test standard. The resultant force on head is measured by applying impact load[6] on helmeted head. Tied contact is given between outer shell and foam. ABS plastic is used as outer shell material and EPS is used as foam material. The material properties of ABS and EPS are shown in Table 1. The dummy head model is assumed to behave like skull. Hence the head model is assigned skull properties. The skull properties are shown in Table1. Automatic surface to surface contact is assigned between skull and foam.

3. Results and Discussions

Figure 10 shows the energy plot with respect to time of outer shell and foam for front impact. The energy absorbed by outer shell and foam is 6.7 KJ and 23.8 KJ. The outer shell rebounds and transfers some part of its energy to foam. Figure 11 shows the impact force plot with respect to time for frontal impact. The impact occurs at 0.02s with a magnitude of 1378 N.

Table 1. Material properties

Part	Density (Kg/m^3)	Young's Modulus (N/m^2)	Poisson ratio	Yield Strength (N/m^2)
Outer shell (ABS)	1200	2 x 10^9	0.37	34.3 x 10^6
Foam (EPS)	44	1.8 x 10^7	0	0.6 x 10^6
Head (skull)	2100	6 x 10^9	0.21	-

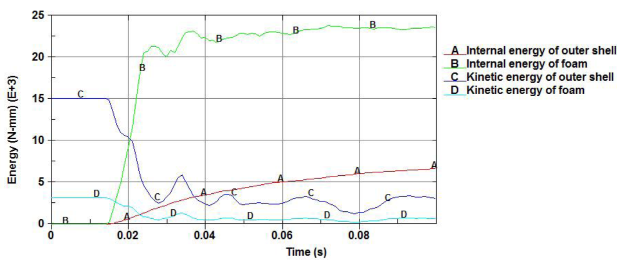

Figure 10. Energy plot of outer shell and foam for front impact.

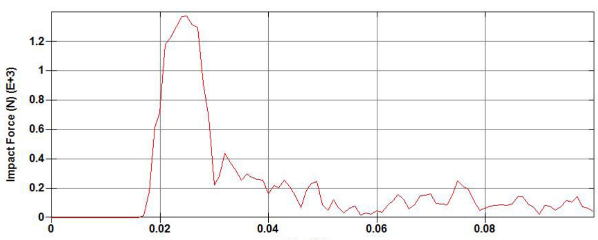

Figure 11. Impact force plot of outer shell and foam for front impact.

The stress distributions during front, rear, side and top impact are shown in Figure 12 to Figure 15. The stress distributions shown are for velocity of 7m/s. Outer shell thickness and foam thickness are 4mm and 18mm.

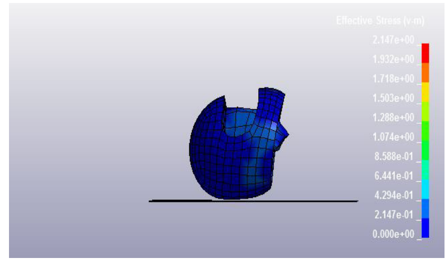

Figure 13. Stress distribution during rear impact.

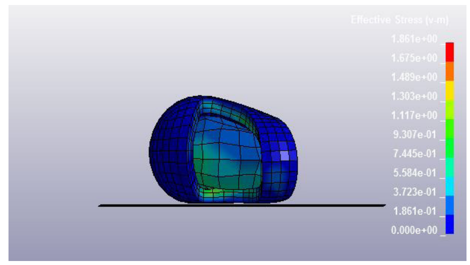

Figure 14. Stress Distribution during side impact.

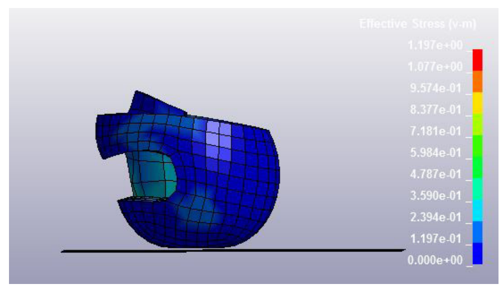

Figure 15. Stress distribution during top impact.

The variation of resultant force on head in different direction of impact is shown in Figure 16.

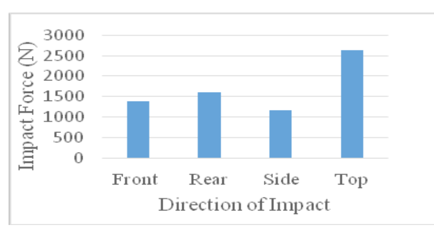

Figure 16. Variation of resultant force on head with direction of impact.

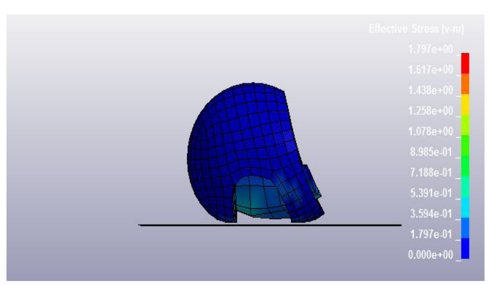

Figure 12. Stress Distribution during front impact.

The variation of resultant force on head for front, rear, side and top impact with increase in outer shell thickness are shown in Figure 17 to Figure 20. The thickness of outer shell is varied from 4 mm to 8 mm.

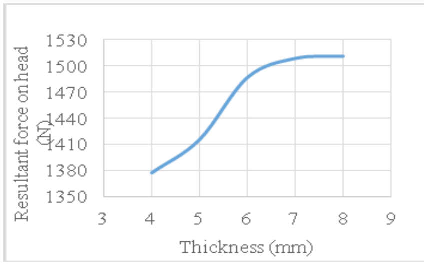

Figure 17. Variation of resultant force on head for front impact.

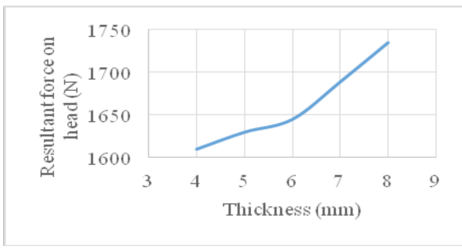

Figure 18. Variation of resultant force on head for rear impact.

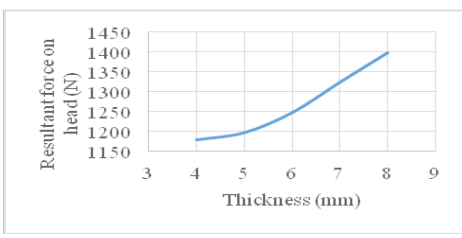

Figure 19. Variation of resultant force on head for side impact.

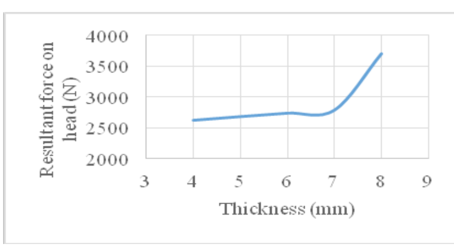

Figure 20. Variation of resultant force on head for top impact.

The velocity of helmeted head is varied from 7 m/s to 15 m/s. The variation in resultant force on head due to increase in velocity is shown in Figure 21 to Figure 24. As the velocity of helmet is increased the resultant force on head increases.

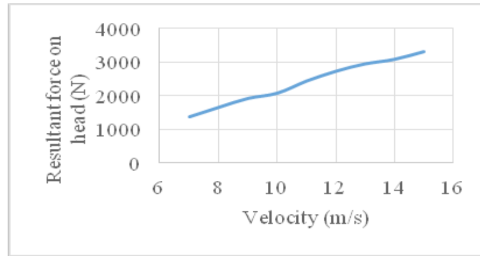

Figure 21. Variation of resultant force on head for front impact.

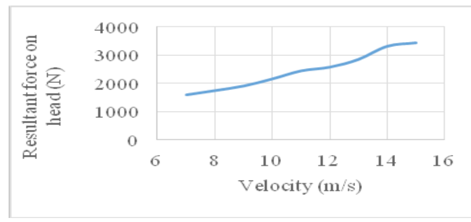

Figure 22. Variation of resultant force on head for rear impact.

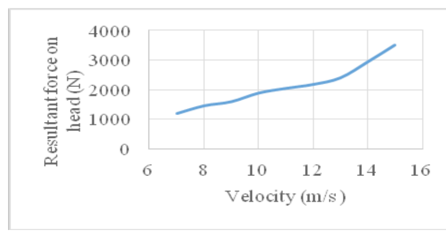

Figure 23. Variation of resultant force on head for side impact.

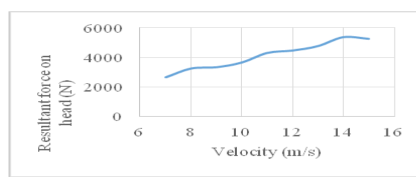

Figure 24. Variation resultant force on head for top impact.

4. Conclusion

A comparison is made between frontal and non-frontal motorcycle accidents. The helmeted head is impacted from front, rear, side and top. The results show that largest impact is taken from top compared to remaining sides. The least impact is taken from side and front and the rear subjected to intermediate level. As the thickness of outer shell is increased, the resultant force on head increases during all direction of impacts. As the velocity of helmet increases the resultant force on head increases for frontal and non-frontal impacts. Hence, it can be concluded that while designing a helmet thickness of outer shell must be optimized and also the effect of frontal and non-frontal impacts must be considered for increased safety. Various optimization techniques can be used to optimize the outer shell of helmet.

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