International Research Journal of Engineering and Technology (IRJET) **e-ISSN: 2395-0056**
Volume: 05 Issue: 05 | May-2018 **www.irjet.net** **p-ISSN: 2395-0072**

Design and Analysis of the Motorcycle Helmet using Finite element analysis as per FMVSS 218

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Abstract - *Brain injuries in motor vehicle accidents have high significance due to their mortal effects on the nervous system of the occupant. The purpose of Federal Motor Vehicle Safety Standards (FMVSS) No. 218 is to reduce deaths and injuries to motorcyclists and other motor vehicle users resulting from head impacts. This regulation ensures the proper helmet performance during the accident. Finite Element Analysis (FEA) is an advanced tool to simulate and compare the different stiffness of foam padding to enhance the helmet safety. In this research work, detailed motorcycle helmet shell, padding, and foam were modeled with nonlinear material properties. Different test setup details are given in FMVSS218 regarding impact attenuation of the helmet. Two cases were simulated based on foam padding stiffness to enhance the impact attenuation capability of the helmet.*

Key Words: **Helmet, FMVSS 218, FEA, Crash, and Safety**

1. INTRODUCTION

Brain injuries are an important field of research due to their lethal and permanent effects on the nervous system of occupants. The neurotrauma is a physical harm that occurs when the human head is abruptly subjected to high levels of mechanical impact [1]. Road accidents, attacks, waterfalls, and wounds occurring during recreational activities are some of the major causes of neurotrauma. Maximum of the research in this field was started by military aircraft industry in the sixties, but today such researches are carried out and sponsored by car and motorcycle producers. The global head injury fatality rate is about fifteen to thirty per one lac population yearly. Yearly about more than 1 million deaths is due to the head injuries [1].

Motorcycle crashes (MCCs) have more importance due to a considerable number of their injuries leading to death. In order to provide head protection, a standard helmet must pass impact tests as per FMVSS 218 [2]. The use of computer simulations among the researchers has recently increased to diminish the expenses of conducting experimental tests. There is a similar trend in the researches carried out on the head impact. It is because of limitations in conducting actual tests on living creatures (e.g. monkeys).

Several research works have been done in this field. Anzelius [3] is the first who performed similar research in the forties. Gurdjian et al. [4] performed impact tests on animals and measured brain response. Dynamic brain pressure in the brain of animals was measured by Nahum et al. [5]. Finite Element (FE) Model of brain and tissues were used to analyze the brain injuries [6]. Further detailed non-linear FE model was used to assess the brain damage [7]. A finite element model of a helmet and its chin bar was used by Chang et al. [8].

Advanced FE approach was used by Aida [9] to see the influence of mechanical characteristics of the brain tissue on head injury. This research work concluded that head injury criterion (HIC) is insensitive to the type of material used to model the brain tissue. The viscoelastic model for the brain was used by Brands [10] to analyze the effect of angular accelerations on head injuries.

The influence of the head and brain size and the direction of the impact on injuries to the head were investigated using Finite Element Method (FEM) by Kleiven [1]. A simplified model of helmet and head was used by Kostopoulos et al. to investigate the protection of helmets with different materials [11].

In the present study, detailed FE model of helmet is prepared with nonlinear material properties. The FMVSS 218 hemispherical anvil tests were simulated using LS-DYNA. Effect of foam stiffness in helmet protection was analyzed in this research work.

2. METHODOLOGY

In this study, full face helmet FE model was used to simulate the FMVSS218 motorcycle helmets test and propose finest optimized helmet designed for use by motorcyclists. The purpose of this standard is to reduce deaths and injuries to motorcyclists and other motor vehicle users resulting from head impacts. The medium headform had been selected for the testing according to the standard FMVSS 218. The headform had been designed in the Computer Aided Design (CAD) software CREO Parametric 3.0 as per the dimensions shown in figure 1.

Detailed 3D FE model was developed using tetra elements as shown in figure 2. A rigid material property was assigned to the 3D FE model of the headform. The accelerometer was used to get the results with high accuracy at the Centre of Gravity (CG) of the headform.

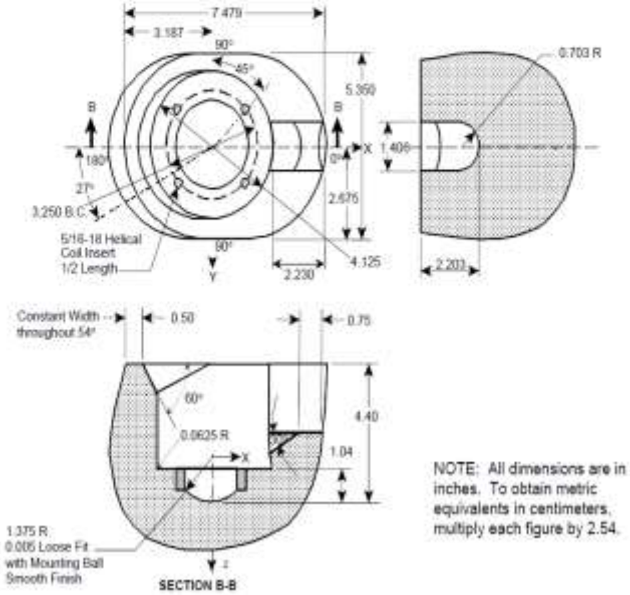


Fig-1: Medium head form dimension

Fig-2: Detailed FE model of Headform

The 3D model of motorcycle helmet contains helmet shell and foam padding as shown in figure 3.

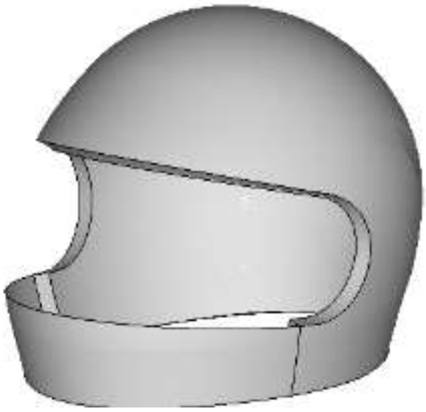


Fig-3: 3D Model of Helmet

HyperMesh 13 was used to develop mesh on CAD surface of the helmet. Figure 4 shows the FE model of the helmet shell and its padding.

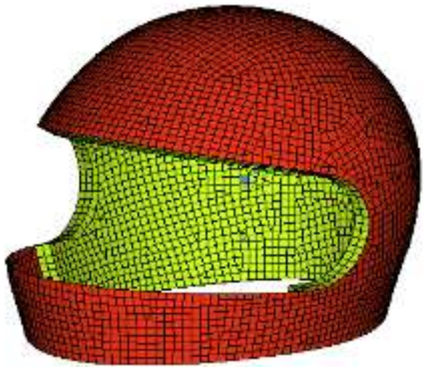


Fig-4: Helmet FE Model

IS515 1.6mm steel sheet metal was used for helmet shell. A bilinear material property was used to check its nonlinear behavior. Foam properties were taken from the previous research. The helmet assembly was integrated with an anvil. The gap between padding and headform was adjusted to avoid penetration in the model as shown in figure 5.

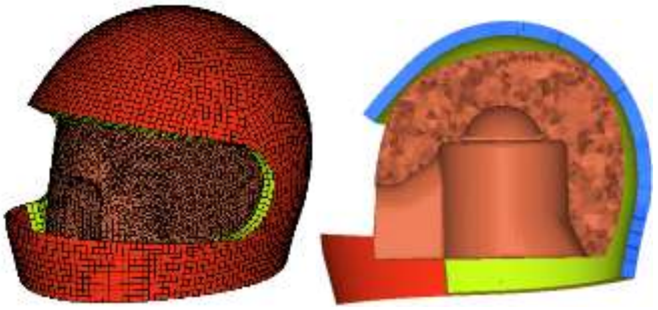


Fig-5: Helmet FE Model with the headform

FMVSS 218 hemispherical impact test simulation setup was done as shown in figure 6. As per test requirements, initial velocity was set as 5.2 m/s.

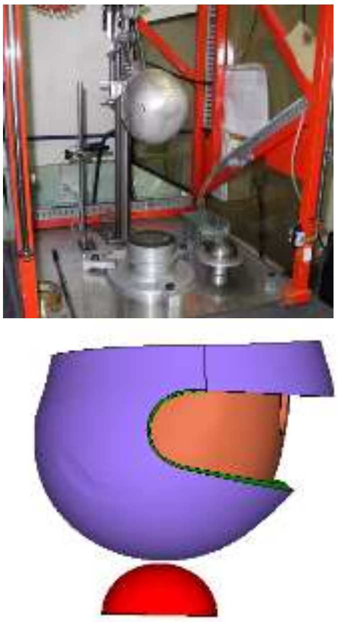


Fig-6: FMVSS 218 test setup

The anatomy of the brain is shown in figure 7. Similarly, three impact locations were selected to check the helmet protection.

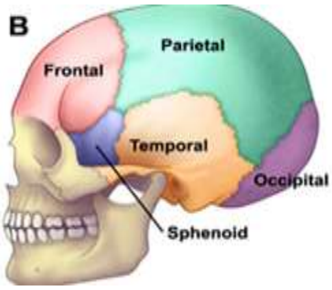
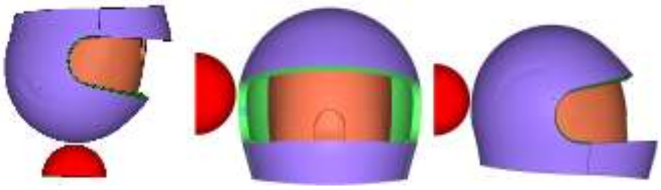


Fig-7: Brain lobes and locations

Figure 8 shows the three impact scenario. These cases mainly named:

1. Parietal
2. Temporal
3. Occipital

Initially, the parietal impact case was simulated using the baseline foam properties. Further foam stiffness was reduced by 10 times to improve the helmet protection. Finally, rest two cases i.e. temporal and occipital locations with lower stiffness foam were simulated. As per the test requirements, the peak acceleration of the assembly should not exceed 400g.



(a) (b) (c)

Fig-8: Test scenario for (a) Parietal (b) Temporal and (c) Occipital impact cases

3. RESULTS

Figure 9 shows the cross-sectional view of parietal impact test simulation. A deep deformation was observed on the impact location.

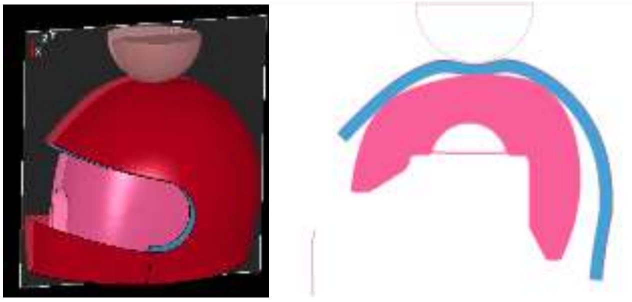


Fig-9: Cross section of helmet assembly and helmet deformation with stiffer foam in parietal impact

Figure 10 shows the cross-sectional view of parietal impact test simulation in lower stiffness foam case. A deep deformation was observed in the impact location. Higher deformation was found in case of lower foam stiffness case.

Fig-10: Cross section of helmet assembly and helmet deformation with low stiffer foam in parietal impact

Figure 11 shows the cross-sectional view of temporal impact test simulation in lower stiffness foam case. A deep deformation was observed in the impact location. Higher deformation was found in case of lower foam stiffness case.

Fig-11: Cross section of helmet assembly and helmet deformation with low stiffer foam in the temporal direction

Figure 12 shows the cross-sectional view of occipital impact test simulation in lower stiffness foam case. A deep deformation was observed in the impact location. Higher deformation was found in case of lower foam stiffness case.

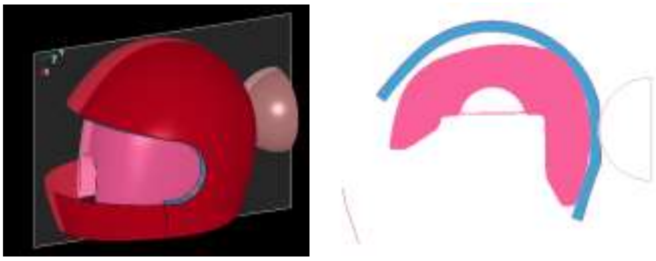
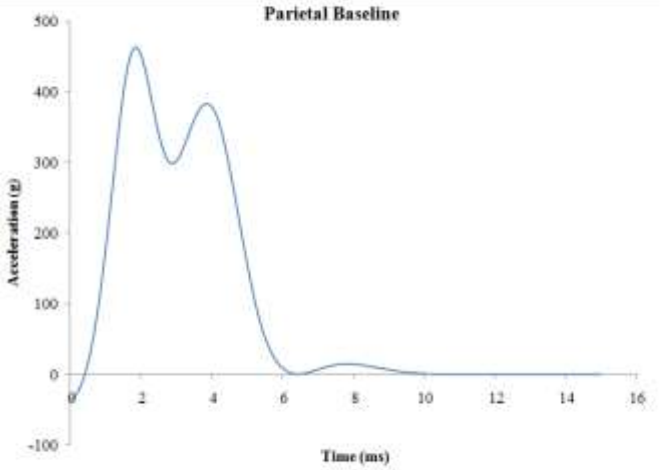


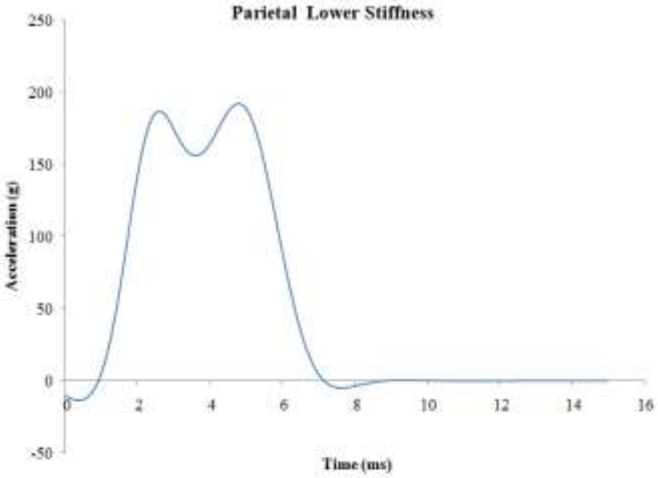
Fig-12: Cross section of helmet assembly and helmet deformation with low stiffer foam in occipital direction

Graph 1 shows the acceleration time history of headform helmet assembly in parietal impact location with the high stiffness of foam. The peak acceleration was found to be higher than the criteria i.e. 400g.



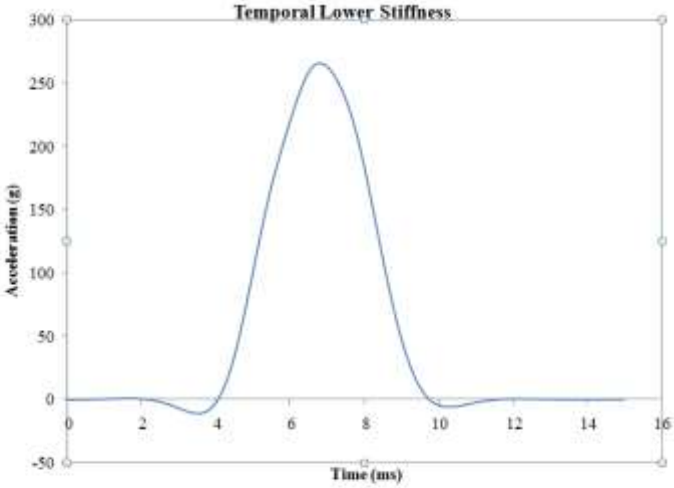
Graph 1: Headform Acceleration in high stiffer foam in parietal direction

Graph 2 shows the acceleration time history of headform helmet assembly in parietal impact location with the low stiffness of foam. The peak acceleration was found to be lower than the criteria i.e. 400g.



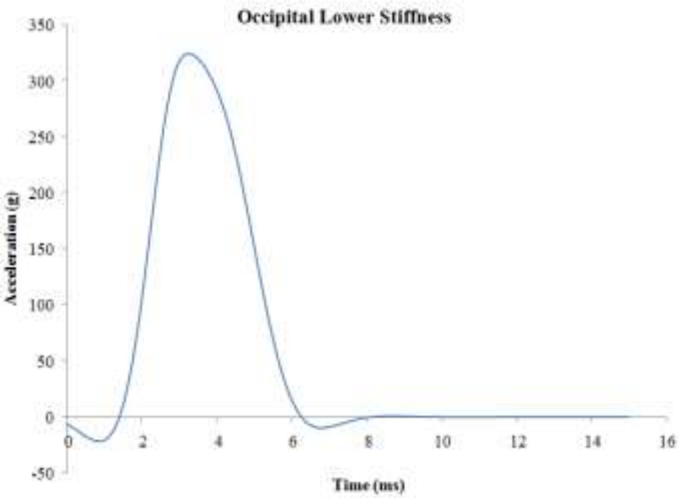
Graph 2: Headform Acceleration in low stiffer foam in Parietal direction

Graph 3 shows the acceleration time history of headform helmet assembly in temporal impact location with the low stiffness of foam. The peak acceleration was found to be lower than the criteria i.e. 400g.



Graph 3: Head form Acceleration in low stiffer foam in Temporal direction

Graph 4 shows the acceleration time history of headform helmet assembly in occipital impact location with the low stiffness of foam. The peak acceleration was found to be lower than the criteria i.e. 400g.



Graph 4: Headform Acceleration in low stiffer foam in occipital direction

4. CONCLUSIONS

In this research work, a full face motorcycle helmet was designed and then tested according to the norms of regulation FMVSS218 and proposed finest optimized helmet design for use by motorcyclists. Different directional simulations were performed. Foam stiffness was found to be a key player in acceleration reduction. The baseline case was not meeting the test requirements. With reduced foam stiffness, significant acceleration was reduced.

REFERENCES

[1] Kleiven, S. (2002). Finite element modeling of the human head, Ph. D. dissertation, Department Aeronautics, Royal Institute of Technology, Sweden.

[2] Snell memorial foundation, 2000 Standard for Protective Headgear, www.smf.org/standards/pdf /m2000std, accessed on 10-03-2007.

[3] Anzelius, A. (1943). The effect of an impact on a spherical liquid mass, Acta Pathologica et Microbiologica Scandinavica Suppl., Vol. 48, 153-159.

[4] Gurdjian, E. S.; Lissner, H. R.; Latimer, F. R.; Haddad, B. F; Webster, J. E. (1953). Quantitative determination of acceleration and intracranial pressure in experimental head injury: a preliminary report, Neurology, Vol. 3, 417-423.

[5] Nahum, A. M.; Smith, R. W.; Ward, C. C. (1977). Intracranial Pressure Dynamics During Head Impact, Proceedings of 21st Stapp Car Crash Conference.

[6] Ward, C. C.; Thompson, R. B. (1975). The development of a detailed finite element brain model, SAE paper number: 751163.

[7] Gilchrist, A.; Mills, N. J. (1994). Modeling of the impact response of motorcycle helmets, International Journal of Impact Engineering, Vol. 15, 201-218.

[8] Chang, C. H.; Chang, L. T.; Chang, G. L.; Huang, S. C.; Wang, C. H. (2000). Head injury in facial impact-a finite element analysis of helmet chin bar performance, Journal of Biomechanical Engineering, Vol. 122, 640-646.

[9] Aida, T. (2000). Study of human head impact: brain tissue constitutive models, Ph.D. dissertation, Department of Mechanical Engineering, West Virginia University.

[10] Brands, D. W. A. (2002). Predicting brain mechanics during closed head impacts, University Press Facilities, Eindhoven.

[11] Kostopoulos, V.; Markopoulos, Y. P.; Giannopoulos, G.; Vlachos, D. E. (2002). Finite element analysis of impact damage response of composite motorcycle safety helmet, Composites: Part B Vol. 33, 99-107.