Research Article *ISSN: 2319-507X*
Mukesh Chaudhari, IJPRET, 2013; Volume 1(8): 23-34 *IJPRET*

INTERNATIONAL JOURNAL OF PURE AND APPLIED RESEARCH IN ENGINEERING AND TECHNOLOGY

A PATH FOR HORIZING YOUR INNOVATIVE WORK

OPTIMIZATION OF BONNET THICKNESS FOR ADULT PEDESTRIAN SAFETY- A FEA APPROACH

MUKESH CHAUDHARI[1], KHARDE B.R [1]

1. PG Students of AVCOE Sangamner.
2. Faculty of AVCOE Sangamner.

Accepted Date:
27/02/2013
Publish Date:
01/04/2013

Keywords
Bonnet,
Head Injury,
Optimal Design,
Pedestrian Safety

Corresponding Author
Mr. Mukesh Chaudhari

Abstract

Pedestrian injuries, fatalities, and accessibility continue to be a serious concern in India. Pedestrian safety is influenced by both behavioral human factors and physical environmental factors. Collisions between pedestrians and road vehicles present a major challenge for public health, trauma medicine, and traffic safety professionals. Adult skull and face injuries in car pedestrian accidents is account for 60 percent of all pedestrian serious injuries, whereas 18 percent of skull injuries were due to the structure of bonnet. The above values show the essential to think more carefully the role of the bonnet in pedestrian skull safety. Redesigning the bonnet structure to improve pedestrian safety has recently received considerable attention by automobile industry and institutes. However, there is a lack of delve into that considers methods of choosing the most effective thicknesses of bonnet covering and bonnet strengthening with respect to pedestrian safety. This study analyses the effects of the bonnet skin and bonnet reinforcement thicknesses on pedestrian head injury by performing simulations of head form-impactor-to-bonnet tests according to the European Enhanced Vehicle-safety Committee Working Group 17 regulations for different thicknesses. Many positions on the bonnet surface are considered to enhance pedestrian kindliness by using this method. Based on the proposed method, this study presents steps for optimizing the bonnet skin and bonnet reinforcement thicknesses using a particular automobile model.

INTRODUCTION

A Research on adult pedestrian protection currently is focusing mainly on passenger cars and commercial vehicles. However, impacts with heavy goods vehicles and buses are also important, especially in urban areas and in developing countries. Pedestrian safety is the important issues across the world. Transportation network is a heart of a nation and transport services are considered as growth engine of economy. Thousands of pedestrians are killed or badly injured in automotive accidents annually. According to the National Highway Traffic Safety Administration (NHTSA), In 2010, 32,885 people died in motor vehicle traffic crashes in the United States—the lowest number of fatalities since 1949 (30,246 fatalities in 1949) This was a 2.9-percent decline in the number of people killed, from 33,883 in 2009, according to NHTSA's 2010 Fatality Analysis Reporting System (FARS). In 2010, an estimated 2.24 million people were injured in motor vehicle traffic crashes, compared to 2.22 million in 2009 according to NHTSA's National Automotive Sampling System (NASS) General Estimates System (GES). This slight increase (1.0% increase) in the estimated number of people injured is not statistically significant from the number of people injured in crashes in 2009 [1].

These figures reflect the need for the automotive industry to pay more concentration for pedestrian safety. The leading reasons for pedestrian fatalities are head and face injuries, accounting for 60 per cent of all pedestrian fatalities by body region [2], and 17.3 percent of all pedestrian fatalities involving the head are caused by contact with the bonnet [4]. Two main approaches have been developed to protect pedestrians against the effects of automotive accidents. The first approach is active protection, which involves sensors placed in automobiles to detect oncoming pedestrians and potential accidents, and it subsequently offers solutions to avoid accidents [5]. Although this approach can be solved efficiently and offers an efficient means of responding to safety problems, the sensor system which must be installed in the car is more expensive and required more care. Also the sensor system is activated when the vehicles crashes to any other objects, beams, dividers, etc The second approach is passive protection, in which design measures are implemented either to protect pedestrians from injury or to minimize the severity of potential injury [5]. For instance, passenger cars can be equipped with advanced devices such as external air bags and lifting-bonnet systems [10–12], which reduce pedestrian injuries in the event of accidents. All solutions are continuously developing because each solution highlights the role of automobile owners for protecting pedestrians.

Redesigning the structure of the bonnet to improve pedestrian protection has recently received considerable attention by automobile manufacturers and industry, institutes. Figure 1 illustrates a method of protecting pedestrians by creating more holes in the ribs of reinforcement to reduce the bonnet stiffness [6]. Previous research on improving pedestrian safety also increased the number of ribs to create a bonnet surface with more uniform stiffness [7].

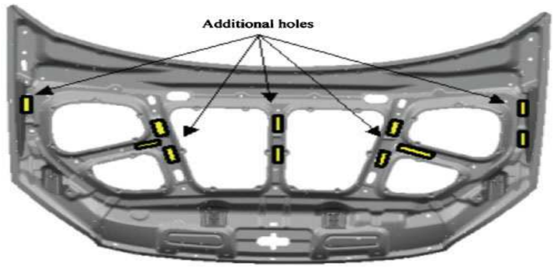

Fig. 1 Pedestrian protection by the modified original reinforcement structure [6]

If the bonnet has poor stiffness, there is a risk that components within the engine compartment may strike the bonnet during collision, increasing the danger to the pedestrian and negating the benefits of the reduced stiffness. Therefore, bonnet redesign not only must simply reduce the bonnet stiffness and mass but also should consider the bonnet deflection during collision. Presently there are two methods for evaluating pedestrian injury. The first method uses pedestrian impactors to evaluate corresponding areas on the vehicle. The second method uses a complete dummy to evaluate the vehicle's frontal structure. Both the complete dummy and the pedestrian impactor methods require complicated physical testing systems. Furthermore, the pedestrian impactors must pass a series of tests to obtain certification. Testing the material properties of pedestrian impactors is time consuming. Numerical simulation offers another reliable method of solving the above problems. One advantage of this method is its ability to solve optimization problems. While mathematical analysis is not an easy method of solving optimization problems, analysis of simulation results is relatively simple and effective. Because of the above advantages, all pedestrian-head-to-bonnet-top tests in this study will be performed using numerical simulation.

This study analyses the effects of the bonnet skin and bonnet reinforcement thickness on pedestrian head injury by performing number of simulation of head form impactor to bonnet top test as per European Enhanced Vehicle-safety Committee (EEVC) Working Group 17 (WG17) regulations using different thicknesses. Many points on the bonnet surface will be considered to enhance pedestrian friendliness by using this method. A bonnet with the optimal thicknesses not only is pedestrian friendly but also is as stiff as possible. Based on the proposed method, this study presents steps for optimizing the bonnet skin and bonnet reinforcement thicknesses for a particular automobile model.

2 SIMULATIONS OF PEDESTRIAN -HEAD- TO BONNET TESTS

2.1 Pedestrian-head-to-bonnet tests

The European Commission also published a directive to assess the level of pedestrian protection for vehicle fronts in 2003. The European Parliament supported the commitment on pedestrian safety proposed by the European Automobile Manufacturers' Association, and thus pedestrian protection measures have been required on all passenger cars sold in Europe since 2005 [8]. The EEVC WG17 established a series of component tests based on the three most important areas of injury: head, upper leg, and lower leg. The EEVC WG17 developed this method for assessing the pedestrian friendliness of a vehicle. The EEVC WG17 tests consist of four models of pedestrian impactor models, namely child headform, adult headform, upper-legform and lower-legform impactors. Figure 2 illustrates the pedestrian protection concept proposed by the EEVC WG17 [9].

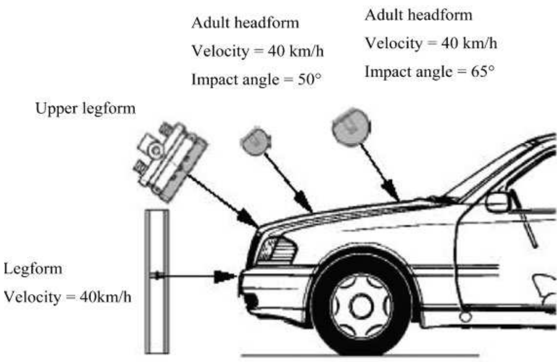

Fig. 2 Pedestrian protection concept proposed by the EEVC WG17 [9]

These EEVC WG17 regulations thus will be completed and applied to vehicle manufacturing in Europe. In India there is no such regulation for vehicle manufacturing. The adult headform impactor is used to test the points lying on boundaries described by a WAD of 1500mm and the rear of the bonnet top, or a WAD of 2100mm for a long bonnet.

In each part, a minimum of three tests is carryout at spots with high injury risk. Test points should vary according to the types of structure, which vary throughout the assessment area. The selected test points for the adult headform impactor should be a minimum of 165mm apart, a minimum of 82.5mm inside the defined bonnet side reference lines, and a minimum of 82.5mm forwards of the defined bonnet rear reference line. The impact angle for tests with the adult headform impactors must be 65^0 with respect to the ground reference level. The initial impact velocity is 40 km/h for the adult headform impactors. Distances (WADs) (Fig. 3) of 1000mm and rear reference line. Each selected test point for the child headform impactor should also be a minimum of 130mm rearwards of the bonnet leading-edge reference line.

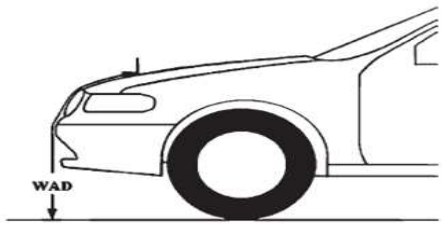

Fig. 3 Determination of WAD [9]

The impact angle for tests with the adult headform impactors must be 65^0 respectively with respect to the ground reference level. The initial impact velocity is 40 km/h for and the adult headform impactors.

2.2 Finite element model and simulation

In Finite element the model of vehicle and adult headform is crated. This study analyses the effect of the bonnet skin and bonnet reinforcement thicknesses on pedestrian head injury by performing headform impactor simulations of the EEVC WG17 regulations using different thicknesses. Figure 4(b) shows the finite element models of adult headform impactors.

The vinyl skin is modelled using viscoelastic material, and a steel core with elastic material [10]. All headform impactor parts use solid elements. The adult headform impactor model consists of 3713 nodes and 13 783 solid elements.

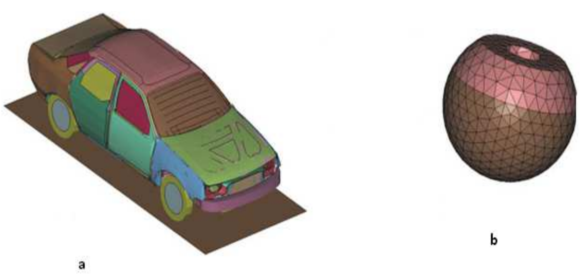

Fig.4 The FE model used in pedestrian –head –bonnet impact simulations: (a) the passenger car model [11]; (b) the headform impactor model [10]

The adult headform impactors satisfy the EEVC WG17 certification tests [10], demonstrating the feasibility of their use in simulating headform impactor tests. This study does not consider the effect of the engine compartment arrangement on the head injury criterion (HIC) value. Therefore, all parts in the engine compartment that are close to the bonnet are moved down to ensure that the bonnet does not impact any parts in the engine compartment during simulation. Figure 5 shows the selected positions on the bonnet top to assess the pedestrian friendliness. The impact positions for the adult headform impactor are located between a WAD of 1500mm and the rear reference line. The impact angles selected for the adult headform impactor simulations are 65^0 with respect to the ground reference level.

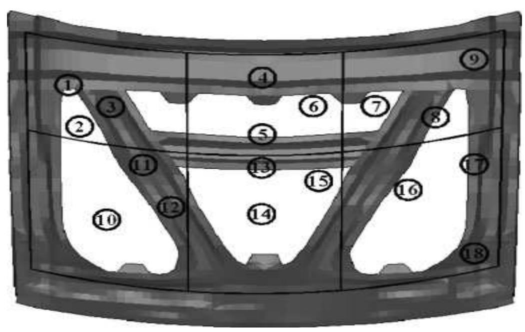

Fig. 5 Positions were selected to assess the pedestrian friendliness of the bonnet

2.3 Assessing the levels of head injury is based on the HIC value.

The HIC value is calculated on the basis of the resultant acceleration of the head's centre of gravity during impact from instant T1 to instant T2. Given that T1 is less than T2, the HIC value is defined as [9]

$$\mathrm{HIC} = \max\left(\frac{1}{T_2 - T_1}\int_{T_1}^{T_2} A \, \mathrm{d}T\right)^{2.5} (T_2 - T_1)$$

With the condition

$$\Delta T = T_2 - T_1 \leqslant 15 \text{ ms}$$

Where A is the resultant acceleration of the head's centre of gravity (in units of g), and T1 and T2 are the two time instants (in seconds). The HIC value of 1000 is the safety threshold for adults. The higher the HIC value is, the more severe the head injury will be. Euro-NCAP classified pedestrian protection into five levels based on the range of HIC values, using a colour coding system (Table 1).Table 1 lists proposed HIC tolerance levels correlated with brain injury and skull fracture [12]. Based on this tolerance, the level of 1800 represents the maximum allowable HIC value, and an HIC value less than 650 represents the best pedestrian protection, which is the level of zero injury.

Table 1 Proposed HIC tolerance levels correlated to brain injury and skull fracture [12]

HIC range	Brain injury	Skull fracture	Euro-NCAP
< 150	No concussion	No fracture	< 650, green
150–500	Mild concussion, less than 1 h	No fracture	< 650, green
500–900	Severe concussion, 1–24 h	Minor fracture	< 650, green 650–767, yellow 767–883, orange
900–1800	Severe concussion, 1–24 h	Major fracture	883–1000, brown > 1000, red
> 1800	Life threatening	Life threatening	> 1000, red

3 THE EFFECT OF THE BONNET THICKNESS ON PEDESTRIAN HEAD INJURY AND DEFLECTION

3.1 Assessment of the pedestrian friendliness of the original bonnet

Figure 6 shows the results of the HIC values for the simulations at 18 selected positions. These results show that there is no position with an HIC value less than 650, the level of zero injury. There are only three of the 18 positions with HIC values at the level of slight injury (650(HIC (1000), and six of the 18 positions with HIC values at the level of serious injury (1000(HIC (1800). Meanwhile, nine of 18 positions had HIC values greater than 1800, which is the pedestrian -life-threatening level. Some of these positions with extremely high HIC values are positions 4, 8, and 9. During the impact process, the headform impactor centre moves in two directions, i.e. tangential and normal to the bonnet surface in the initial state (i.e. the state when the bonnet has not been deformed because of a collision). Positions 4, 8, and 9 are close to the rear line or the corner of the bonnet, where the support structure is located. Therefore, the movement of the headform impactor centre in the normal direction in the initial state is strongly impeded because of the support structure. Furthermore, when the headform impactor impacts positions that are close to the rear line, the rear line is not deflected downwards but warps upwards because the bonnet surface draws it back. The simulation results confirm that the bonnet is not friendly to the pedestrian head and thus has to be redesigned for pedestrian safety. The next section presents procedures for redesigning the bonnet structure by optimizing the thicknesses of the bonnet skin and bonnet reinforcement.

3.2 The effect of the bonnet thickness on deflection

All the simulations assessing pedestrian friendliness are repeated with different bonnet skin and bonnet reinforcement thicknesses.

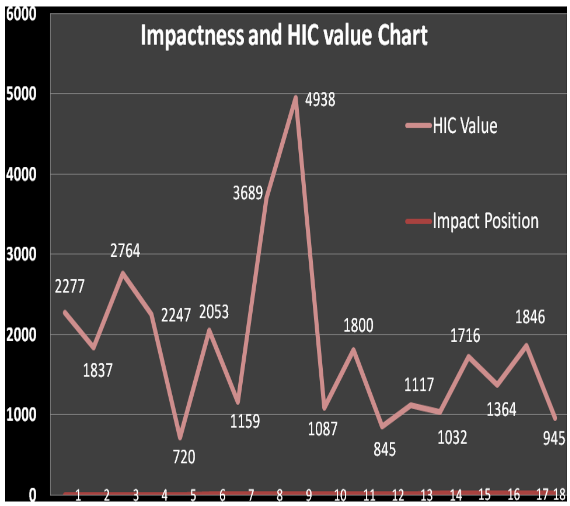

Fig. 6 Evaluation of the friendliness of the original bonnet structure with the pedestrian head

The thicknesses of the bonnet skin and bonnet reinforcement are increased and decreased in 0.15mm increments. Only one parameter is changed each time (the thickness of the bonnet skin or the thickness of the bonnet reinforcement), with the other parameter retaining its original value. After each parameter has been shifted, all the simulations of the head-to-bonnet-top test are performed again. The simulation results can determine both the IC values and the deflection of the bonnet surface corresponding to the change in the thickness. Comparison of these results with the results using the original thicknesses can determine the effect of the thickness change on the HIC values and bonnet deflection.

4 OPTIMIZING THE BONNET THICKNESS FOR PEDESTRIAN HEAD SAFETY

Previous research has shown that the space available for bonnet deformation during the collision process strongly influences pedestrian head injury [7]. Consequently, reducing pedestrian head injury resulting from collision with the bonnet requires ensuring that the bonnet surface does not contact any components in the engine compartment during the collision. Therefore, protecting pedestrian's requires allocating space in the engine compartment for the bonnet to deform freely during the collision.

However, the space available to be allocated for bonnet deformation is limited because some components in the engine compartment, such as the top of the engine or the suspension tower, are close to the bonnet surface. Moreover, these components are difficult to lower because of their dimensions and interrelationship with other components. Therefore, to prevent the bonnet from contacting components in the engine compartment during collision, some components in the engine compartment should be lowered and the deflection of the bonnet above these components should be minimized. This problem can be solved by combining LS-DYNA and LS-OPT to simulate and analyze the simulation results.

There is only one position on the bonnet surface which is analyzed to determine its friendliness towards pedestrians using this algorithm. However, a pedestrian-friendly bonnet requires that all positions on the bonnet surface ensure safety of the head of a pedestrian in the event of a collision.

5 CONCLUSIONS

This study shows that the interdependence of the HIC value, the bonnet reinforcement thickness, and the bonnet skin thickness is very complicated. This study analyses and proposes a method of identifying the most effective values for the bonnet reinforcement thickness and the bonnet skin thicknesses to protect pedestrians while maximizing the bonnet stiffness. The method presented in this study uses the regression technique to design constraints for the optimization problem. The proposed algorithm identifies numerous critical positions on the bonnet surface with respect to pedestrian safety. The algorithm used to optimize the thicknesses is solved by combining LS-DYNA and LS-OPT to simulate and analyze the simulation results. Compared with the original bonnet, the optimal bonnet is more pedestrian friendly but slightly less stiff than the original bonnet. Tests on the torsional stiffness's of the original and optimal bonnets are also performed. Although the torsional stiffness of the optimal bonnet is lower than that of the original bonnet, it still satisfies the requirement. Therefore, the bonnet reinforcement thickness and the bonnet skin thickness of the optimal bonnet can be used instead of the original values for pedestrian protection. The proposed algorithm can be used to optimize other parameters to develop better designs for a pedestrian- friendly bonnet.

REFERENCES

1. "National Center for Statistics and Analysis", Motor vehicle traffic crash fatality counts and estimates of people injured for 2012: 2012 annual assessment. Report DOT HS 811 552, National Highway Traffic Safety Administration, Washington, DC, USA, February 2012.

2. T. Ishikawa, H. Kore, A. Furumoto, and S. Kuroda, "Evaluation of pedestrian protection structures using impactors and full-scale dummy tests", 18th International Technical Conference on The enhanced safety of vehicles (ESV), Nagoya, Japan, 19–22 May 2003, paper 271, 12 pp. (National

Highway Traffic Safety Administration, Washington, DC).

3. I.Kalliske, and F.Friesen, "Improvements to pedestrian protection as exemplified on a standardized car", 17th International Technical Conference on The enhanced safety of vehicles (ESV), Amsterdam, The Netherlands, 4–7 June 2001, paper 283, 10 pp. (National Highway Traffic Safety Administration, Washington, DC).

4. F. Laimbock and Resele, "Safety and crash behavior", Da-Yeh Inst. Technol., Taiwan, AE&ICE Ser., 1993, 21, 1–74.

5. K. Fuerstenberg, "Pedestrian protection using laser scanners", 8th International IEEE Conference on Intelligent transportation systems (ITSC '05), Vienna, Austria, 16 September 2005, pp. 437–442 (IEEE, New York).

6. C. K. Simms, "Developments in crash safety: a triumph of design in bioengineering", In Perspectives on design and bioengineering: essays in honour of C. G. Lyons (Eds C. K. Simms and P. J. Prendergast), 2008, pp. 39–55 (Trinity Centre for Bioengineering, Dublin).

7. Directive 2003/102/EC of the European Parliament and of the Council of 17 November 2003 Report. Off. J. Eur. Un., 2003, L 321/15 (OJEU, Luxembourg).

8. "Improved test methods to evaluate pedestrian protection" afforded by passenger cars. Report, Working Group 17, European Enhanced Vehicle safety Committee, 2002.

9. T. L. Teng and T. H. Nguyen, "Development and validation of FE models of impactor for pedestrian testing", J. Mech. Sci. Technol., 2008, 22(9), 1660– 1667.

10. "FHWA/NHTSA National Crash Analysis Center", The George Washington University, Ashburn, Virginia, USA, Applications, Finite element model archive, 2000–2009,

11. A. R. Payne, and S. Patel, "Head injury criteria tolerance levels", Report (Project 427519), Motor Industry Research Association, Nuneaton, Warwickshire, UK, 2001.

12. Fredriksson, R., Ha˚land, Y., and Yang, J. K. Evaluation of a new pedestrian head injury protection system with a sensor

in the bumper and lifting of the bonnet's rear part. In Proceedings of the 17th International Technical Conference on The enhanced safety of vehicles (ESV), Amsterdam, The Netherlands, 4–7 June 2001, paper 131, 12 pp. (National Highway Traffic Safety Administration, Washington, DC).