Procedure To Obtain The Bonnet Thickness For Adult Pedestrian Head Safety

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Abstract

Almost two-thirds of the 1.2 million people killed annually in road traffic crashes worldwide are pedestrians. Despite the magnitude of the problem, most attempts at reducing pedestrian deaths have focused solely on education and traffic regulation. However, in recent years crash engineers have begun to use design principles that have proved successful in protecting car occupants to develop vehicle design concepts that reduce the likelihood of injuries to pedestrians in the event of a car-pedestrian crash. These involve redesigning the bumper, hood (bonnet), and the windshield and pillar to be energy absorbing (softer) without compromising the structural integrity of the car. The hood of most vehicles is usually fabricated from sheet metal, which is a compliant energy absorbing structure and thus poses a comparatively small threat. Most serious head injuries occur when there is insufficient clearance between the hood and the stiff underlying engine components. Most limb injuries occur due to a direct blow from the bumper and the leading edge of the hood. This leads to contact fractures of the femur and the tibia/fibula and damage to the knee ligaments due to bending of the joint. Thus, attempts at reducing these injuries involve reducing the peak contact forces by making the bumper softer and increasing the contact area and by limiting the amount of knee bending by modifying the geometry of the front end of the car.

The objective of project is to Optimize Bonnet to increase pedestrian safety. The main focus will be to design a bumper and bonnet front shape to reduce lower and upper leg injuries. The system will be analyzed using computational codes like LS Dyna and Optimization tools like HyperStudy.

Most pedestrian deaths occur due to the traumatic brain injury resulting from the hard impact of the head against the stiff hood or windshield. In addition, although usually non-fatal, injuries to the lower limb (usually to the knee joint and long bones) are the most common cause of disability due to pedestrian crashes.

1. Introduction

Definition of pedestrian- A pedestrian is a person travelling on foot, whether jumping, jogging, walking or running. In some communities, those travelling using tiny wheels such as roller skates, skateboards, and scooters, as well as wheelchair users are also included as pedestrians. In modern times, the term mostly refers to someone walking on a road or sidewalk.

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. This study is an attempt to show the distribution of injury patterns focused on the head injury mechanism. The head was found the most injured region. According to the National Highway Traffic Safety Administration (NHTSA), 6745 pedestrians died as a result of automotive-related accidents in the USA in 2009 [5] averaging one fatality every 113 min. Moreover, about 57 per cent of pedestrian fatalities and 75 per cent of pedestrian injuries are attributed to passenger car accidents [5]. This shows that automobile industries have to pay more attention on pedestrian safety.

Besides functioning as an engine compartment cover, the bonnet of modern vehicles can also help manage the impact energy of a pedestrian's head in a vehicle-pedestrian impact. However, a bonnet's ability to absorb impact energy may be impeded by the proximity of the bonnet to components packaged inside the engine compartment, i.e., by its underbonnet clearance. For example, for a given bonnet design, the bonnet's ability to absorb impact energy through deformation can be significantly reduced when the bonnet and engine block are in close proximity. [2]

Head and face injuries in car–pedestrian accidents account for 60 per cent of all pedestrian fatal injuries, whereas 17.3 per cent of head injuries were due to the bonnet [1]. The above values show the necessity to consider more carefully the role of the bonnet in pedestrian head safety. Redesigning the bonnet structure to improve pedestrian protection has recently received considerable attention by automobile manufacturers and industry institutes. However, there is a lack of research that considers methods of choosing the most effective thicknesses of bonnet skin and bonnet reinforcement with respect to pedestrian safety.

The aim of these tests was to compare the general pedestrian friendliness of steel and aluminium, used as hood material. The tests were conducted on a car that is still available on the market with either a steel or aluminium hood, both having the same design. Knowing that the hood design was not developed to meet pedestrian safety requirements, the results compare the application of both steel and aluminium to assess which hood material is favourable for pedestrian protection.

2. Tools Used

2.1 LS Dyna: LS-DYNA is a general-purpose finite element program capable of simulating complex real world problems. The code's origins lie in highly nonlinear, transient dynamic finite element analysis using explicit time integration. Typical uses include:

Automotive crash (deformation of chassis, airbag inflation, seatbelt tensioning)

Explosions (underwater Naval mine, shaped charges)

Manufacturing (sheet metal stamping)

2.2 Altair Hyperworks: Altair HyperWorks Enterprise provides the most comprehensive set of capabilities to manage and automate CAE and test analysis. It consists various modules for Pre Processing, Post Processing and Optimization.

HyperMesh: Pre Processor
HyperView: Post Processor
HyperGraph: Post Processor
HyperStudy: Optimization tool

2.3 LS Prepost: LS-PrePost is an advanced pre and post-processor that is delivered free with LS-DYNA. The user interface is designed to be both efficient and intuitive.

3. Mass of human head and head injury criteria

The mass of human head can be taken by comparing the research results which is shown in table 1.

Bibliographic Entry	Result (w/surrounding text)	Standardized Result
Paul, Brindza. How Many Atoms are in the Human Head? Jefferson Lab. May-June 2006.	"A pound is 454 grams so a 10 pound human head is 4,540 grams."	4.5kg
Yee, Danny. Average Human Head Weight. Danny Yee. May-June 2006.	"An adult human head cut off around vertebra C3, with no hair, weighs somewhere between 4.5 and 5kg, constituting around 8% of the whole body mass."	4.5kg-5kg
Goldstein, Jonathan P. Goldstein Helmet Study. Biker's Rights. May-June 2006.	"The weight of the human head is 8-12 pounds while the average weight of the helmet used in our sample is 2.7 pounds."	3.6kg-5.4kg
Item from Budget Request 2001 (The BBC -- Boy Band Collider). Ryerson Astronomical Society. May-June 2006.	"A human head weighs about 5kg; and there are approximately 2 × 10^26 atoms in a human head."	5kg

Jerry Maguire. Dir. Crowe Cameron. Perf. Tom Cruise [Jerry], Cuba Gooding Jr. [Rod], Renée Zellweger [Dorothy], Jonathan Lipnicki [Ray]. Sony Pictures, 1996.	"Ray: D'you knows that the human head weighs 8 pounds?"	3.6kg

Head injury criteria can be calculated by using the formula

$$HIC = \left\{ (t_2 - t_1) \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t)dt \right]^{2.5} \right\}_{max}$$

Where t1 and t2 are the initial and final times (expressed in seconds) of the interval during which the HIC attains a maximum value and a (t) is the resultant acceleration (expressed in G) measured at the head CG. [3] The time duration (t1 - t2) used in the calculation should be taken as the contact time for the impact, however, this is often very difficult to ascertain in physical evaluations using crash test dummies or head form simulators. In using HIC for assessing the potential of concussion then a maximum time duration of 15 m sec should be used, which was the maximum time duration for which the original tolerance curve was developed.
Longer contact time durations can be used to predict skull fracture. The highest acceleration, independent of location or direction, should be used in the Head Injury Criterion, which will therefore be the resultant acceleration measured at the heads centre of gravity.
The headform model as shown in Figure 1 consists of 28696 nodes, 22240 solid, 3712 shell. A typical headform impactor has three main parts: a steel base mounted with an accelerometer, a spherical aluminum core, and a PVC skin which shall cover at least half of the sphere. The skin is 12 mm thick for the child headform and 14 mm thick for the adult headform. The adult headform has a weight of 4.5 kg simulating a 50th percentile male and the child headform, simulating a 6 year old child weights 3.5 kg. The diameter is 165 mm for both headform impactors. The adult headform had earlier, according to regulations, a weight of 4.8 kg and this headform is still used sometimes. The impactors are equipped with a damped triaxial accelerometer, with seismic masses within the maximum tolerated distance from their centre of gravity. The x, y, and z component accelerations acquired by this accelerometer are used to calculate a resultant acceleration vs. time trace, which is used to calculate head injury criterion (HIC) from the impact.

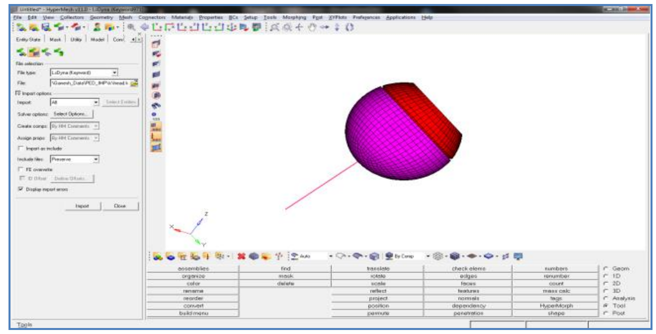

Fig.1 FEA model of Adult headform

3. 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 [4]. 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 [5].

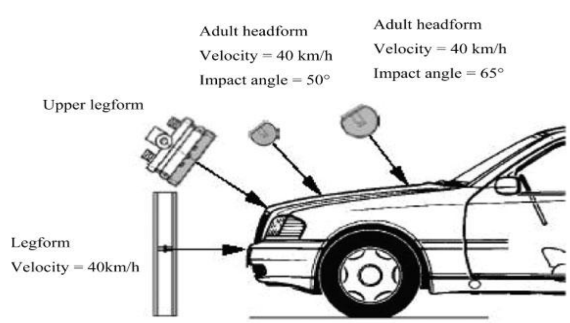

Fig.2 Pedestrian protection concept proposed by the EEVC WG17 [5]

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. Each section is divided into three parts, as illustrated in Fig.3.

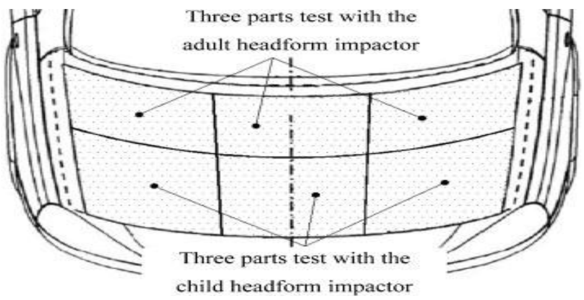

Fig. 3 Description of the impact area for pedestrian headform- impactor-to-bonnet-top tests

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 650 with respect to the ground reference level. The initial impact velocity is 40 km/h for the adult headform impactors. Distances (WADs) (Fig. 4) 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. The impact angle for tests with the adult headform impactors must be 650 respectively with respect to the ground reference level. The initial impact velocity is 40 km/h for and the adult headform impactors.

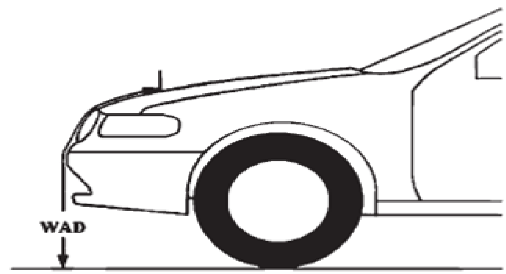

Fig. 4 Determination of WAD [5]

4. 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 6(b) shows the finite element models of adult headform impactors.

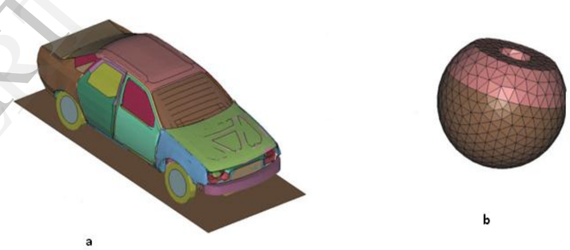

Fig. 5 The finite element model used in pedestrian-head–bonnet impact simulations: (a) the passenger car model [7]; (b) the headform impactor model [6]

The vinyl skin is modelled using viscoelastic material, and a steel core with elastic material [6]. All headform impactor parts use solid elements. The adult headform impactor model consists of 3713 nodes and 13 783 solid elements. The adult headform impactors satisfy the EEVC WG17 certification tests [6], demonstrating the feasibility of their use in simulating headform impactor tests. Bonnet-top simulations are performed using the adult headform impactors simulations of the headform-to-bonnet-top test are performed using the finite element models of the headform impactor mentioned above and a Ford Taurus car model [7], as shown in Fig. 6 (a). In the engine compartment, components that are close to the bonnet top include the oil cap and the battery. 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. The vinyl skin is modelled using viscoelastic material, and a steel core with elastic material [6]. All headform impactor parts use solid elements. The adult headform impactor model consists of 3713 nodes and 13 783 solid elements. The adult headform impactors satisfy the EEVC WG17 certification tests [6], demonstrating the feasibility of their use in simulating headform impactor tests. Bonnet-top simulations are performed using the adult headform impactors simulations of the headform-to-bonnet-top test are performed using the finite element models of the headform impactor mentioned above and a Ford Taurus car model [7], as shown in Fig. 5 (a). In the engine compartment, components that are close to the bonnet top include the oil cap and the battery. 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.

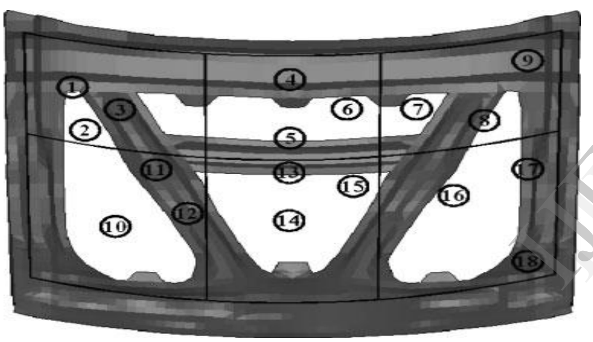

Fig. 6 shows the selected positions on the bonnet top to assess the pedestrian friendliness.

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 650 with respect to the ground reference level.

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

Table2 lists proposed HIC tolerance levels correlated with brain injury and skull fracture [3]. 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.

5. Conclusion

In this way we can simulate the bonnet to head impact test. The result obtained are the approximate the same as tested in the real test. By using simulation we can save the time cost of the test. 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 to simulate and analyse the simulation results. Compared with the original bonnet, the optimal bonnet is more pedestrian friendly but slightly less stiff than the original bonnet.

10. References

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