Head Impact Analysis Validation for Aluminium Bonnet

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Abstract

In recent years, vehicle manufacturers are making improvements to find more reliable solutions to pedestrian accidents. The manufacturers have to confirm these studies on some tests to carry out the requirements of international regulations. One of important these tests is head impact test.

In the head impact test, one of the most important factors that affect the injury or fatality is bonnet. The subject of this article; in recent years, lightweight vehicle is more important for fuel consumption and cost of vehicle. One of these studies will be examined by virtually analysing how the aluminium bonnet affected the head impact test, and whether or not the pedestrians are damaged. In addition, the analysis will be validated with the test to improve accuracy for future studies.

Keywords:

Pedestrian Safety, Head Impact, Aluminium Bonnet

1 Introduction

Pedestrian deaths occur in large part of vehicle-pedestrian accidents. According to statistics, in U.S., it is happening 70.000 accidents that including pedestrians per year and in more than 5000 of them pedestrian deaths occur [1]. Additionally, the death rate of vehicle-pedestrian accidents in Europe is 20% [2]. Bonnet is also one of important parts which may cause risk of injury in vehicle-pedestrian accidents.
At the same time, aluminium and aluminium alloys are most commonly used material instead of using steel in modern industry. They are in the form of important material since they are light, good conductive of heat and electric, have an increasable strength and resistance of corrosion [3]. Therefore, as a result of increasing competition in automotive industry day by day, it is increasing the aluminium usage rate in body parts each passing day to produce vehicles that have a better design according to weight advantage, CO2 emission and body performance. In case a vehicle have a 1400 kg weight, comprehensive aluminium usage may cause the 300 kg weight reduction and also provide the 20% decrease in total weight of the car [4].
Our purpose in this project, in the reference vehicle that we produce as TOFAŞ, to understand the loss of performance when the bonnet is re-designed with aluminium instead of steel. Due to re-designed bonnet, 3 kg weight reduction was provided. Aluminium bonnet application was investigated to use on vehicle and analysis in CAE firstly in TOFAŞ.
For the newly designed aluminium bonnet has various safety and structural virtual requirement that have to be performed. According to UN 127 regulation, head impact is one of these validations. According to regulation, Child headform is thrown onto hood with 50 degree with horizontal axes and 35 km/s velocity and HIC(Head Injury Criteria) values are examined. Head Injury criterion (HIC) is used to evaluation the severity of injury, which is calculated base on head acceleration as follows.

$$\mathrm{HIC} = \max_{t_1 < t_2,\ t_2 - t_1 \leq 15\mathrm{ms}} \left\{ \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} a(t)\,dt \right]^{2.5} (t_2 - t_1) \right\}$$

2 Pedestrian Head Impact Test Protocol

There are some requirements published by EEVC for the pedestrian safety system. Experimental set up prepared according to Regulation No. 127 which is published in 2014 [5]. This procedure is applied on the pedestrian safety test.
During the testing phase, the first boundary condition where the head impact calculation is to be determined the head impact area. The head impact area measures the head of the front bumper/vehicle as specified in the relevant norms. The performance of all points within this defined area during the development phase should be known. But making this account at all points is not possible in project constraints. After the map's area is created, it is separated 50mm grids through horizontal and vertical lines equally. In this way head impact points are assigned. But, for the physical test it is not possible to impact whole area, so, it is only necessary to make this test with the critical point.
According to the regulation, the head impact area is divided into two areas, being the child and the adult zone. Their determination is performed by some standard measures
This procedure will be followed using suitable tapes of suitable lengths, describe wrapping distances of 1,000 mm (WAD1000), 1,700 mm (WAD1700) and 2,100 mm (WAD2100) (Figure 1). For the child headform the WAD is taken as 1000 - 1700 mm and for the adult headform the WAD is taken as 1700 - 2100 mm according to regulation [6].

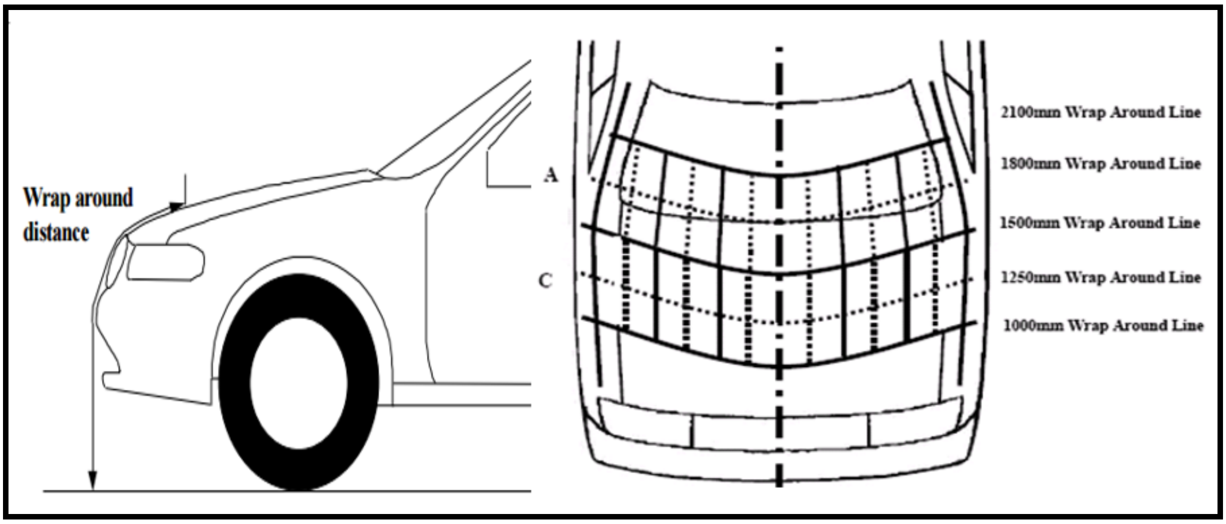


Fig 1 (a) Determination of WAD (b) Pedestrian impact area for headforms

Measuring point for test means a point on the vehicle's outer surface selected for assessment. The measuring point is where the headforms's profile contacts the vehicle outer surface cross section in a vertical longitudinal plane through the centre of gravity of the headform (see Figure 2)
For the headforms, two type head form are used . One of them is a child head with a mass of 3.5 kg and the other is an adult head form with a mass of 4.5 kg. The child head form strikes to the front of the bonnet with 35 km/h by 50^{o} pozitioned in reference to horizontal longitudinal plane while the adult head form strikes to the rear of the bonnet and beyond with 35 km/h by 65^{o} positioned in reference to horizontal longitudinal plane.

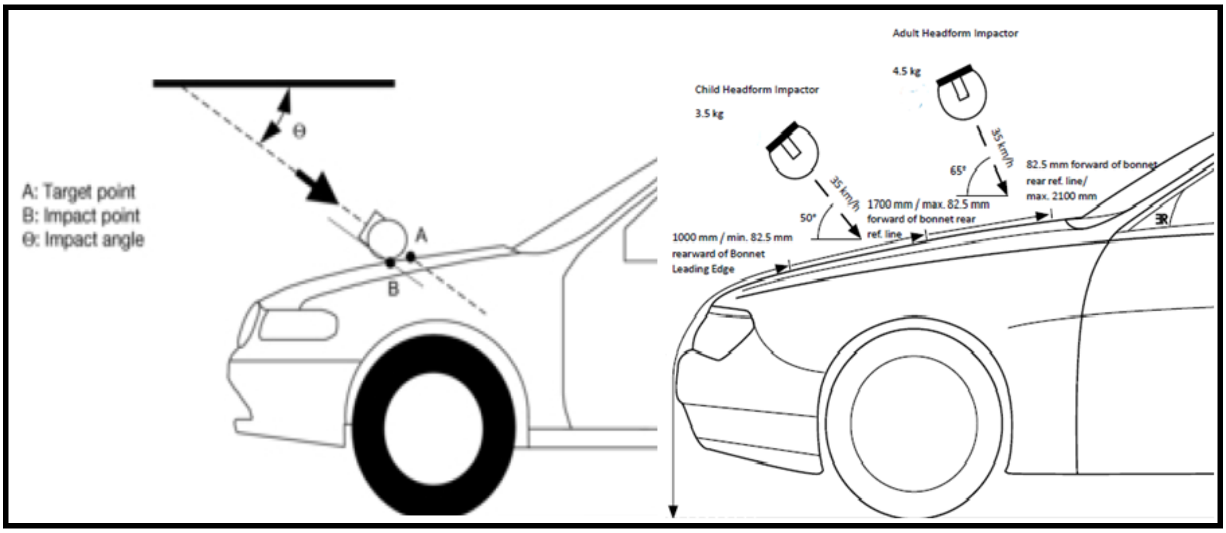


Fig 2 (a) Measuring point end of the test (b) Pedestrian impact concept for EC directive

3 Finite Element Model And Simulation

In Finite element the model of vehicle is created and child headform impactor is used. This study examines the effect of the bonnet skin which is produced Aluminium, on pedestrian head injury by performing headform impactor simulations of the UN 127 regulation [5]. Thus it is related with only child head zone.
Due to the cpu cost , the reduced car model is created when the vehicle is standing on the ground floor shown in Figure 3. All degrees of freedoms are fixed at the cutting plane of the vehicle.

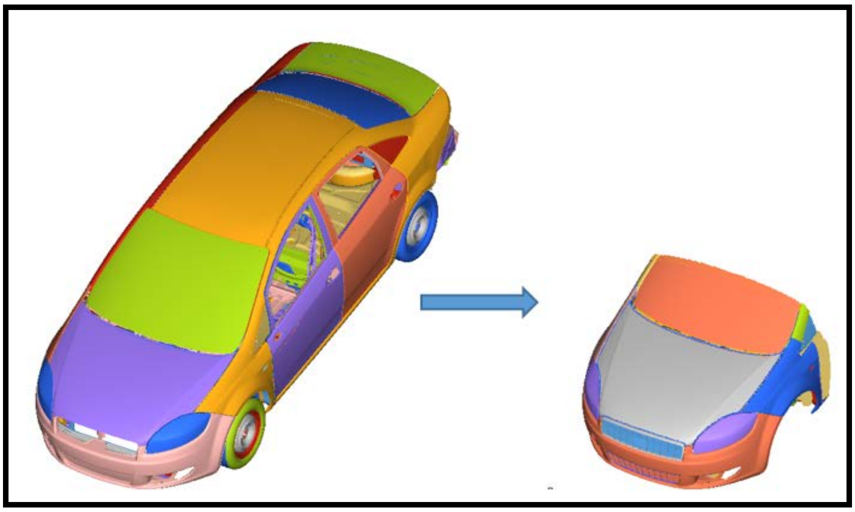


Fig 3 Finite Element original model and reduced model (representative model)

Bonnet simulations are performed using only child headform impactors simulations. Test are performed using the finite element models of the headform impactor mentioned above. Impact area created as following WAD point rule for the child head zone are shown in Figure 4. It is considered to effect of the engine compartment and other vehicle components that are close to the bonnet. Thus it is investigated behaviour of the whole vehicle.

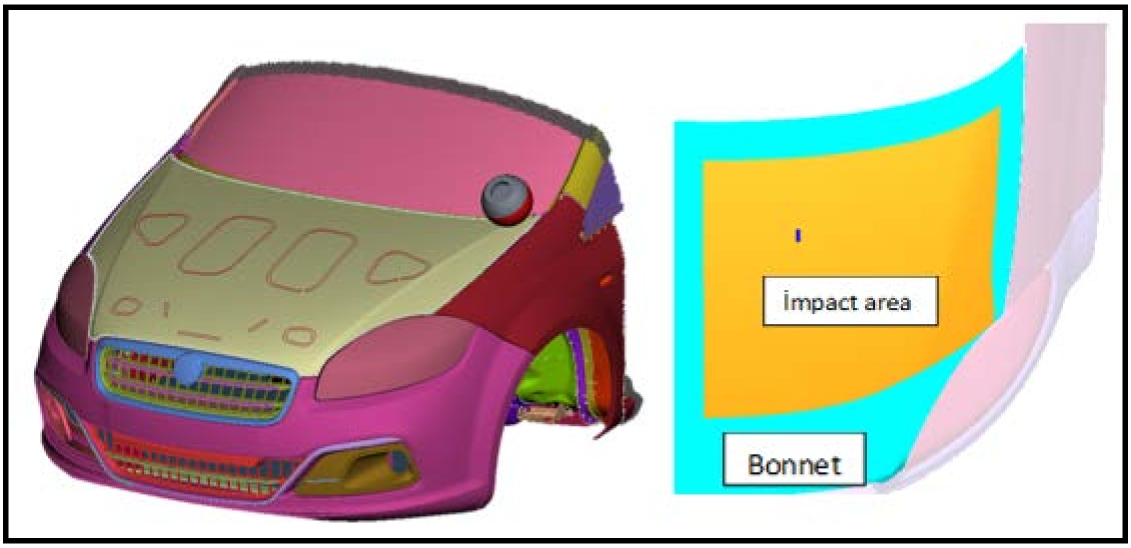


Fig 4 Impact area for child headform (representative model)

In this FE model is solved in LS DYNA and FE model has different type of material but especially *MAT_PIECEWISE_LINEAR_PLASTICITY material card is used [7].
*CONTACT_AUTOMATIC_SURFACE_TO_SURFACE is used to contact between the headform skin and bonnet surface .*CONTACT_AUTOMATIC_SINGLE_SURFACE is used in BIW interior contact except headform. In addition that *TIED_SHELL_EDGE_TO_SURFACE contact is used between spotweld and adhesive connection [7]. As well as adhesive connection effect the test response , so FE model of adhesives are critical which are modeled solid element.
Figure 5 shows the bonnet exploded view. The study's bonnet contain four component. As you see following picture hood outer panel , hood hinge reinforcement braket and hood inner panel are different type of aluminum material and striker braket is metal sheet material.

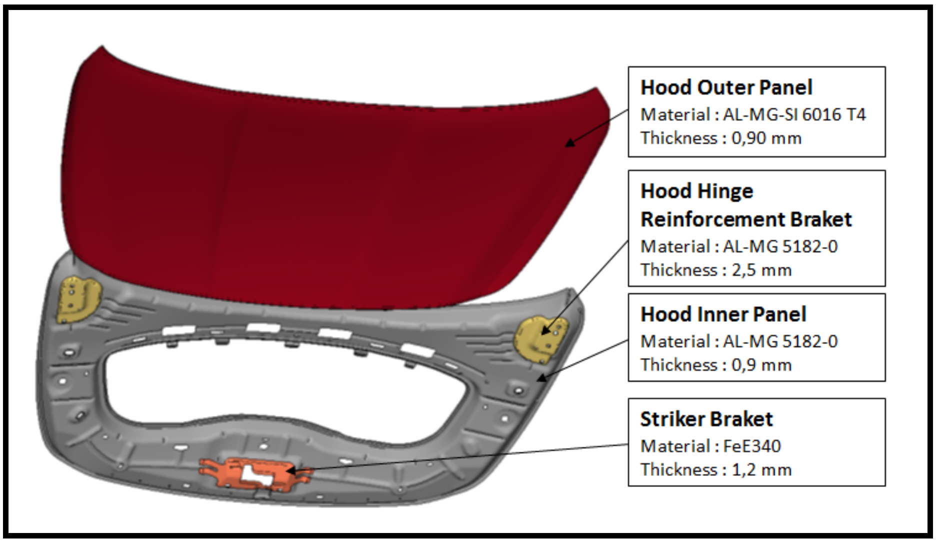


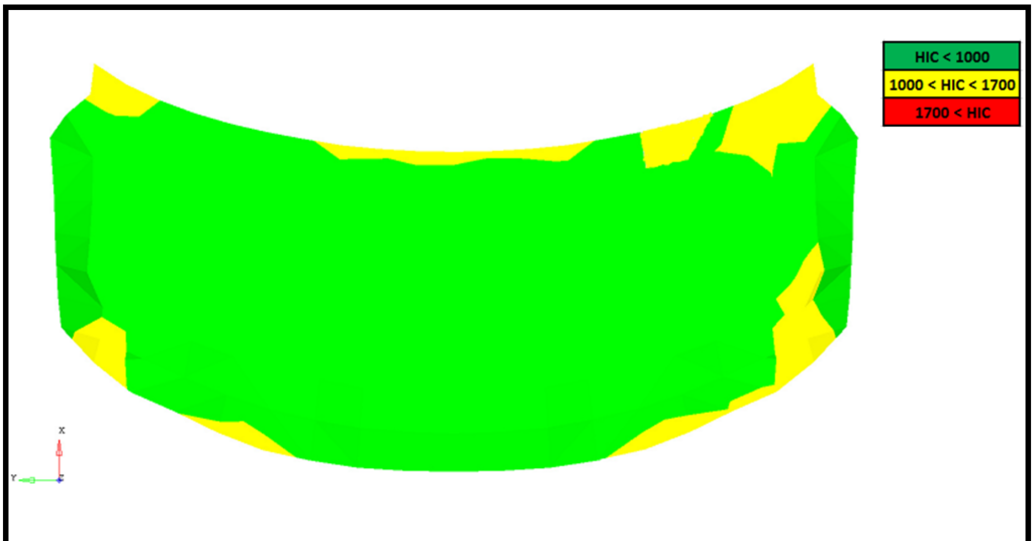
Fig 5 Bonnet exploded view

Aboves bonnet is the first loop of the study, so if ıt is observed any negative situation, the design, materials or thickness might be changed with regard to our companies strategy.

4 Simulation and Test Results

4.1 Simulation Results

The following results were examined by considering child headform impact area. Regarding to test targets, The HPC (head performance criterion) shall not exceed 1000 over one half of the child headform test area and , in addition, shall not exceed 1000 over 2/3 of the combined child and adult headform test areas. The HPC for the remaining areas shall exceed 1700 for both headforms [8].
As a result of analysis, you can see the HIC distribution as shown below. (figure 6) Green regions are the areas that HIC value is under 1000 and they are 86.4% of total area (all of child headform test area). Also, there isn't any region that HIC value is upper than 1700.



mm^2	HIC < 1000	1000 < HIC < 1700	Total
CZ	747737.341	117699.397	865436.738

mm^2	HIC < 1000 [%]	Lowest Limit [%]
CZ	86.4	66.6

Fig 6 HIC distribution on impact area

4.2 Comparison of Simulation and Test Results

Physical test was performed for some points that we have seen high HIC values in simulation. The results of red marked points in Figure 7 have been examined. The simulation and test results of the normalized acceleration pulse of the child headform are shown in figure 8,9,10 and 11 compared with physical test results. For all positions, the validation of the acceleration pulse as well as HIC between the simulation and test are good. When it is observed the differences between HIC values for test and simulation; the differences were seen that 6% for point 5, 9% for point 18, 16% for point 159, 1% for point 175. Additionally, physical tests will be performed for more critical points during the later stages of the project.

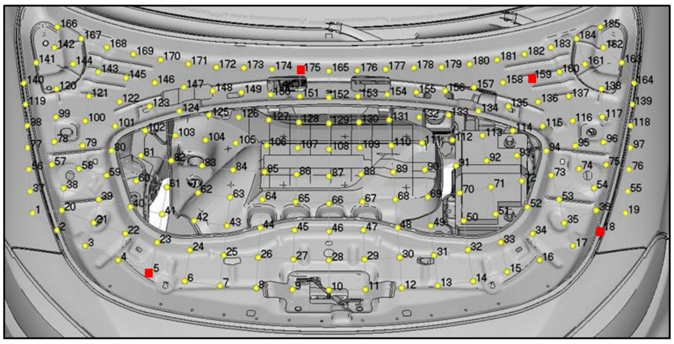
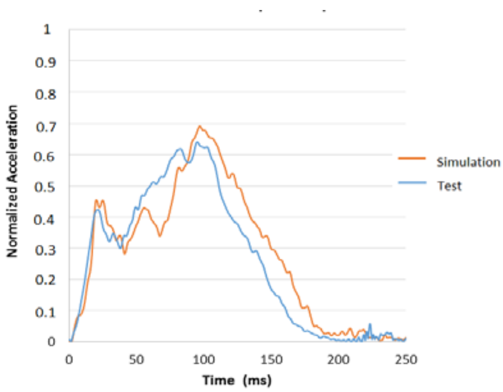
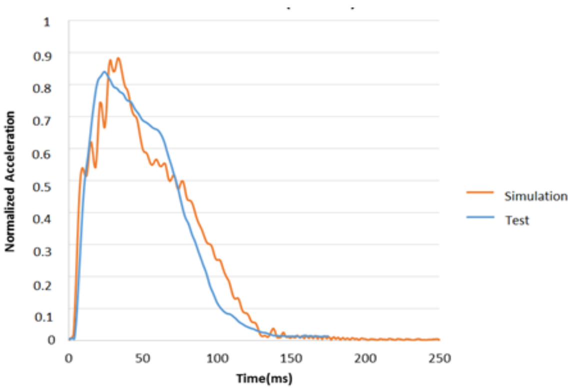


Fig 7 test impact points are shown red points



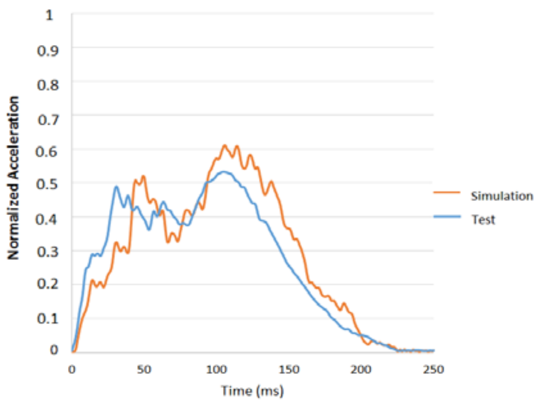
Point	HIC Test	HIC Simulation
Point 5	1016	1086

Fig 8 Acceleration validation between simulation and test result at point 5



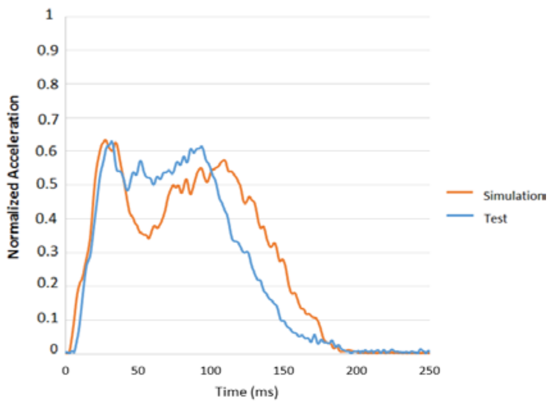
Point	HIC Test	HIC Simulation
Point 18	1475	1331

Fig 9 Acceleration validation between simulation and test result at point 18



Point	HIC Test	HIC Simulation
Point 159	869	1011

Fig 10 Acceleration validation between simulation and test result at point 159



Point	HIC Test	HIC Simulation
Point 175	1137	1140

Fig 11 Acceleration validation between simulation and test result at point 175

5 Summary

In this study, when aluminium is used in the bonnet, the behaviour of the head impact test was performed and the tests are verified by FE analysis results. It was observed that the result can be acceptable but ıt needs to be developed for optimum design. Although the study is a research project and the bonnet is not producing for vehicle production, the simulation results show a good validation with UN 127 regulation test results in terms of acceleration curves and HIC value. Therefore, this methodology can be an effective method for head impact evaluation and development of future study. By using simulation we can save the time cost of the test. From now on in a possible aluminium project, the reliability of the model will be known which is in safe margin but ıt needs to be improved. So that the work will continue

6 Acknowledgments

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7 Literature

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