

Assessment of a Car Hood of Aluminum Foams

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Abstract—In vehicle-pedestrian impacts, the severity of pedestrian injuries are affected by car hood. The structure and material of the hood is believed that strongly effect on pedestrian head injury. Therefore, the improvement design of hood structures has a great help for reducing pedestrian head injuries. In order to reduce injuries of pedestrians in case of accident, the aluminum foam as a hood material is proposed in this study. This study constructs the finite element model of headform impactors and pedestrian friendliness of a vehicle hood using LS-DYNA software based on the EEVC WG17 regulation. Aluminum foam is applied on the hood structure for minimizing pedestrian head injury. To confirm the feasibility of aluminum foam as a hood material, the resultant acceleration of head center of gravity and HIC value are measured, and the results of new hood material are compared with the original material.

Keywords—pedestrian; car hood; style; aluminum foam; headform impactors

I. INTRODUCTION

In contrast to emphasis on passenger safety, considerations for pedestrian safety have been insufficient. In recent years, although incidence levels of passenger casualties in automobile accidents have been substantially reduced, pedestrian casualty incidence levels have not improved. Hence, researchers have started to collect information related to car accidents with pedestrians and with regard to pedestrian safety. For example, the United States National Highway Traffic Safety Administration, Japan Automobile Research Institute, and European Enhanced Vehicle-Safety Committee (EEVC) have conducted statistical research on pedestrian collisions in automobile accidents and have composed related death analysis reports. These organizations have investigated means of pedestrian safety protection and formulated relevant laws and regulations.

Study findings revealed that the probability of pedestrians receiving an AIS2+ on the Abbreviated Injury Scale for head or neck injuries resulting from car collisions was 28%, and the probability of head injuries resulting in death was 62% [1]. One cause of pedestrian head injury is collision of the pedestrian's head with the hood of the car. The structure and the material of a car hood is a major factor in the degree of head injury resulting from hood collision; therefore, research on car hood structural and material design may lead to innovations that will reduce incidence and severity of pedestrian head injury in car accidents.

Automobile manufacturers have begun to emphasize pedestrian safety features as they put new cars on the market. In

particular, European and Japanese automobile manufacturers and policymakers have developed several safety protection systems and introduced regulations to protect pedestrians. These endeavors include pedestrian-protection airbags and hood lift systems, as well as the EEVC Working Group (WG) 17 impactor test standards established by the European Union. Clementw *et al.* (1998) [2] utilized a sandwich-structure material for a car hood and body to analyze the structure's effect on weight reduction. They also conducted stiffness analysis of the car hood. Ge *et al.* (2007) [3] used the software LS-DYNA to analyze the dynamic responses of pedestrian head collisions with aluminum car hoods and discovered that an aluminum hood caused relatively less severe injuries to pedestrians' heads in instances of collision. Marjoux *et al.* (2007) [4] employed the Head Injury Criterion (HIC) and Head Impact Power criterion to develop an evaluation standard for human head injuries; specifically, they proposed a standard for using finite element analysis to explore head injury mechanisms. Sunan *et al.* (2009) [5] evaluated and optimized a reversible hood for preventing head injury among adult pedestrians in vehicle-pedestrian collisions. Van-Luc Ngo (2010) [6] optimized the thickness of the inner and outer panels of a hood structure. Tai (2011) [7] designed the front outlook of a car according to pedestrian safety considerations with the goal of reducing pedestrian casualties in traffic collisions.

In this study, an aluminum foam composite material was proposed for use in automobile hoods to reduce odds of severe pedestrian head injuries in incidences of pedestrian and car hood collision. The headform impact testing method established in the EEVC WG 17 was utilized to evaluate theoretical pedestrian head injuries and the feasibility of using the proposed material. To reduce the costs and complications of physical collision experiments, this study utilized the finite element analysis software LS-DYNA and the EEVC WG 17 regulations to formulate a numerical model for impact simulation and analysis. The composite material proposed in this study may serve as a reference for designing new hood models specific to the pedestrian environment in Taiwan. In addition, the tools of analysis used in this study may be employed in engineering studies of automobile structure modifications and in the development of automobile safety features.

II. ANALYSIS MODEL FOR IMPACT TESTING WITH HEADFORM IMPACTORS

A. Finite Element Model with Headform Impactors

In this study, the finite element model with headform impactors was established according to the EEVC regulations. Geometric models of adult and child headform impactors were constructed in PRO/E. The meshes of the headform impactor models were divided into tetrahedral elements. The finite element model for the adult headform impactor comprised 2662 nodes and 9852 solid elements, and the model for the child headform impactor comprised 970 nodes and 3101 solid elements (Figure I). Each model was composed of a spherical core and a layer of skin-like material, which were both formed from elastic material. The headform impactor models adopted in this study were verified [6] to ensure that they met EEVC WG 17 regulations.

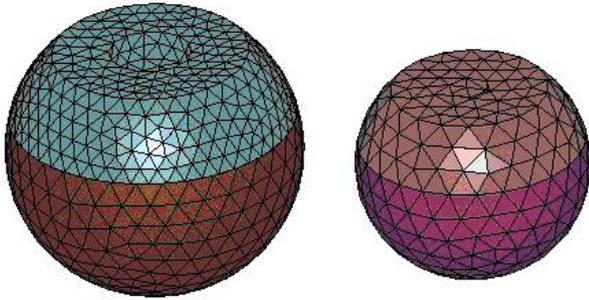


FIGURE I. FINITE ELEMENT MODELS OF HEADFORM IMPACTORS

B. Automobile Finite Element Models

The automobile model utilized in this study was the 2010 Honda Accord. The finite element model of the entire automobile comprised 226 parts, with 130 835 nodes, 100 189 shell elements, 24 342 solid elements, and 59 beam elements, and the whole model weighted 1324.94 kg. The hood of the automobile model comprised two parts: the inner panel (658 shell elements; 14.53 kg) and the outer panel (493 shell elements; 6.93 kg).

C. Test Models for Headform Impactors

The headform impact tests conducted in this study complied with the EEVC WG 17 standards. The impact angles for the adult and child headform impactors were set to $65^\circ \pm 2^\circ$ and $50^\circ \pm 2^\circ$, respectively. The impactors collided with the hood of the whole-vehicle model at a speed of 11.1 ± 0.2 m/s, as illustrated in Figure II and Figure III. According to the regulations on headform impact tests with car hoods, at least nine test points should be identified on the car hood for both the adult and child headform impactor tests, and the test points should pertain to positions on the hood where head collision could result in major injuries. The hood test points selected for use in this study are shown in Figure IV.

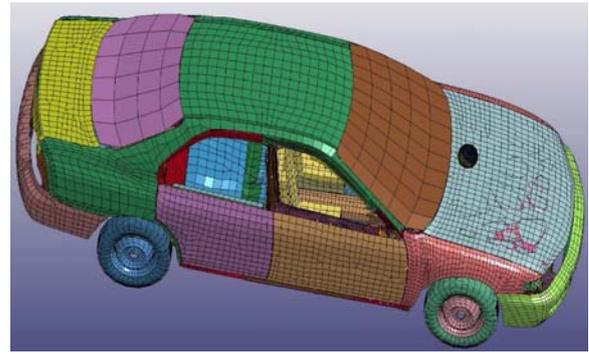


FIGURE II. FINITE ELEMENT MODEL FOR THE IMPACT TEST WITH ADULT HEADFORM IMPACTOR

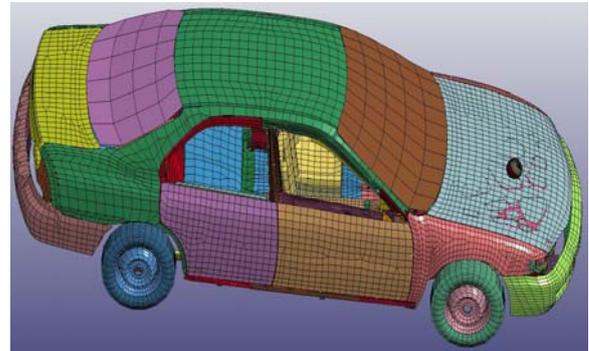


FIGURE III. FINITE ELEMENT MODEL FOR THE IMPACT TEST WITH CHILD HEADFORM IMPACTOR

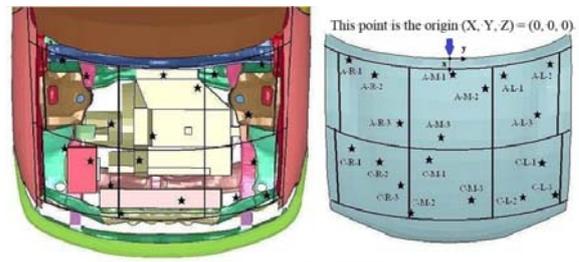


FIGURE IV. TEST POINT SELECTIONS

III. HEAD INJURY SIMULATION ANALYSIS RESULTS

This section presents simulation analysis results for adult and child headform impact against corresponding test points. All HIC scores are displayed in Tables I and II. For adult headform impactors, the HIC scores were 1041 at the A-R-1 point and 1623 at the A-L-2 point. These points are both located at hood hinges, and both HIC scores exceeded the specified maximum of 1000. Therefore, hood hinges were found to pose severe head injury risk. The HIC scores in other regions were more homogeneous and were all under 800, possibly because these regions did not collide with other components inside the hood during impact. The data also revealed that compared with the adult headform impactor results, the HIC scores for child headform impact points were more homogeneous and ranged between 600 and 900, with none exceeding 1000. The smaller mass of the childform impactor and the smaller impact angle may explain the relatively homogeneous HIC scores. Further

investigation into protection for pedestrian children should not be neglected on the basis of these relatively homogenous HIC scores of less than 1000.

IV. IMPLEMENTING ALUMINUM FOAM FOR AUTOMOBILE HOOD

A. Impact Test Model With an Aluminum Foam Hood

The aluminum foam hood used in this study was 10 mm thick and weighed 2.67 kg. The density of the aluminum foam was 0.23 g/cm³, and the Young's modulus was 1.1 GPa. Additional parameters (such as the finite element models of the vehicle, adult headform impactor, and child headform impactor; the boundary conditions; and the selected testing points) were all as presented in Section 2.

B. Simulation Results From the Aluminum Foam Impact Test

The HIC scores of the adult headform impactor against the aluminum foam hood at various test points are listed in Table I. The HIC scores of impact points A-R-1 and A-L-2 were 895 and 653.7, respectively, and both of these scores met the threshold score of 1000 in the regulations. The HIC scores of other test points were between 470 and 660. Results from the pedestrian headform impact test reflected that the aluminum foam hood more effectively absorbed impact than did the hood made of the material used by the original manufacturer. The HIC scores of the child headform impactor against the aluminum foam hood are listed in Table II. The data demonstrated that the aluminum foam hood was also superior to the original hood in impact absorption.

TABLE I. SCORES OF EACH TEST POINT FOR THE ADULT HEADFORM IMPACTOR

Test Point		A-R-1	A-R-2	A-R-3	A-M-1	A-M-2	A-M-3	A-L-1	A-L-2	A-L-3
HIC Scores	Original Material	1041	640.6	635.3	563.4	497.6	762.7	660	1623	783
	Aluminum foam	895	604.9	554.7	475.7	551.3	636.3	564.3	653.7	651.3

TABLE II. SCORES OF EACH TEST POINT FOR THE CHILD HEADFORM IMPACTOR

Test Point		A-R-1	A-R-2	A-R-3	A-M-1	A-M-2	A-M-3	A-L-1	A-L-2	A-L-3
HIC Scores	Original Material	797.3	816	806.7	732.8	784.3	892.2	666.1	753.6	665.1
	Aluminum foam	706.2	605.6	716	354.9	799.4	555.6	631.2	303.9	562.7

V. CONCLUSION

Results from collision simulation of headform impactors with the proposed aluminum foam hood revealed that the impact score at each test point met EEVC WG17 regulations. In addition, the aluminum foam hood weighed 61.4% less than that of the original hood. The hood material used by the original manufacturers was not entirely conducive to pedestrian safety; although the original hood passed EEVC WG 17 regulations in child headform impact tests, the HIC scores of two test points in the adult headform impact test exceeded the threshold score of 1000 specified in the regulations. Overall, the values on the center of gravity head acceleration curve and the HIC scores for each test point on the aluminum foam hood were smaller than those of the original hood. In addition, both the adult and child headform impact test results of the aluminum foam hood met the EEVC WG 17 standards, and the hood weight was lighter than that of the original hood. On the basis of these findings, aluminum foam was determined to be feasible for use in automobile hoods.

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