Performance Analysis on H-Shaped Airbag for Pedestrian Protection

Lihai Ren[1], Jikuang Yang[1,2]
[1]*State Key Laboratory of Advanced Design and Manufacture for Vehicle Body, Hunan University, China*
[2]*Chalmers University of Technology, Sweden*
Email: rlhai@sina.com

Abstract: Pedestrians are the most vulnerable road users, and frequently involved in vehicle traffic accidences. In the current paper, an H-shaped airbag was developed to improve the performance of a car in EuroNCAP headform impact tests. A parameter study was conducted to analyze the performance of the airbag. The results showed that the evaluated airbag had a good performance in the headform impact visual tests. The HIC values of the headform were reduced with factor between 3 and 9.

Keywords: pedestrian safety; airbag; head injury; FE model

1. Introduction

Accident statistics showed that 25,000 pedestrians were killed in the traffic accidents each year in China [1]. In the European Union, 15% of all road fatalities were pedestrians; and 35% in Japan[2]. Regulations for pedestrian protection have been implement world wide, and also the test procedure has adopted by assessments like NCAP.

To fulfill the requirements of the regulations and assessment, countermeasures have been adopted by car manufactures. Such as, multi-cone hood inner, deformable hood hinge and pop-up hood[3,4]. This last system is one of the countermeasures for pedestrian head protection, which can lift up the hood to make a distance lager between the hood and the nearby stiff parts when a pedestrian is struck by the car. However, the pop-up hood system can't avoid the head contact with A-pillars and other stiff parts at the rear end of car front.

The airbag system had been introduced to combine with the pop-hood system for pedestrian protection. Maki et al. [5] developed A-pillar airbag system combined with pop-up hood system to provide the collisions between pedestrian head and A-pillars. Also, U-shaped pedestrian airbag had been developed by car manufactures and institutes[6]. That is proved that the airbag will increase the level of pedestrian protection but it is not clear what is the potential of this structure to reduce the risk of certain injuries for example to the head. And both the deployed A-pillar airbag and U-shaped airbag can't cover the wings where has a high stiffness.

In the current paper, an H-shaped airbag system was introduced to improve the pedestrian protection performance of a car in the EuroNCAP headform impact tests. A parameter study was conducted to evaluate the head protection performance of the airbag.

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2. Material and method

In the current study, a large sedan car was chosen for the design of the H-shaped airbag system. In evaluation of the influence of H-shaped airbag characteristic on pedestrian protection the FE models of headform were used. Also, an orthogonal experimental design was applied to conduct the parameters analysis of the pedestrian protection performance of the H-shaped airbag system.

2.1. GTR Headform FE Models

The FE models of the adult and child headform were used that were based on GTR regulations. The weight of adult headform model weight 4.5 kg, including 13,143 nodes and 11,682 elements. And the weight of child/small adult headform model was 3.5 kg, including 10,705 nodes and 8,930 elements. Both the adult and child headforms consisted of four parts—back plate, sphere, skin and null shell. The injuries parameter of HIC value was calculated from the linear accelerations. The validity of the adult had been verified previously by the simulation of the GTR drop test performed by Xu et al [7].

In the current study, the drop test model was conducted to verify the validity of the child/small adult headform as shown in Figure 1, that the maximum resultant linear acceleration of the headform was between 245g and 300g (Figure 2) that is requirement of regulation, so the model could be approved for further investigation

2.2. Car Front FE Model

In the study, a model of large sedan car was chosen for the design of the airbag system. The FE model of the car had detailed structures of car front, and had more than 1 million nodes and elements. The simulations according to EuroNCAP headform impact tests were performed. As shown in Figure 3, the car front has a high stiffness in the boundary of hood and a low stiffness in mid section. In the current study, a simplified FE model of the car front was used, which had hood, wings, scuttle, windscreen and A-pillars.

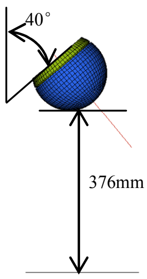


Figure 1. Drop test model of child/small adult headform

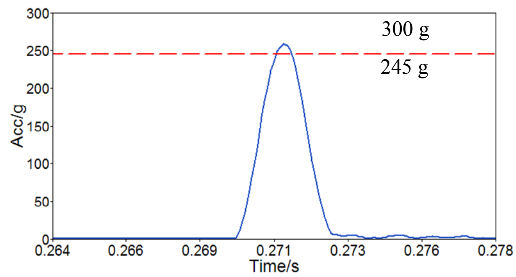
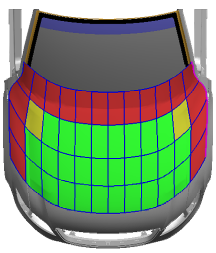


Figure 2. Resultant linear acceleration of child/small adult headform



Red-area that don't fulfill the requirements

Green-area that fulfill the requirements

Figure 3. Distribution of car front stiffness evaluated by EuroNCAP headform impact test

2.3. Description of the H-Shaped Airbag System

To improve the pedestrian protection performance of the red areas form Figure 3, several countermeasures had been conducted as modify the shapes and materials of relative structures. However, there wasn't a clearly change. The H-shaped airbag as shown in Figure 4 was developed to improve the pedestrian protection performance of the car, especially of the red areas form Figure 3. The airbag module was installed in the scuttle, and the airbag deployed when the hood started to pop up. The deployed airbag could cover the A-pillars, windshield frame, scuttle and parts of the area of the wings to protect the pedestrian head from the collisions with these stiff structures. The properties of the airbag material and the basic mass flow rate of the inflator were presented in Appendix, which were the same set values as used by Su[8].

2.4. Parameters Study of the Pedestrian Airbag

To evaluate the pedestrian protection performance of the airbag system, the simulations of the impact with headform models were conducted at the same conditions as described by the EuroNCAP headform test procedure. Three test areas: A-pillar (A), mid of scuttle (B) and wing (C), were chosen as shown in Figure 5. The adult headform was used to impact the A and B areas; meanwhile the child/small adult headform was used to impact the C area, which was located in the child/small adult head test zones (Figure 6). For adult headform, the initial impact speed was 40 km/h and the impact angle was 65 degrees from the horizontal plane; for child/small adult headform, they were 40 km/h and 50 degrees[9]. The HIC values and the total score of the three test areas were calculated. The HIC level and the way of calculation of score values were based on EuroNCAP as shown in Table 1. In the evaluation o the airbag system we used the total score that is the sum of scores obtained in points A, B and C. The higher value of total score the better protection is.

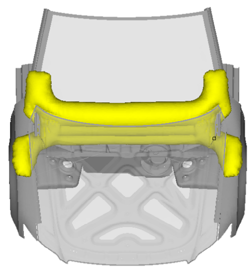


Figure 4. Deployed H-shaped airbag

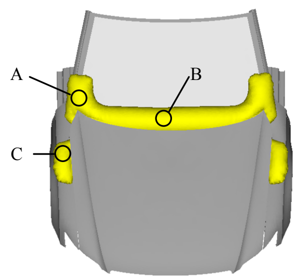


Figure 5. Selection of headform impact areas

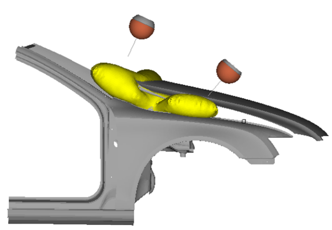


Figure 6. Headform impact test model

A parameter study of the airbag system was conducted to improve the car's pedestrian safety performance. For the pedestrian airbag, scale factor of Mass Flow rates (MF), Vent Hole size (VH) and Deployment Time (DT) have obvious influences of the pedestrian head protection performance[10], therefore we included these factors in the investigation. As shown in Table 2, the MF were chosen to be 0.5, 0.75 and 1.0; the VH were chosen 300 mm^2, 500 mm^2 and 700 mm^2; the DT were chosen 0 ms, 13.5 ms and 27 ms. An orthogonal experimental design was applied to conduct the parameters analysis.

Table 1. HIC level and calculation of score

HIC15	Score
<1000	0.5
1000~1350	$\frac{1350-HIC}{1350-1000}*0.5$
>1350	0

Table 2. Orthogonal experimental design

Test NO.	Factors		
	MF	VH/mm^2	DT/ms
1	0.5	300	27
2	0.5	500	13.5
3	0.5	700	0
4	0.75	300	13.5
5	0.75	500	0
6	0.75	700	27
7	1	300	0
8	1	500	27
9	1	700	13.5

3. Results

The results of the mathematical simulations of headform impact test are presented in Table 3.

Table 3. Results of simulations of headform test

Test No.	HIC15			Total score
	A	B	C	
1	833	944	1706	1.00
2	617	797	544	1.50
3	572	705	519	1.50
4	941	1192	757	1.23
5	876	1070	767	1.40
6	884	1208	685	1.20
7	1165	875	1083	1.15
8	1345	1524	1100	0.36
9	1254	1076	994	1.03

The influence of the parameters on the total score of headform impact test is shown in Figure 7. The influence of VH was lower than that of MF and DT. The best performance of the airbag was found when the combination of investigated variables was: MF=0.5, VH=700 mm^2, DT=0 ms.

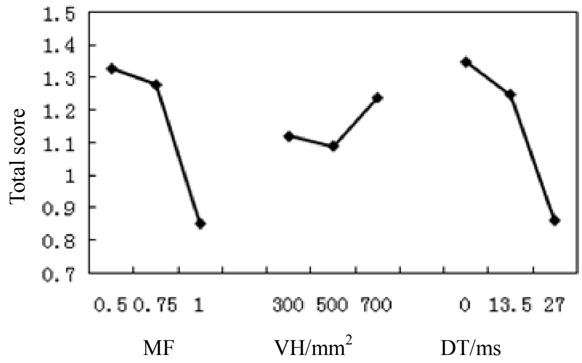


Figure 7. Trend lines of total score from headform impact simulations

The HIC values of the headform for both with/without airbag from the simulations of headform impact test are listed in Table 4

Table 4. HIC value of the headform

	HIC15(A)	HIC15(B)	HIC15(C)
Without airbag	4630	2310	3400
With airbag	572	705	519

4. Discussions

The current paper is a preliminary study for the development of the pedestrian airbag system. The simulations according to EuroNCAP headform impact test procedure were conducted to evaluate the pedestrian protection performance of the car and airbag. The results showed that the H-shaped airbag had a good performance in our simulations. Strong reduction of HIC values with factor between 3 and 9 could be achieved in simulations using the H-shaped airbag.

The HIC values fluctuate strongly as the design parameters of airbag are changed, with the maximum of 1706 and the minimum of 519. And also, the HIC values higher than 1000 are exit in several tests. So, characteristic analysis of the pedestrian airbag system is necessary to make sure that the airbag will has a better protection of the pedestrian head in real accident.

Analysis of trend lines of total score from headform impact simulations shows that when the airbag pressure is high it would result in a large rebound force to headform and consequently lead to a large HIC value and also low level of total score. When the airbag deployment is late it would result in on insufficient deformation space and direct contact of the head model with rigid structure of the car.

In the current paper, the simulations of EuroNCAP headform impact test were conducted. Therefore, the collisions between the overall pedestrian body and the car were not modeled. In the future study, a full scale pedestrian dummy model will be used to evaluate the pedestrian performance of the H-shaped airbag system.

5. Conclusions

An H-shaped airbag was designed for pedestrian protection and a parameters study was conducted to evaluate the potential of this structure to reduce injury related parameters, as HIC. The simulations showed that airbag can have a good performance in the EuroNCAP headform impact tests.

The results of the headform test simulations can provide background knowledge for the further study of the airbag pedestrian protection performance in real accidents.

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Appendix

Table A1. Parameters of the airbag material

Maximum load [N]	Axial strain rate [%]	Y’ modulus [MPa]	Horizontal strain rate [%]	Poisson’s ratio	Density [kg/m^3]	Thickness [mm]
3332	53	721	-10.8	0.2034	732.276	0.300

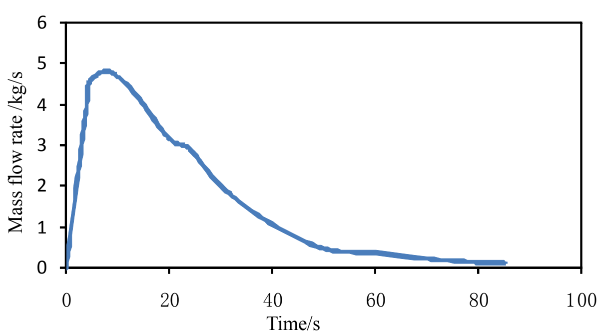

Figure A1. The basis mass flow rate of the inflator