THE STUDY ON DEVELOPING ACTIVE HOOD LIFT SYSTEM FOR DECREASING PEDESTRIAN HEAD INJURY

Keun Bae Lee
Han Jo Jung
Han Il Bae
HYUNDAI - KIA Motors
Korea
Paper Number 07-0198

ABSTRACT

Active hood lift system has been developed to get more spaces for decreasing the head injury during pedestrian impact. This system is composed of detecting sensor, ECU where the algorithm is embedded and the pyro-type actuators which raise the hood. By this system, the rear part of the hood is raised up to approximately 120mm.

The test results of system operation are introduced for each three typical impact cases. In this test the system could detect the lower legform impactor from the other rigid pole and only in case of lower legform the actuator is deployed within the required operating time, 30ms.

To investigate the effects of this system on decreasing head injury, we have carried out the EURO NCAP child headform impact test in which the actuators are fully deployed and the rear part of the hood is initially lifted up to 115mm. Through this tests we could identify that the head injury could be reduced significantly at all target points

INTRODUCTION

In order to satisfy the regulations on pedestrian head protection, passive protection measures, such as the stiffness modification of the hood itself and changes of engine room lay-out, have been frequently tried. Basically, pedestrian head injury would be reduced by the appropriate flexibility of the impact part on the hood. This, in turn, requires sufficient deformation space between hood outer skin and hard structure of the engine room. Generally, there are some limitations to fulfill this requirement by classical passive protection improvements mainly due to the strength regulations of hood itself and the difficulties of reducing the size of structures in engine room. To overcome this problem, the active measures, which lifts the hood before the head impacts the hood, are now being widely studied [1][2].

The fundamental requirement of the active hood lift device is to classify the type of object in crash and, in turn, to differentiate between fire and non-fire case.

First of all, the system must satisfy the current and future regulations [3]. Therefore, we have considered the lower legform impact at a vehicle speed of 20km/h to 40km/h as a main hood lifting condition. The same adult legform of the EC directive 2003/102/EC was considered.

To cover the field stability especially for the case of 6 year old child pedestrian, we designed the lower impactor of small child which weighs typical weight of 6 year child leg, 3.7kg. This child lower legform was assumed to provide the real impact characteristics of the small child pedestrian. Therefore the algorithm should be made to send a pop-up signal when this impactor is detected.

In case of frontal impact against rigid wall, the engine room with a open hood would be deformed more and the occupants are exposed to more severe injury [4]. Therefore the system should differentiate this frontal/offset crash and avoid the activation. Adopting the membranes switch and wheel speed sensor, developed system could prevent this erroneous situation.

To ensure the proper operation for the various misuse case, we have considered as a most difficult case to classify the impact with rigid poles of which the diameter and mass are the same value of the child/adult legform.

DEVELOPMENT OF THE ACTIVE HOOD LIFT SYSTEM

In the developed system, the data collected by the contact sensors, composed of two accelerometers and membrane switch is sent to the ECU where the algorithm decides the activation and non activation case within the required time. The contact sensors consist of two accelerometer and membrane switch installed on bumper fascia. If the algorithm determines the event as a pedestrian or lower legform impact, the fire signal is sent to the pyro-type actuator and the rear part of the hood is lifted with the help of deployment of specially designed hood hinge.

Determination of System Response Time

As shown in Figure 1, the total response time (TRT) of the system which consists of triggering time and actuator deployment time should be less than the first contact time of head to the hood.

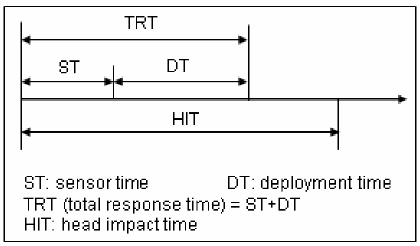
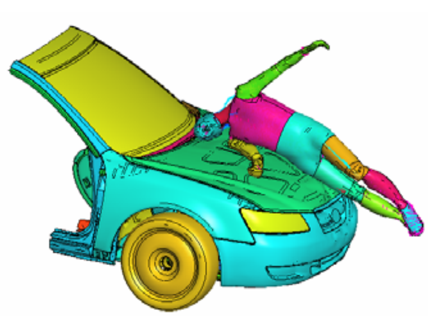


Figure 1. System TTF (Time To Fire) requirement

As shown in Figure 2, to calculate the head impact time (HIT), we have carried out a simulation of pedestrian impact at a vehicle speed of 40km/h for both cases of 6 year child and 50 %ile male human model. As a most severe case, the first contact time of 6 year child's head was measured to 58msec in this simulation condition. Both child and adult pedestrians are initially in a walking posture.

Small sedan, 6yr child



Mid size sedan, 50%ile adult male

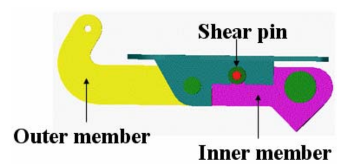
Figure 2. CAE Simulation for pedestrian impact

Typical deployment time of pyro-type actuator is approximately 30msec. Therefore, considering the system's operational margin which depends on vehicles, the triggering time should be less than 15msec at a 40km vehicle speed.

Verification Tests for Actuator Deployment Time

As shown in Figure 3, pyro-type actuator is adopted to raise the hood rear part. This actuator, initially folded in radial direction, is deployed by the exploded gas pressure. Once the actuator is used, it could be changed easily with the new one by twisting and removing from the installed hole.

Hood hinge is newly modified to ensure the target stroke of actuator. As shown in Figure 3, this hood hinge is composed of inner/outer member and shear pin. When the actuator is deployed, the shear pin of the hinge is broken and the inner/outer member move upward as shown in Figure 4.



Actuator Hood hinge

Figure 3. Hood hinge and deployed actuator

Figure 4 shows the test for actuator deployment. This test is carried out to confirm the appropriate operation of the hood lifting part. In this test, the actuator was forced to be activated by an ignition signal. The hood lifting displacement and actuator operation time are measured by the high speed camera.

As shown in Figure 5, the hood rear part is lifted up to the maximum value of 157mm. The operation time to reach the target displacement of hood, 115mm was less then the designed deployment time, 30msec. Through this test it is verified that the hood is fully lifted before the contact of 6 year child head to the hood, if the triggering time is less than 15msec.

Figure 4. Test for actuator deployment

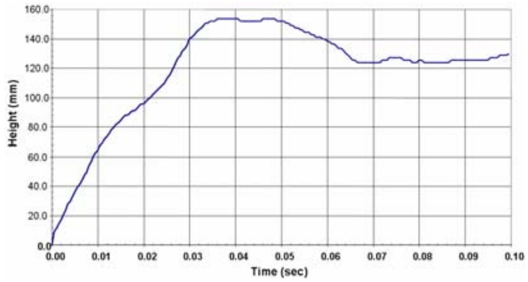


Figure 5. Time history of hood lifting displacement (at the hood hinge bracket point)

<u>Tests to Generate Data for Algorithm Development</u>

As shown in Figure 6, the accelerometers are used as a main impact sensor. Because of the possibility of discrimination between rough road and impact with objects, two accelerometers are installed on the left/right bottom side of the bumper fascia. The main function of these sensors is to detect the impact with an object of a weight and stiffness equivalent to those of a pedestrian.

The sensing signal of the same object changes with the impact location and therefore the threshold value of metric used in the algorithm should be modified according to this impact location. In this study, the membrane switch, shown in Figure 6, is used to detect the impact location. Three membrane switches are attached on the bumper fascia front surface. Sixteen switch nodes are installed at each membrane switch as shown in Figure 7.

Accelerometer Membrane switch

Figure 6. Sensing system

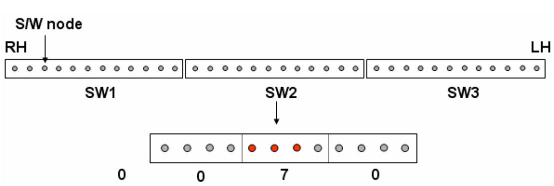


Figure 7. Detecting impact location with membrane switch

As previously mentioned, the impacts of the adult and 6 year child legform are considered as must-fire cases. On the contrary, thick and thin rigid pole, which have similar weight and diameter to the adult and child legform respectively, are adopted as a must-not-fire cases as shown in Table 1.

Table 1 Test matrix for sensing data

	Target Objects
Must Fire	Adult Legform (13.6kg)
	Thin Pole with Foam (~Child Legform, 3.7kg)
Must Not Fire	Thick Rigid Pole (12.2kg)
	Thin Rigid Pole (3.7kg)
	Rough Road (Belgian)
	Rough Road (Wave)

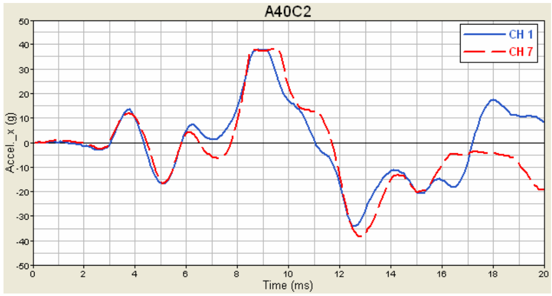
The only difference between legform and rigid pole is the stiffness distribution of the object. There we assumed if the algorithm differentiates the impacts between these must and must-not fire conditions, the developed algorithm could cover most of the real fields misuse cases.

Figure 8 shows the test setup for adult legform impacts against vehicle bumper where several accelerometers and contact switches are installed. The sensing signals were saved within the notebook in real time.

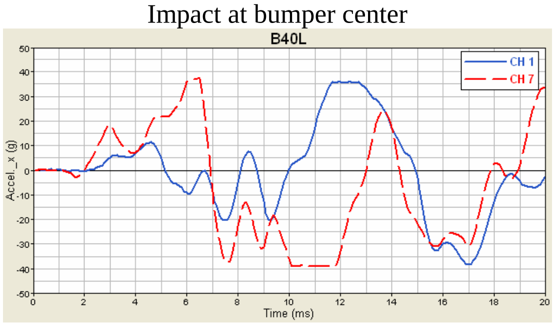
Figure 8. Setup for sensing test (adult legform)

The examples of obtained pulses for the impact legform are shown in Figure 9, where the fact that the pulse characteristics are affected by the bumper kinematics and impact location could be identified.

In order to choose the noise threshold value, the test was carried out on Belgian and wave load. In these cases acceleration larger than 7g was measured as shown in Figure 10. Therefore the algorithm would not start unless both of the 2 accelerations exceed this threshold value.



Impact at bumper center



Impact at bumper left

Figure 9. Acceleration pulse (adult legform)

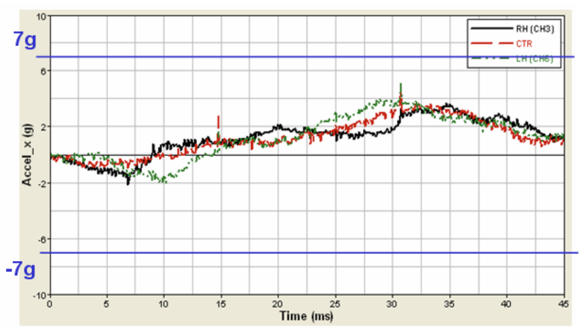


Figure 10. Acceleration pulse (Belgian road)

Algorithm Development and Validation Test

The algorithm developed here is roughly introduced in Figure 11. The raw acceleration date is filtered and sampled. If this processed date exceeds a pre-defined threshold value and the contact switch is triggered, the algorithm starts. Then the impact location is detected and metrics are calculated until the time reaches the moment of deployment decision. The metrics are derived from the collected sensor signal to reflect distinctly the characteristics of the impact object. After the calculation of trigger thresholds (=metrics boundaries) and comparison between this value and metric, the decision of hood lifting is made. The trigger threshold values change with the impact location and vehicle speed.

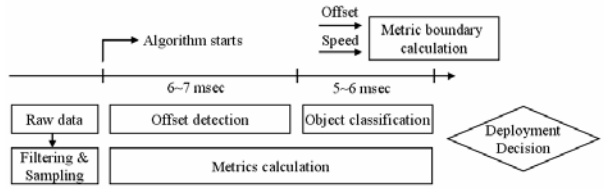


Figure 11. Setup for algorithm test

In order to confirm the algorithm performance, the system was tested with the use of wave form generator, where the sensing pulses were previously inputted. As shown in Figure 12, the input signals from wave form generator and contact switch are sent to the ECU and the algorithm determines the activation of system. If the firing signal is out from the ECU, two LED, assumed to be left/right actuators, would be lighted up. During this process, the input signals and the metrics used in the algorithm could be checked out with the oscilloscope and notebook computer, respectively. The system detected impact location of bumper fascia and discriminated the activation cases correctly for the typical five impact cases,

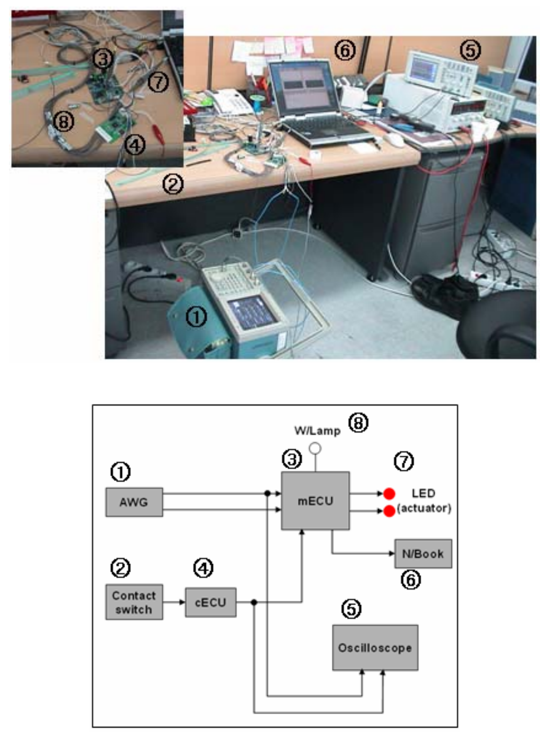


Figure 12. Setup for algorithm test

Verification Tests of System Operation

To verify proper behavior of the system, three typical impact tests were performed. Impact objects and test conditions are shown in Table2. The hood lift device was operated only in the case of adult legform impact. With the aid of high-speed camera, the total operation time, measured from the contact time between legform and bumper to the full deployment of actuator, was identified to be less than 50msec. Figure 13 shows the operation of the system for the legform impact.

Table 2 Test matrix for system validation

Test items	Impact velocity	Impact location	Results
Thin rigid pole	35km/h	Left	Not Fire
Thick rigid pole	30km/h	Right	Not Fire
Adult legform	35km/h	Center	Fire

Figure 13. Test of system operation

HEADFORM IMPACTOR TEST VERIFYING THE EFFECTIVENESS OF SYSTEM

In order to confirm the effects of the hood lifting device on the head injury reduction, the child headform impact tests of EURO-NCAP were conducted. As shown in Figure 14, five target points are selected, where, without hood lift device operation, the HPC value more than 1200 was measured.

Because proper operation of the lifting device was assured by the previous test, the headform was impacted against the initially lifted hood and the actuator was fully deployed. Figure 15 shows the test of headform impact on the projected hood point of the C3B (cowl top panel center).

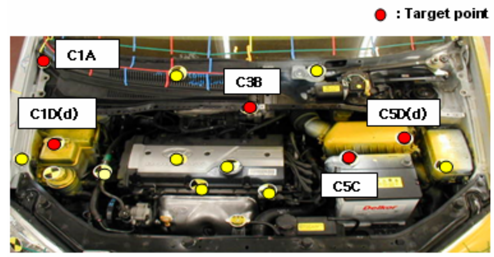
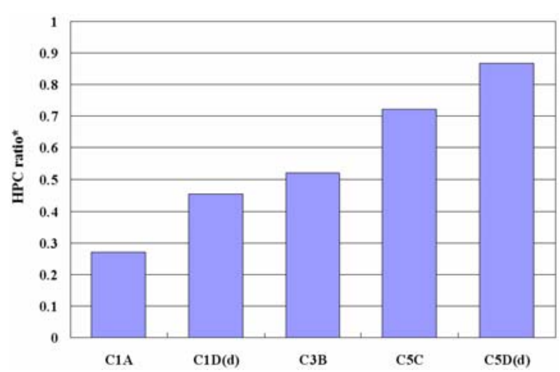


Figure 14. Target points

Figure 15. Child headform impact test

As shown in Figure 16, the improvement of the head injury could be confirmed with the operation of hood lift at all five points. However, due to the small initial space between hood skin and internal structure of engine room, the HPC value at some points were still more than target value of 1000. Therefore, in order to obtain the HPC value less than 1000, classical passive design improvements such as modification of hood structure and engine room layout should be considered simultaneously.



*HPC ratio = HPC_device / HPC_no_device

Figure 16. Test results of headform impact

In order to carry out an optimal design of the developed system at low cost, the simulation model of this device was developed. Figure 17 shows the comparison results of headform acceleration between test and simulation. The curve shape of simulation matches well with test results and peak values of acceleration are similar to each other.

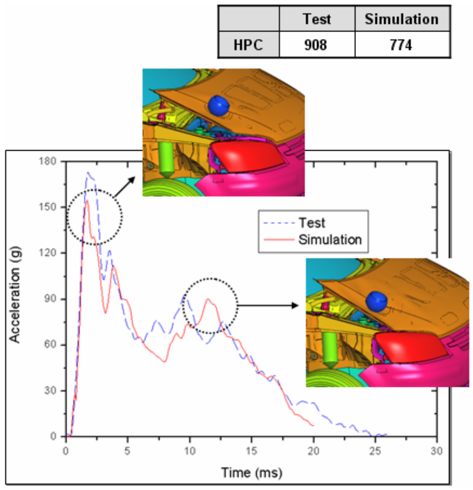


Figure 17. Comparison between test and simulation results

CONCLUSIONS

Active hood lift system has been developed to get more spaces for decreasing the head injury during pedestrian impact. This system is composed of detecting sensor, ECU where the algorithm is embedded and the pyro-type actuators which raise the hood.

Through the development of this system, we could conclude this study as follows.

1) From the simulation of pedestrian impact at a vehicle speed of 40km/h for both cases of 6 year child and 50 %ile male human model, the first contact time of 6 year child's head was calculated to 58msec. Therefore, as a most severe case, the system operation time should be less than this time, 58msec.

2) The hood rear part is lifted up to the maximum value of 157mm. The operation time to reach the target displacement of hood, 115mm was less then the designed deployment time, 30msec. Hood is fully lifted before the contact of 6 year child head to the hood, if the triggering time is less than 15msec.

3) The total operation time of the system, measured from the contact time between legform and bumper to the full deployment of actuator, was identified to be less than 50msec.

4) With the aid of the developed hood lift system, it was confirmed that the pedestrian's head injury could be reduced significantly. However, in order to fulfill the HPC limits required by the regulation or EURO-NCAP on pedestrian protection, the passive design/structural improvements should be also applied to the vehicles, especially for the small sedans, which show relatively small space between hood outer skin and hard structure of the engine room.

REFERENCES

[1] R. Fredriksson, et al. 2001, "Evaluation of a New Pedestrian Head Injury protection System with a Sensor in the Bumper and Lifting of the Bonnet's Rear Part" 17th ESV Conference.

[2] K. Nagatomi, et al. 2005, "Development and Full-Scale Dummy Tests of a Pop-Up Hood System for Pedestrian Protection" 19th ESV Conference.

[3] Directive 2003/102/EC of the European Parliament and of the Council of 17 November 2003, Official Journal of the European Union, L 321/15

[4] Oliver Scherf. 2005, "Development and Performance of Contact Sensors for Active Pedestrian Protection Systems" 19th ESV Conference.