RESEARCH ON THE AE-MDB CAE ANALYSIS FOR THE IMPROVED EURO NCAP SIDE IMPACT TEST PROCEDURE

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ABSTRACT

According to the EURO NCAP side impact test procedures for 2015, the European Enhanced Vehicle Safety Committee(EEVC) Working Group 13(WG13) has made a proposal for an improved side impact barrier: Advanced European Mobile Deformable Barrier(AE-MDB), which subjects test vehicles to more severe conditions compared to the current ECE R.95 MDB in many factors, including higher strength, increased weight and lengthened width. In this paper, development study of AE-MDB Finite Element(FE) model was performed preferentially in order to cope with the enhanced EURO NCAP side impact test procedures. In the second place, analysis and study for AE-MDB side impact were carried out to evaluate its crash severity for compact and midsize vehicles.

INTRODUCTION

Increased traffic intensity, growing concern of the public and new stringent regulations have made vehicle safety one of the major research areas in the automotive industry. In the automotive industry, the goal of engineering efforts in the field of crash and safety is to satisfy, or, to the extent possible, exceed the safety requirements mandated or administered by the various legislations such as FMVSS, NHTSA, EURO NCAP, IIHS and etc. In case of EURO NCAP, the EEVC WG13 has made a proposal for an improved side impact barrier, AE-MDB[1-4] which provides more severe conditions compared to the current ECE R.95 MDB(EU-MDB), including higher strength, increased weight and lengthened width. The detailed configuration of AE-MDB is shown in Figure 1. It is considered that the frontal shape of AE-MDB is more similar to that of a real vehicle compared to the current EU-MDB. The width and weight of the AE-MDB are increased by 200mm and 350kg respectively as compared to the current EU-MDB. The centerline of the MDB is perpendicular to that of the target vehicle and is aligned 250mm aft of the target vehicle's R-point. In addition to above alterations, the Euro SID II 50th percentile dummy is changed to World SID 50th percentile dummy. However, the EU-MDB's 300mm ground clearance and initial velocity of 50km/h remain the same. Therefore, it can easily be shown that the initial kinetic energy of AE-MDB is increased by about 36.8% compared to EU-MDB. (Figure 2.)

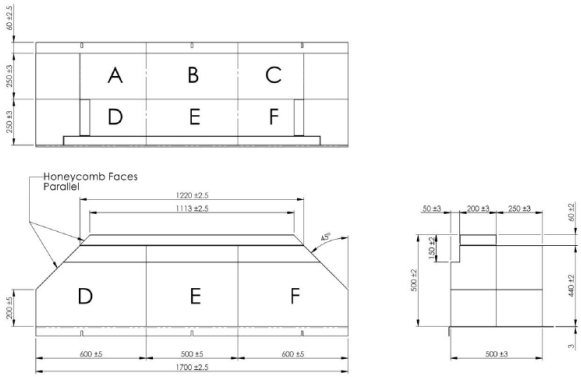


Figure 1. Configuration of AE-MDB [1]

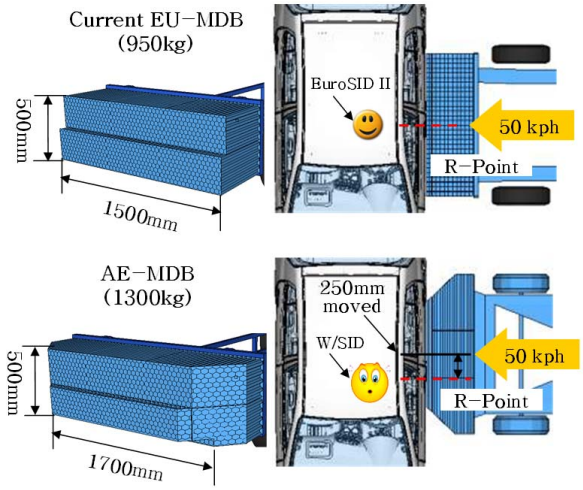
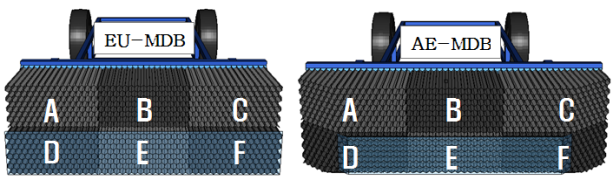


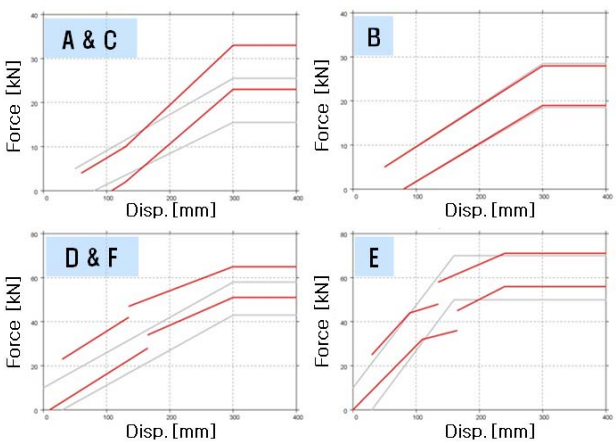
Figure 2. New EURO NCAP side impact test procedures for 2015

The dynamic corridor plots of EU-MDB and AE-MDB are shown in Figure 3 to check the stiffness and strength of deformable barrier itself. It can be

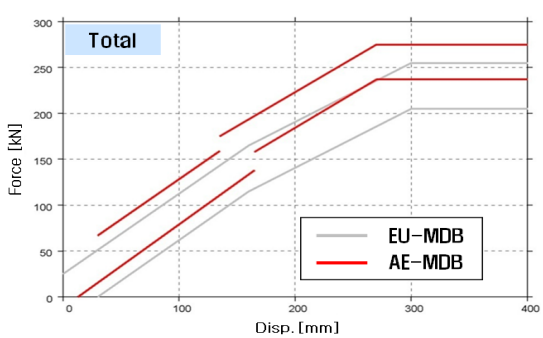
considered that the block B and E of EU-MDB and AE-MDB have similar stiffness and strength on the basis of similar slope and magnitude between the two corridors. On the other hand, the pairs of block A/C and D/F of AE-MDB showed increase in force level, about 26% and 16% respectively compared to EU-MDB. Finally, the total dynamic corridor of AE-MDB showed 11.3% increase in force level compared to EU-MDB. It is assumed that the AE-MDB has been updated to reflect the recent vehicle frontal structures, such as frontal bumper back beam, side member and apron which have increased stiffness and strength compared to the past vehicle structures.



(a) MDB block division



(b) Dynamic corridor of each MDB block



(c) Dynamic corridor of total MDB blocks

Figure 3. Comparison of dynamic corridor

In this paper, development study of AE-MDB FE model was performed preferentially in order to cope with the enhanced EURO NCAP side impact test procedure. To verify the reliability of the AE-MDB FE model, the following steps were taken: First, collapse test and simulation of honeycomb specimen were performed. Second, single component test of AE_MDB and simulation of 100% full overlap and offset crash tests against the rigid wall were carried out. Lastly, EURO NCAP side impact test and simulation of vehicle using AE-MDB were conducted to evaluate its crash severity for the compact and midsize vehicles.

DEVELOPMENT OF THE AE-MDB FE MODEL

The FE model of AE-MDB has been developed by Hyundai Motor Company(HMC) based on the AE-MDB version 3.9 in 2012, to study preveniently with the 2015 EURO NCAP side impact test procedure in regard. The development process of AE-MDB FE model is shown in Figure 4.

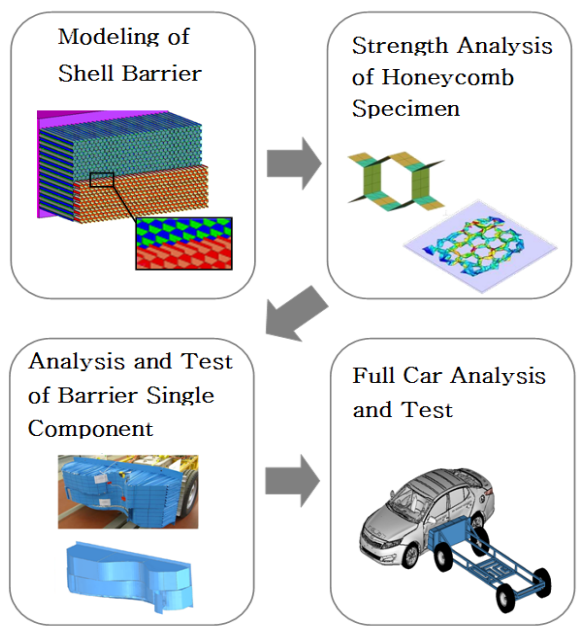


Figure 4. Development process of AE-MDB FE model

Firstly, the FE model is made with consideration of honeycomb fracture and separation between plate and block. This FE model is mainly composed of shell elements which have average of 3mm mesh size. Total number of elements is 2,229,681. Secondly, the axial collapse analysis of honeycomb sample specimen was performed to check the strength requirement. Thirdly, several types of AE-MDB single component analysis were conducted to check the force level compared to the corridor range. Lastly, the side impact analysis of

vehicles was performed with the developed AE-MDB FE model. Debugging work was done when the requirements of AE-MDB conditions were not satisfied in each process.

Strength Analysis of Honeycomb Specimen

As reported previously, the axial collapse analysis of honeycomb sample specimen was performed to evaluate the strength requirement of AE-MDB. As shown in Figure 5, quasi static analysis was performed with loading in axial direction on the honeycomb sample specimen that is 165mmX162mm square type with 25mm height. As a result, this model satisfied the strength curve requirement range; 1.587~1.793MPa.

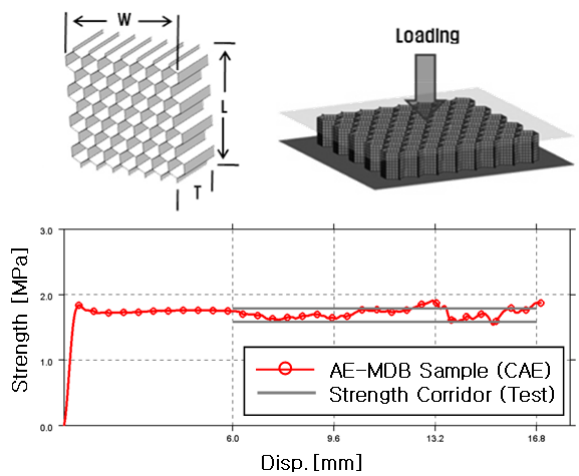


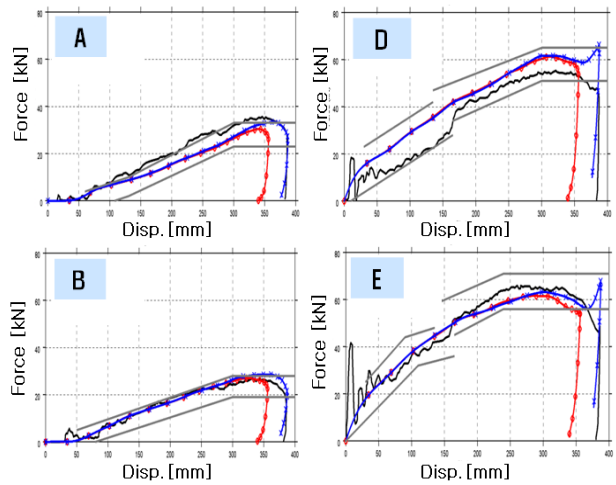
Figure 5. Result of strength analysis

Crash Analysis of Planar Rigid Wall

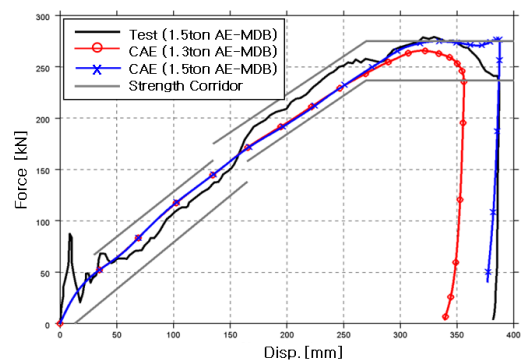
After inspection of strength analysis result of the honeycomb sample specimen, the AE-MDB single component crash analysis against the planar rigid wall was performed to check the force level of each AE-MDB block compared to the each corridor range. The test condition is that the AE-MDB crash into the planar rigid wall with velocity of 35km/h. The test and analysis result are shown in Figure 6, which shows good correlation in the corridors. It is thought that the difference of 30~40mm displacement could be from the 200kg increased MDB weight.

Crash Analysis of Rigid Pole

The AE-MDB single component crash analysis against the rigid pole was performed to check the force level and deformed shape of AE-MDB under local loading condition. The test condition is that the AE-MDB crash into the 30% offset rigid pole which has 350mm diameter with velocity of 20km/h. The test and analysis results are shown in Figure 7. Mostly, the force level of the FE model showed similar curve with the test result. However, the FE model of AE-MDB showed higher level of force, with maximum of 30% in the 80~240mm displacement range compared to the test result. On the other hand, FE model of AE-MDB showed similar deformed shape on the border between MDB blocks and separation phenomena on the back plate.

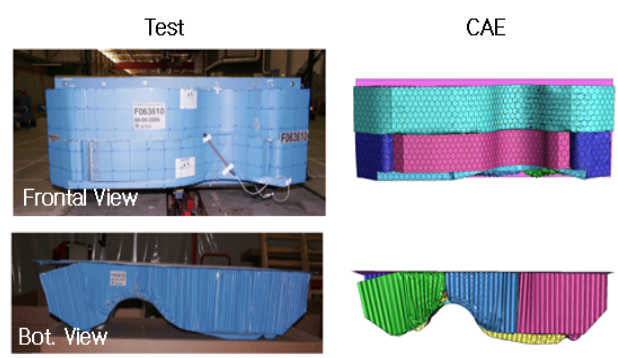


(a) Response results of each MDB block

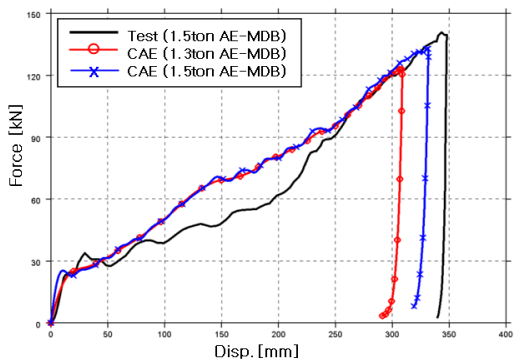


(b) Response results of total MDB block

Figure 6. Result of planar rigid wall crash analysis



(a) Comparison of deformed shape



(b) Response results of total MDB block

Figure 7. Result of rigid pole crash analysis

SIDE IMPACT ANALYSIS UNDER NEW EURO NCAP TEST PROCEDURE

After the analysis and verification of AE-MDB single component FE model, the vehicle side impact analysis and test were performed to compare and analyze the change of crash performances as compared with the results which were done by the current EURO NCAP side impact test procedures. The side impact performance indices that were used for comparison are crash energy absorption, structural displacement, and intrusion velocity. The compact and midsize vehicles utilized for side impact test and analysis are shown in Figure 8.

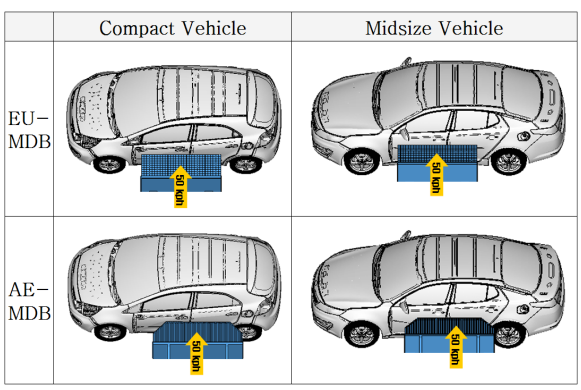
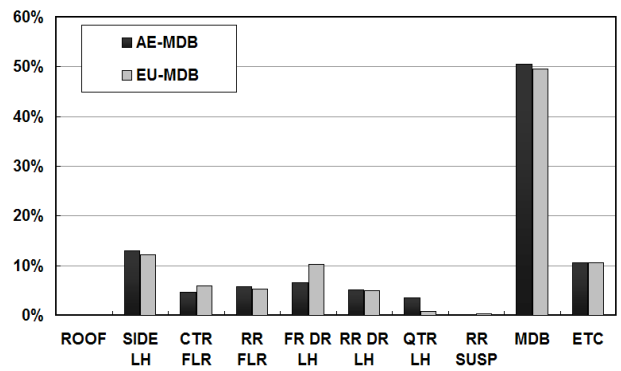


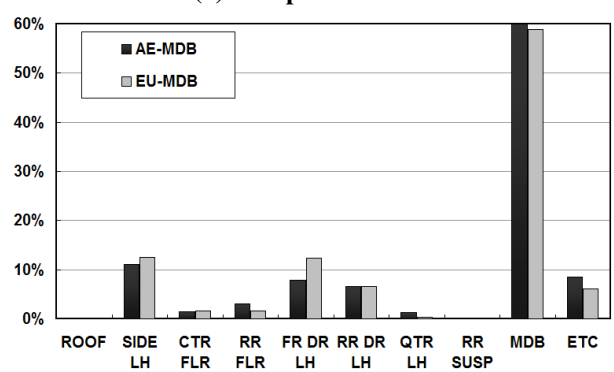
Figure 8. Condition of side impact analysis and test

Comparison of Absorbed Energy

The side impact analysis of the compact and midsize vehicle using FE models were conducted based on the conditions shown in Figure 8. The results of energy absorption quantity of structural parts which mainly absorb the energy under side impact conditions with EU-MDB and AE-MDB are shown in Figure 9. The results showed that the absorbed energy of rear floor, rear door, quarter LH and some other parts increased in both compact and midsize vehicles when the AE-MDB was used for side impact analysis. With the compact vehicle in particular, the AE-MDB target area was extended to wheel arch and rear quarter panel, so the energy of quarter LH, center & rear floor parts increased more compared to the midsize vehicle. The main reason is that the wheelbase of the compact vehicle is relatively shorter than midsize vehicle.



(a) Compact vehicle



(b) Midsize vehicle

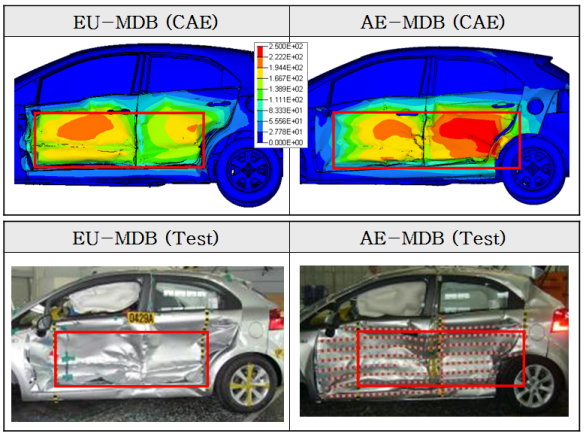
Figure 9. Comparison of energy

Comparison of Structural Displacement and Intrusion Velocity

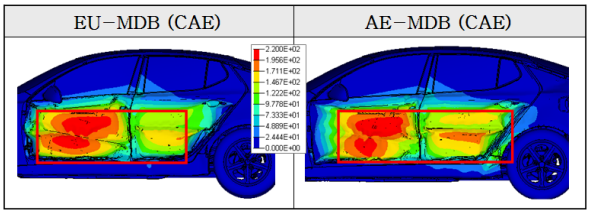
The results of intrusion contour view of compact and midsize vehicle's exteriors are shown in Figure 10. The rectangular shape with bold line shows configuration of EU-MDB and AE-MDB respectively. As the target area moved rearward, the intrusion contour color extended from rear door to quarter panel. The contour view of AE-MDB results also showed that intrusion of rear door was increased compared to EU-MDB results.

The door intrusion velocity presented in Figure 11 shows that the level of rear door intrusion velocity was higher than that of the front door in both compact and midsize vehicles. In case of the compact vehicle, the level of intrusion velocity of front and rear door showed 3% and 10% increase respectively when the AE-MDB was utilized. In case of the midsize vehicle,

the level of intrusion velocity of front and rear door showed 8% and 29% increase respectively when the AE-MDB was utilized. Therefore, it is expected that the injury of rear dummy will be increased if the same rear dummies are used for side impact test on the basis of above results. According to recent EURO NCAP test procedures, it is noted that the Q10 and Q6 dummies will be seated on the rear seat. However, the injury criteria and limit of rear dummies are not fixed yet, so it is currently unclear to conclude regarding the rear dummy injuries.

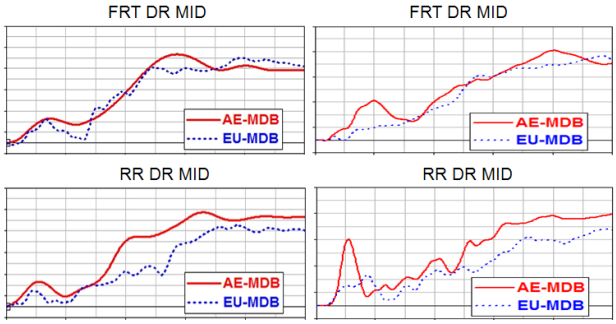


(a) Compact vehicle



(b) Midsize vehicle

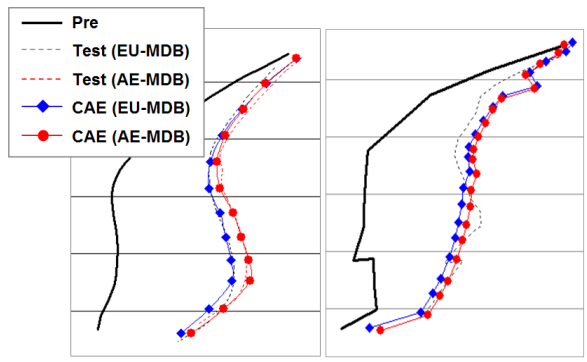
Figure 10. Result of intrusion contour



(a) Compact vehicle **(b) Midsize vehicle**

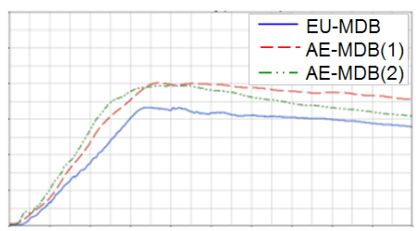
Figure 11. Result of door intrusion velocity

The B-pillar profiles according to types of MDB are shown in Figure 12. The displacement of B-pillar was a little bit increased when the AE-MDB was utilized for side impact analysis and test. Thus, the safety zone of the compact and midsize vehicles decreased 4.5% and 2% respectively. The safety zone means the distance between the center line of front seat and maximum deformed point of inner B-pillar. The curves of lateral velocity and the top view of the compact vehicle while impacting with EU-MDB and AE-MDB are shown in Figure 13. Due to the increased kinetic energy of the AE-MDB, the maximum lateral velocity of the compact vehicle increased by about 21.2% compared to the EU-MDB result, and the rotation angle increased as well. The left photo of Figure 13(b) is the EU-MDB result and the other is AE-MDB result. It is thought that the differences of velocity and angle result from the increased yaw moment as the AE-MDB target point moved 250mm rearward.

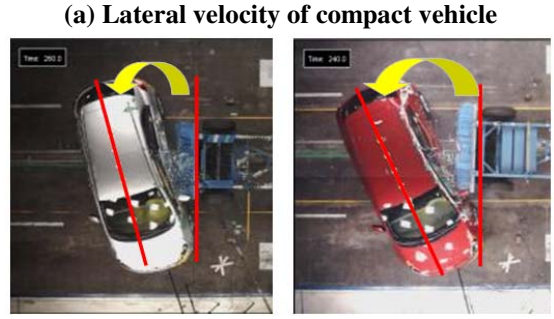


(a) Compact vehicle **(b) Midsize vehicle**

Figure 12. Result of B-pillar profiles



(a) Lateral velocity of compact vehicle



(b) Top view of compact vehicle

Figure 13. Result of velocity and top view of test

Comparison of AE-MDB Deformation

The AE-MDB deformed shape and intrusion data of the compact vehicle are shown in Figure 14 and 15. The

result of FE model of AE-MDB showed valid correlation of deformed shapes. The most deformed B/E blocks in particular, which impacted the B-pillar, shows similar shapes with the test result. The FE model of AE-MDB also showed good correlation of deformed shape with the test result regarding fracture and face detachment on the D/F blocks. Above reported contents can be verified with the intrusion results of AE-MDB as shown in Figure 15. On the whole, the displacement curves of AE-MDB upper and lower blocks showed good fidelity between the test and CAE results. As a result, it is thought that the FE model of AE-MDB shows high degree of accuracy and fidelity as compared with test results.

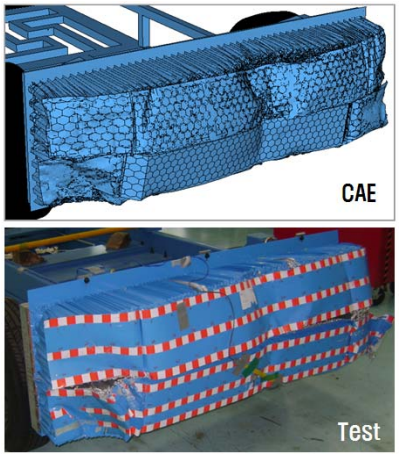
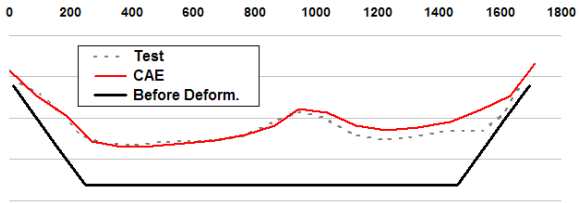
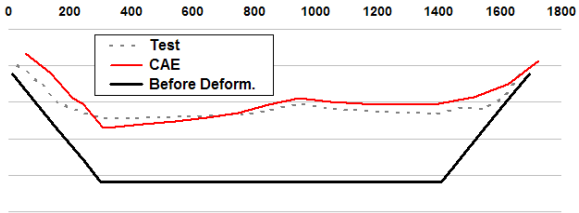


Figure 14. Comparison of deformed shape of AE-MDB between test and CAE results



(a) Center line of upper blocks of AE-MDB

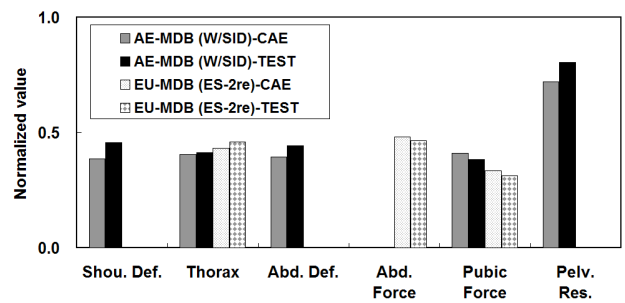


(b) Center line of lower blocks of AE-MDB

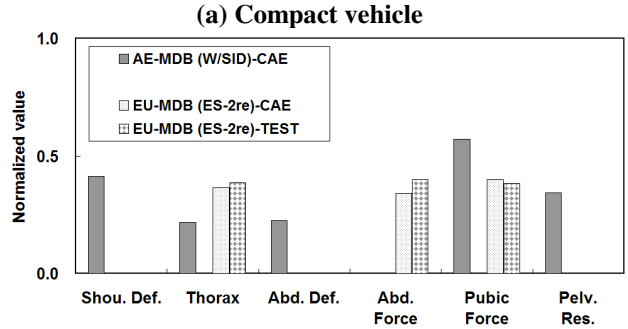
Figure 15. Comparison of displacement of AE-MDB between test and CAE results

Comparison of Dummy Injury

As of now, the exact assessment criteria and ratings of the World SID 50th percentile and Q10 and Q6 dummies are unclear. The injury assessment criteria and threshold of those dummies have not been decided yet according to recent test procedures with AE-MDB. Although it is difficult to calculate the ratings accurately, it is possible to compute and compare the results of normalized data based on the current regulation criteria of World SID 50th percentile dummy injuries as shown in Figure 16. In case of the compact vehicle, all the items except the pelvis resultant acceleration showed stable level, having normalized values lower than 50%. Meanwhile, the midsize vehicle showed that all the items except the pubic force have stable level, having normalized values lower than 50%. Consequently, it is expected that the equal ratings can be computed when the current level of assessment criteria is applied. However, if severe injury assessment criteria and threshold are enacted regarding the World SID 50th percentile and Q10 and Q6 dummies, the assessment results and ratings can be deteriorated. Thus, we are monitoring the modification of the injury assessment criteria and threshold closely.



(a) Compact vehicle



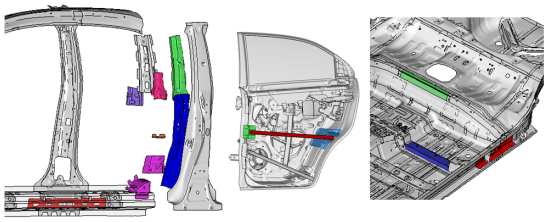
(b) Midsize vehicle

Figure 16. Comparison of dummy injury

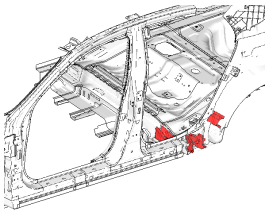
CASE STUDY OF STRUCTURAL ENHACEMNET

In this section, a case study regarding the application of structural reinforcement concept was performed to retain larger safety zone and to diminish injuries of dummies. In this case study, the optimization process for weight reduction was not considered while enhancing the structural stiffness and strength. In Figure 17, the reinforcements on the B-pillar, door impact beam, rear floor and side sill were taken into

consideration to enhance the structural stiffness and strength with reducing the intrusions of vehicle structure. There are several ways to enhance the structural stiffness and strength such as increase of the thickness, exchanging of materials, modification of cross-sectional shape and installation of reinforcement, etc. In this case study, several items for enhancement were chosen from above methods. As a result, the weight of compact and midsize vehicle increased 3.9kg and 0.9kg respectively, for improved structure.



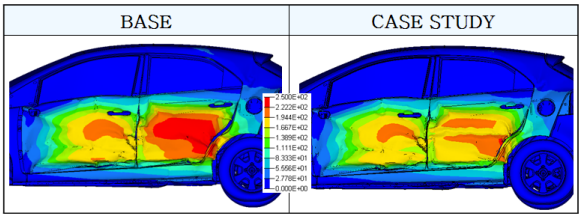
(a) Compact vehicle



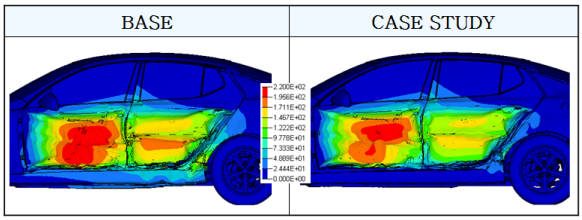
(b) Midsize vehicle

Figure 17. Concept of structural enhancement

The results of the case study are shown in Figure 18. As expected, the intrusion contour view of compact and midsize vehicle's exteriors are changed to somewhat lighter color compared to the baseline model. The structural safety zones of the compact and midsize vehicle also increased by 6% and 2.2% respectively.



(a) Compact vehicle



(b) Midsize vehicle

Figure 18. Result of intrusion contour of case study

The front and rear door intrusion velocity of the compact vehicle decreased by 3.6% and 3.4% respectively and that of the midsize vehicle decreased 0% and 1.4% respectively. The normalized injury values based on the current regulation criteria of the World SID 50th percentile showed 0~10% decrease.

CONCLUSIONS

In this paper, advanced research of the AE-MDB was performed to cope with the enhanced EURO NCAP side impact test procedure which will be implemented after the year 2015. The summarized studies are as follows.

(1) The detailed shell FE model of AE-MDB that satisfied all requirements of the test specifications was developed in order to use in the vehicle development process considering the EURO NCAP AE-MDB side impact test and simulation.
(2) The structural safety zone of compact and midsize vehicles decreased by 4.5% and 2% respectively, and the rear door intrusion velocity increased by 10% and 29% respectively, when the AE-MDB was applied for simulation.
(3) The case study showed that the reinforcements on the B-pillar, door impact beam, rear floor and side sill were effective in reducing the displacements of vehicle body and dummy injuries.
(4) Further study of dummy injuries and restraint systems, paired with structural optimization should be going on after confirmation of the injury assessment criteria and threshold to enhance the ratings of EURO NCAP.

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