DEVELOPMENT OF NEW GENERATION MOBILE DEFORMABLE BARRIER

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Paper Number 07-0299

ABSTRACT

The barrier face that using the current regulation of Japan and EU was developed in the stiffness of ’70s vehicles[1]. Therefore, the stiffness of this barrier is different from the current vehicles that adapts to the frontal impact tests and considering of compatibility. Then, we did the development of the new barrier face that the stiffness of the current vehicles including the small sized sports utility vehicles was reproduced.
First, we investigated the stiffness of the front-end of the vehicle for ’98MY in IHRA-SIWG[2],[3]. Next, we started the development of the barrier face in based on the results of this investigation. In the same time, they started the development of new barrier face in Europe[4]. So, we cooperated with their development for harmonization.
The developed barrier face named the advanced European mobile deformable barrier (AE-MDB) is the almost matched to the stiffness of investigated results of current vehicles. However, the deformation mode was different between the car-to-car test and the MDB-to-car test. Therefore, we did more improvement in the barrier face. The improvement items were the addition of the beam element and the tuning of the stiffness of lower row. The beam element is reproduced the bumper reinforcement of the actual vehicle. In these improvements, we completed the development of the new barrier face that matched to the stiffness of the current vehicle, and the same deformation mode between the car-to-car (CTC) test and the MDB-to-car test.
We hope that this barrier face is adopted in the new regulations for side impact.

INTRODUCTION

Japan adopts the side impact test procedure equal to EU. The barrier face used for this test procedure reproduced the stiffness of the vehicle in the ’70s. The stiffness of current vehicles are different from ’70s vehicles, because they are adapting to various safety regulations for example the frontal impact test, the compatibility and so on. Therefore, the stiffness of the barrier face is different from the stiffness of current vehicles. As for this, the results of the investigations in IHRA-SIWG are clear[5],[6],[7]. Then, the development of the barrier face that reproduced the stiffness of the current vehicles was necessary. They started the development of the various type of the new barrier face in IHRA-SIWG and EEVC WG13 etc. Japan also started the development of new barrier face called J-MDB. However, Japan did join the development in Europe from the viewpoint of the international harmonization, because the same regulation is adopted in Europe, and they were doing development with the same concept as Japan. The developed barrier face in this group was called AE-MDB V2[8]. However, this barrier face had some problems.

THE DEVELOPMENT OF BARRIER FACE

The Problems of AE-MDB V2

The deformation modes were different when the results of the tests using AE-MDB V2 and the CTC tests were compared.
In the struck vehicles, as shown in Figure 1, the deformation of the AE-MDB tests was larger than the CTC tests in door-height (thorax and H-point level)

section, but it's the contrary trend in the side-sill-height section. In the door-height section, the deformation of the door was larger in the AE-MDB tests than the CTC tests, and the deformation of the B-pillar was smaller than that.

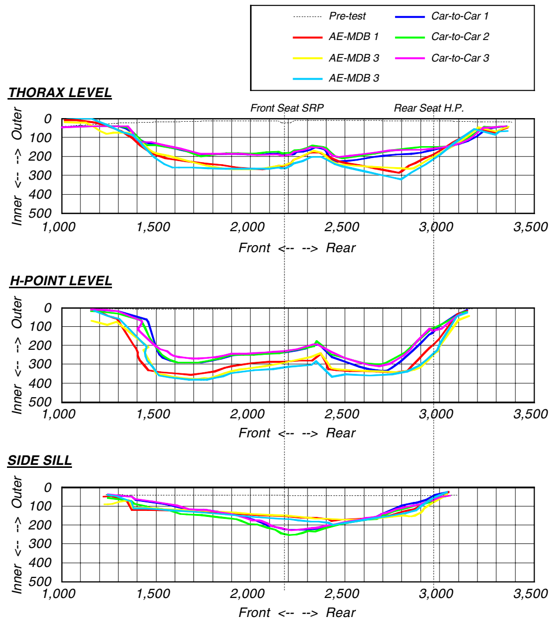

Figure 1. The comparison of deformation of the struck vehicle between the AE-MDB V2 tests and the car-to-car tests.

In the striking vehicles, as shown in Figure 2, the deformation mode was different between the AE-MDB tests and the CTC tests. The deformation of the center area of the AE-MDB was very big in comparison with the deformation of the actual car.

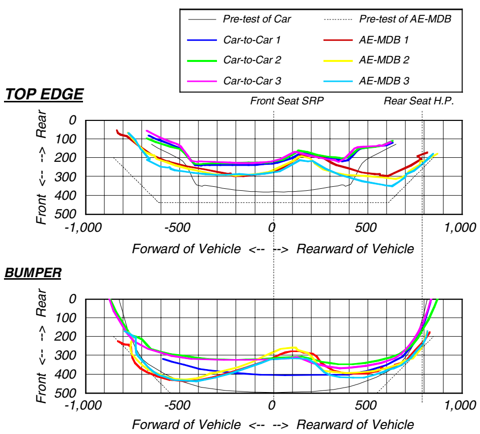

Figure 2. The comparison of deformation of the striking vehicle between the AE-MDB V2 tests and the car-to-car tests.

Therefore, we investigated the cause that the deformations were different between AE-MDB tests and CTC tests. In the AE-MDB, that is made of the individual six blocks which are covered the face plate of 0.5mm thickness, same as ECE Reg.95 barrier face. In the actual car, that is the structure that the left and right longitudinal members are connected with the bumper beam. And, the bumper beam will be stiffer year by year for compatibility.

So that, as shown in Figure 3, we suggested adding the independent bumper on AE-MDB for reproduced bumper-beam, to fit the deformation mode of AE-MDB test to the car-to-car tests.

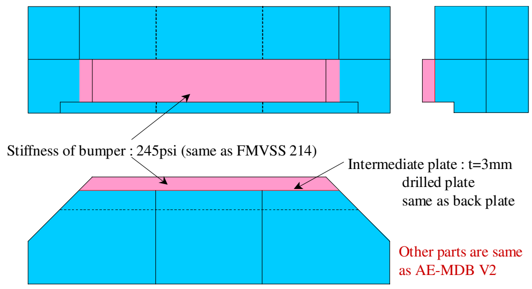

Figure 3. The modification proposal of the AE-MDB.

Development of the 'Modified AE-MDB'

We developed the 'Modified AE-MDB' to solve the problem of AE-MDB V2 that deformation mode was different from the CTC test. As shown in Figure 4, the lower row was changed with the 'Modified AE-MDB' from the AE-MDB V2. The modified points were follows.

- Cut off the bumper section.
- Add the independent bumper with drilled plate on the main-body of the lower row.
- Covered by face plate of original barrier face.

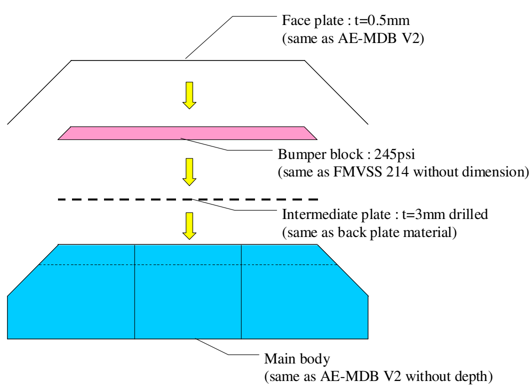

Figure 4. The lower row structure of the 'Modified AE-MDB'.

However, the stiffness of main-body was not changed from the AE-MDB V2.

Load Cell Wall Test - We carried out the load cell wall test to confirm the stiffness of the developed the 'Modified AE-MDB'. The test procedure for the 'Modified AE-MDB' is same as the barrier calibration test of ECE Reg.95 without the mass of trolley. The mass of trolley was 1500kg required in the AE-MDB specification. The collision velocity of the LCW test of the 'Modified AE-MDB' was 35km/h.

The force-deflection curves of the 'Modified AE-MDB' are shown in Figure 5. The upper row blocks, Block A, Block B and Block C, which were not changed from the AE-MDB V2, were within the required corridor. However, the lower row blocks especially Block E was without the required corridor to stiffer side. The both side blocks of the lower row, Block D and Block F, were upper limit of the required corridor in the initial part of the displacement. Also, the whole barrier face stiffness, Total, was almost at upper limit of the required corridor.

This is because; the 'Modified AE-MDB' was cut off the softer part of the lower row from original AE-MDB V2. Then, the stiffer independent bumper than the main body was added there. Because of that, the blocks of the lower row become stiffer. Furthermore, it can think that the load value of the Block E was increased by the load exchange with the stiffer blocks of the both side.

Using this 'Modified AE-MDB' to confirm the influence of bumper-beam though this was not matched for the required corridor carried out the full-scale test.

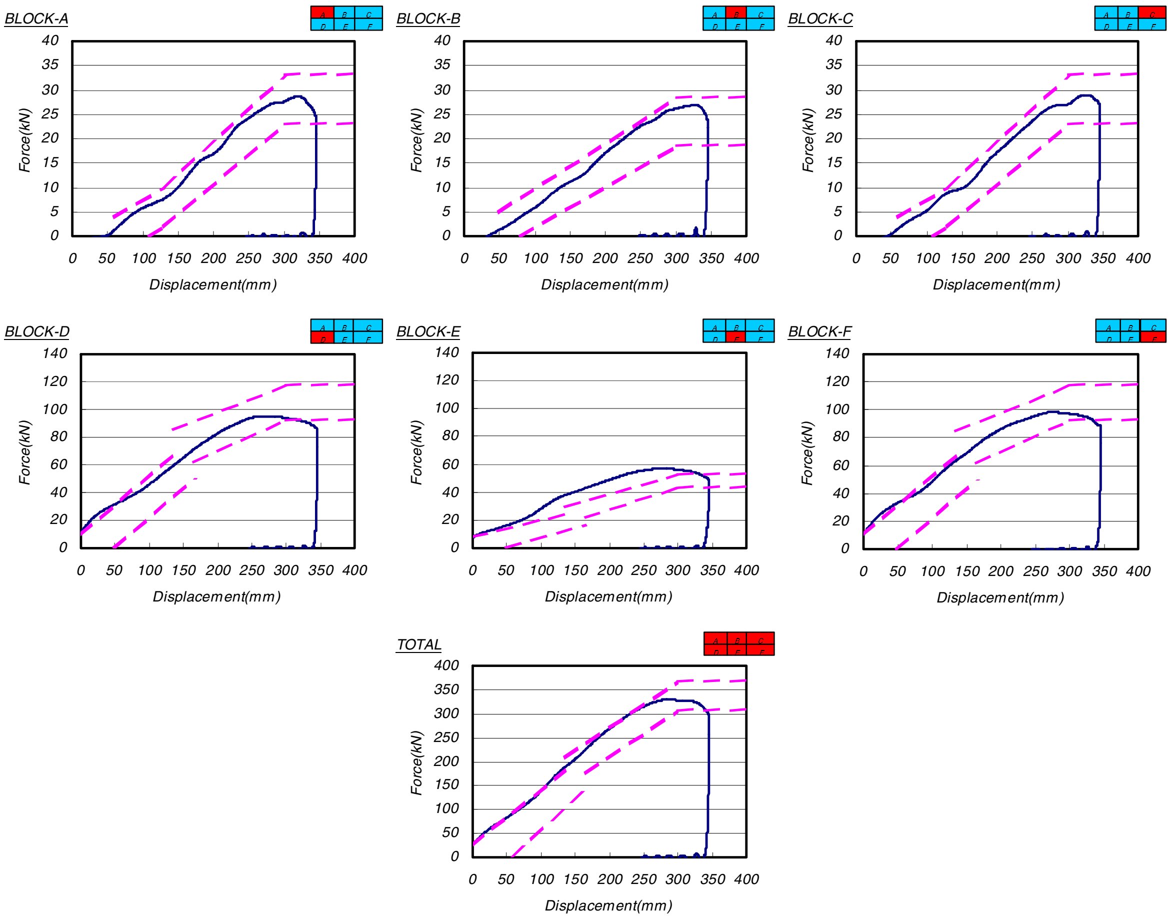

Figure 5. The force-displacement curve of the 'Modified AE-MDB'.

Full-Scale Test - We carried out the full-scale side impact test using the 'Modified AE-MDB'. The test condition of this test was same as ECE Reg.95. The impact point was put on the position where the centerline of the MDB corresponded to the seating reference point of the struck vehicle. And, the impact velocity was 50km/h.

In the struck vehicles, as shown in Figure 6, at the thorax level were almost similar between the AE-MDB V2 and the 'Modified AE-MDB'. This is because; the upper row of the 'Modified AE-MDB' was not changed from the AE-MDB V2. At the H-point level in the B-pillar position, 2,300 to 2,400 in lateral axis, the 'modified AE-MDB' was larger than the AE-MDB V2. And, it almost corresponds with the deformation mode of the 'Modified AE-MDB' test when it increases the deformation mode of the CTC test 80mm. The deformation by the 'Modified AE-MDB' was larger than the deformation by the AE-MDB V2 in side sill level.

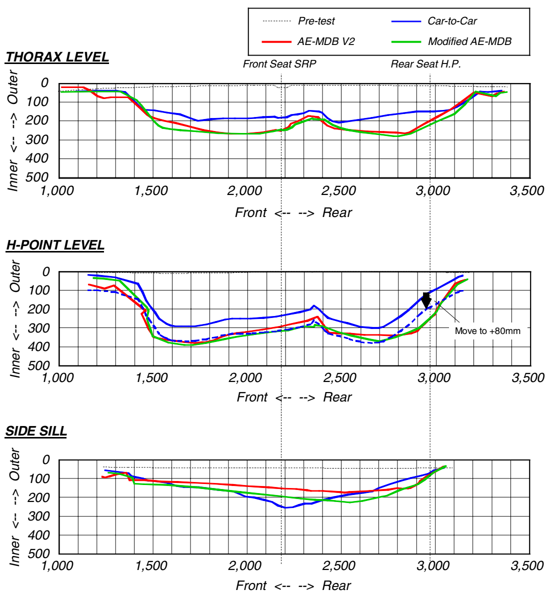

Figure 6. The comparison of deformation of the struck vehicle between the AE-MDB tests and the car-to-car test.

In the striking vehicles, as shown in Figure 7, in the bumper level, the deformation of the 'Modified AE-MDB' was smaller than for the AE-MDB V2. And, it almost corresponds with the deformation mode of the 'Modified AE-MDB' and the deformation mode of the bumper beam of actual vehicle.

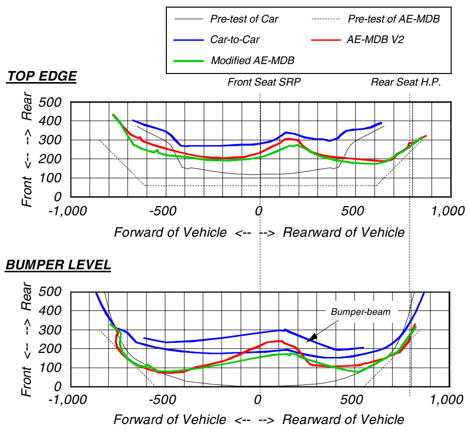

Figure 7. The comparison of deformation of the striking vehicle between the AE-MDB tests and the car-to-car test.

The 'Modified AE-MDB' improved the deformation mode of the door section of the struck vehicle and the bumper of the striking vehicle. And, more improvement of the lower row will be necessary.

The Problems of the 'Modified AE-MDB' - The force-displacement curves of the blocks of the lower row were without the required corridor to stiffer side. Therefore, the deformation of the full-scale side impact test using the 'Modified AE-MDB' was larger than the CTC test and the AE-MDB V2 test. And, the face plate of the 'Modified AE-MDB' was split due to the collision. Then, the development of the new barrier face to conform to the required corridor was started.

Development of AE-MDB V3.1J

We developed the new barrier face that matched completely in the required corridor of the AE-MDB. We called that the AE-MDB V3.1J. The structure of the lower row of this barrier face is shown in Figure 8. The point that this barrier face is changed from the 'Modified AE-MDB' to is shown in the following.

- Add the front plate between the face plate and the bumper to prevent the face plate from splitting.
- Tuning the stiffness of the main-body of the lower row for matching to the required corridor.

Other parts of the barrier face were not changed in this improvement.

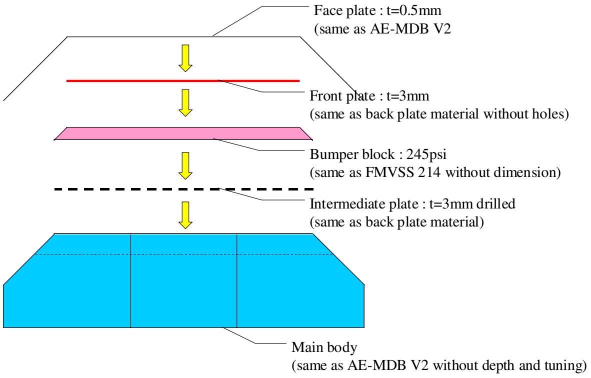

Figure 8. The lower row structure of the AE-MDB V3.1J.

Load Cell Wall Test - Again, we carried out the load cell wall test to confirm the stiffness of the developed the AE-MDB V3.1J. The test procedure for this barrier face is same as the previous LCW test. So, the mass of the trolley was 1500kg, and the velocity of the trolley was 35km/h.

The comparison of the force-displacement curves of the AE-MDB V3.1J and the 'Modified AE-MDB' are shown in Figure 9. The force-displacement curves of the upper row of the AE-MDB V3.1J were almost similar to the 'Modified AE-MDB' within the required corridor. Because, there were no changed from the 'Modified AE-MDB'. In the force-displacement curves of the AE-MDB V3.1J, the both side of the lower row were within the center of the required corridor even in the initial part of the displacement. In the force-displacement curve of the AE-MDB V3.1J, the lower center block was different from 'Modified AE-MDB', and it's within the required corridor clearly. These splendid results could obtain by tuning the main body of the lower row of the AE-MDB V3.1J. And then, the whole barrier face stiffness of the AE-MDB V3.1J was within the required corridor clearly, too.

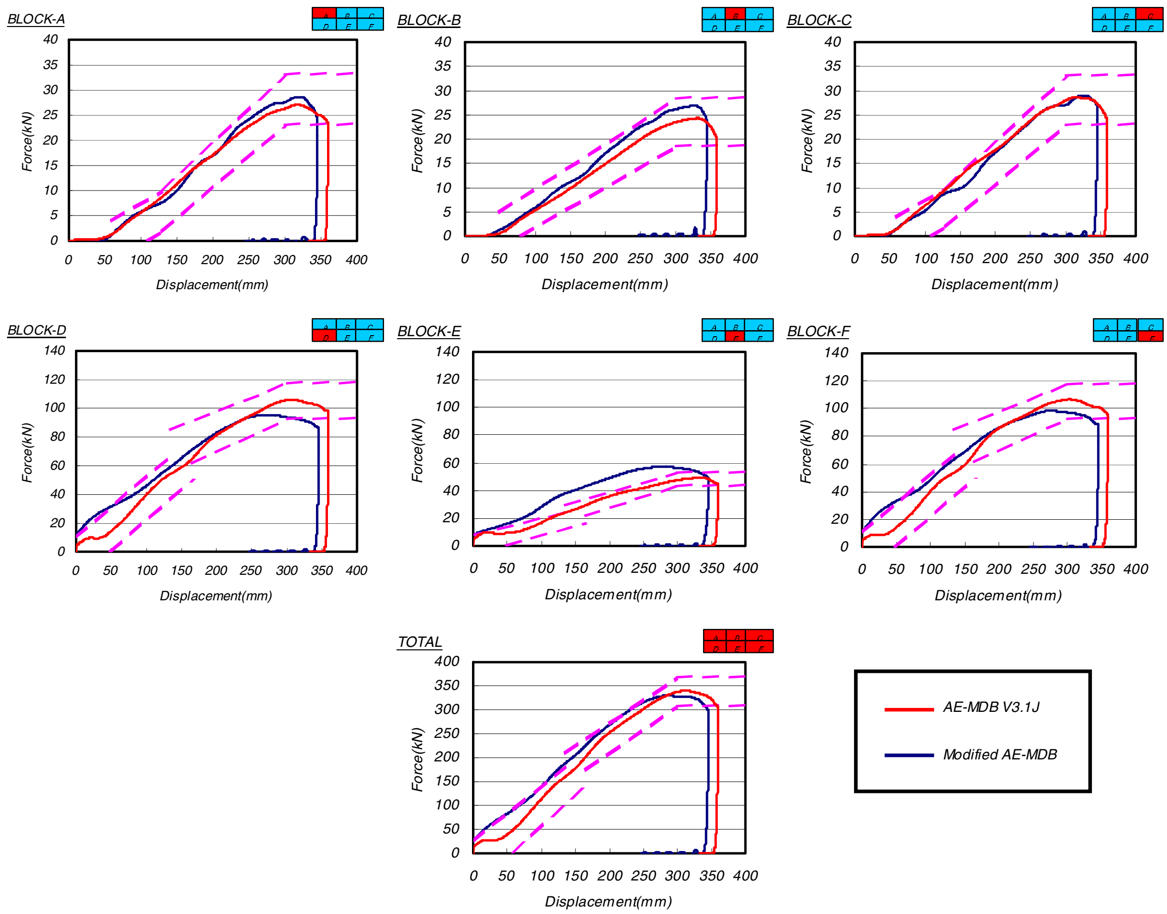

Figure 9. The force-displacement curve of the AE-MDB V3.1J.

Full-Scale Test - We carried out the full-scale side impact test using the AE-MDB V3.1J, too. And, the CTC test was carried out for the comparison. These test configurations are shown in Figure 10.

In the MDB-to-car test, the test condition was different from the test of the 'Modified AE-MDB', and that is same as the test procedure of AE-MDB proposed by EEVC WG13. The impact point was put on the position where the centerline of the MDB corresponded to the 250mm rearward of the seating reference point of the struck vehicle. And, the impact velocity was 50km/h. And, the ES-2 dummies were put on the front and the rear seat in struck side.

In the CTC test, that was carried out on both moving conditions. The impact point was put on the position where the centerline of the striking vehicle corresponded to the seating reference point of the struck vehicle. Then, the velocity of the striking vehicle was 48km/h and the velocity of the struck vehicle was 24km/h. Also, the ES-2 dummies were put on the front and the rear seat in struck side.

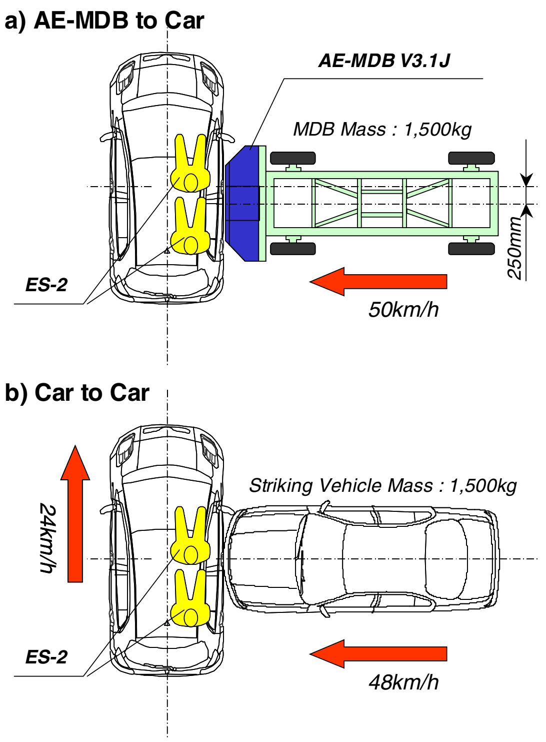

Figure 10. The test configuration.

In the struck vehicle, the deformations after the test were shown in Figure 11. At the thorax level and the side sill were almost similar between the AE-MDB V3.1J and the CTC test. At the H-point level, the results of both tests were not the deformation mode that the door was greatly deformed in comparison with the B-pillar like the previous test series but the passenger compartment area was homogeneously deformed. However, the deformation of the AE-MDB V3.1J was larger than the CTC test in rear seat H-point area. This difference of deformation is supposed an influence by the difference in a position of an initial collision.

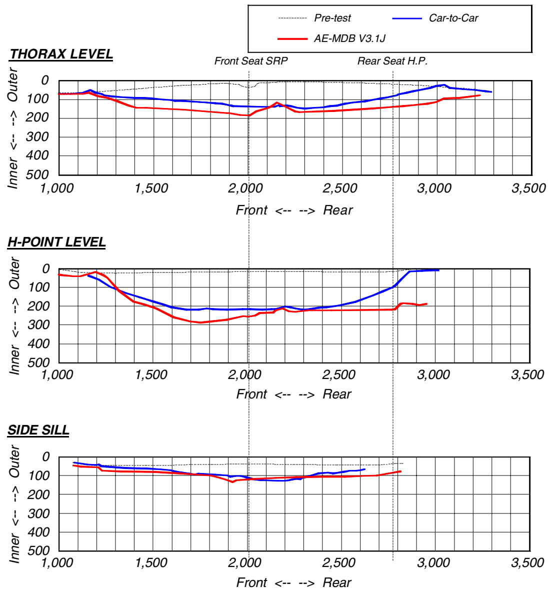

Figure 11. The comparison of deformation of the struck vehicle between the AE-MDB V3.1J test and the car-to-car test.

In the striking vehicle, the deformations after the test were shown in Figure 12. The radiator-core support was measured with the CTC test as the top edge. Also, the bumper-beam was measured as the bumper. In the CTC test, the post-test deformation lines were offset for left side in this figure. As for this, there was dragged on the right direction in front-end of the striking vehicle because the CTC test was both moving condition.

The deformation of the top edge of the AE-MDB V3.1J was larger in the equivalent part to B-pillar of struck vehicle. And, the deformation of the CTC test was homogeneously. Also, the deformation of the bumper section was homogeneously in the both tests.

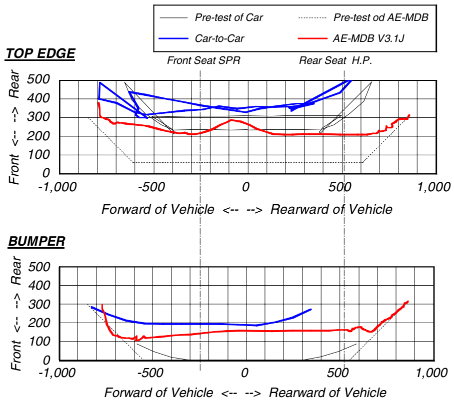

Figure 12. The comparison of deformation of the striking vehicle between the AE-MDB V3.1J test and the car-to-car test.

The injury values of the dummies were shown in Table 1 to compare with the JNCAP results of the same vehicle. Though the velocity of the striking vehicle of AE-MDB V3.1J was 50km/h, the CTC test was 48km/h and the JNCAP test was 55km/h. And, the test vehicles using the AE-MDB V3.1J and the CTC were equipped the SAB (side air-bag) and CAB (curtain air-bag) systems. But, the test vehicle of the JNCAP was not equipped these restraint systems. The injury values of the AE-MDB V3.1J test were larger than the CTC test and the JNCAP test in each region. And the injury values of the rear seat dummy were larger than the front seat dummy.

Table 1.
The injury values of the dummies.

	AE-MDB V3.1 to Car Front : ES-2 Test Velocity : 50km/h	AE-MDB V3.1 to Car Rear : ES-2 Test Velocity : 50km/h	Car to Car Both Moving Front : ES-2 Test Velocity : 48km/h vs 28km/h	Car to Car Both Moving Rear : ES-2 Test Velocity : 48km/h vs 28km/h	Reference : JNCAP Reg.95 Multi Front : EuroSID-1 Test Velocity : 55km/h	Proposed Limits ECE Reg.95
HPC	152	245	43	111	213	1000
Thorax U.Rib Defl. (mm)	-14.4	-23.5	-10.5	-20.3		
Thorax M.Rib Defl. (mm)	-21.8	-22.7	-18.6	-13.6	-19.4	42.0
Thorax L.Rib Defl. (mm)	-25.7	-25.7	-22.5	-6.9		
Thorax U.Rib V*C (m/s)	-0.08	-0.18	-0.04	-0.11		
Thorax M.Rib V*C (m/s)	-0.12	-0.18	-0.13	-0.07	-	1.00
Thorax L.Rib V*C (m/s)	-0.14	-0.27	-0.17	-0.02		
Abdominal Force (kN)	-0.99	-1.84	-0.48	-0.74	-0.96	2.5
Pubic Force (kN)	-2.92	-3.45	-1.38	-1.04	-2.51	6.0

The injury values of the dummies in the AE-MDB test, the CTC test and the JNCAP test were shown in Figure 13. This is shown in the percentage of injury value to proposal limit of current regulation.

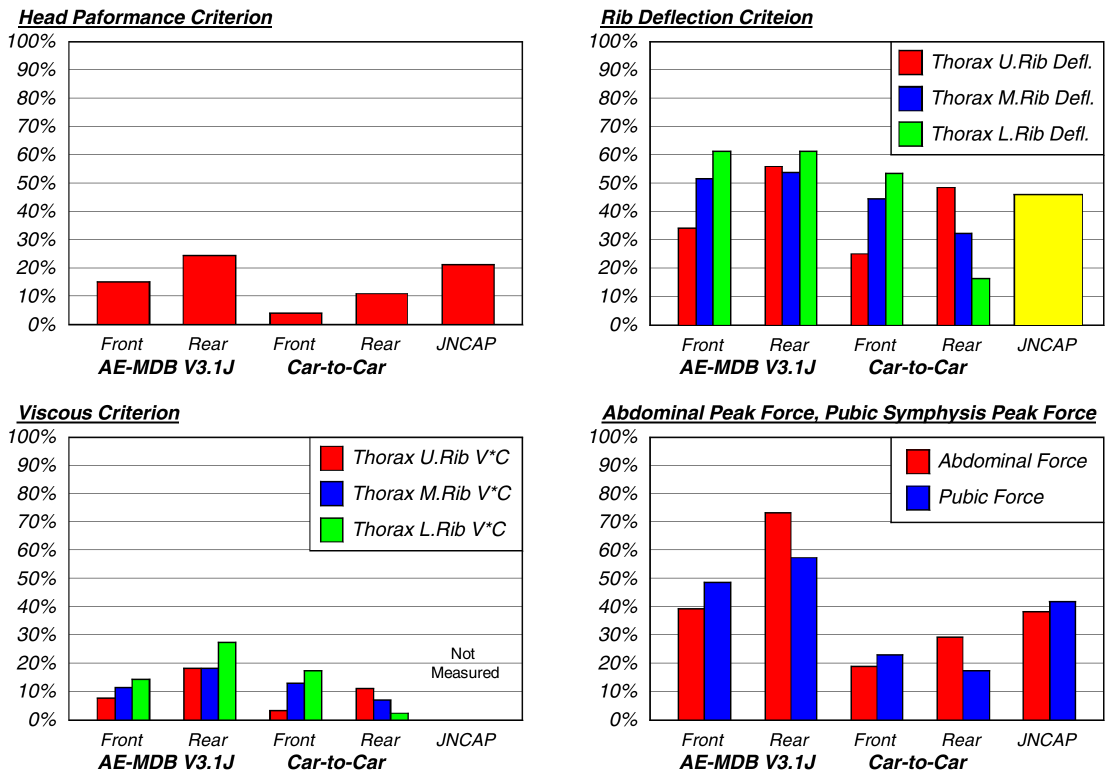

Figure 13. The comparison of injury values between the AE-MDB test, car-to-car test and JNCAP test.

In the head performance criterion (HPC), each result, especially CTC test, was very low value under 30% to the proposal limit. The rear dummies were larger than the front dummies, because the head of the rear dummies without the cover area of the CAB system.

In the rib deflection criterion, the maximum value of each rib deflection is used for the evaluation in the regulation. Therefore, in this case, the lower rib deflection is used for the RDC in the both dummies of the AE-MDB test and the front dummy of the car-to-car test. And, the upper rib deflection is used in the rear dummy of the CTC test. The results of the AE-MDB test were larger by about 30% than the JNCAP test with both dummies of the front seat and the rear seat, though the vehicle of the AE-MDB test was equipped with SAB system in front seat. Also, the results of the CTC test were larger by about 5-15% than the JNCAP test. The rear dummy of the CTC test was different trend from other dummies. In this dummy, the rib deflection was increasing to the upside. But other dummies, the rib deflection was increasing to the downside. This difference of trend is supposed an influence by the vehicle deformation in the rear seat position of the CTC test was smaller than the AE-MDB V3.1J test.

In the rib viscous criterion (V*C), also the maximum value is used for the evaluation in the regulation. The V*C cannot compared with the JNCAP test, because it was not measured in the JNCAP test. The V*C values were very small value under 30% to the proposal limit with both tests of the AE-MDB V3.1J test and the CTC test. The V*C values depended on the RDC values. Therefore a tendency of the V*C values were different only in the rear dummy of the CTC test.

In the abdominal peak force (APF), the result of the front seat dummy of the AE-MDB V3.1J test was almost same value to the result of the JNCAP test, though the vehicle of the AE-MDB test was equipped with the SAB system in the front seat. On the other hand, the result of the front seat dummy of the CTC test was almost half value of the other tests. In the rear seat dummy, though the AE-MDB V3.1J test was almost 2 times of the JNCAP test, the CTC test was small by about 30% than the JNCAP test. The APF values of the rear seat dummies were larger than the front seat dummies in both tests.

In the pubic symphysis peak force (PSPF), though the front dummy of the AE-MDB test was larger about 15% than the JNCAP test, the CTC test was smaller about 45% than the JNCAP test. Also in the rear dummy, though the AE-MDB test was larger about 40% than the JNCAP test, the CTC test was smaller about 60% than the JNCAP test. As for this, the AE-MDB test was larger than the JNCAP test, but the CTC test was smaller than the JNCAP test. Therefore, the results of the AE-MDB were about 2-3 times of the results of the CTC test.

The injury values of the rear seat dummy were larger than the front seat dummy in each region. One of the reasons, the SAB system was equipped only in the front seat.

The injury values of the AE-MDB test were larger than the CTC test in each region. One of the reasons, the lateral element of the velocity for struck vehicle of the AE-MDB test was higher than the CTC test of both moving condition.

CONCLUSIONS

We carried out this study to develop the new barrier face to reproduce the stiffness of the current vehicle including the small sized sports utility vehicles. The force-deflection corridor was not changed from the original AE-MDB that decided by the stiffness of the ’98MY vehicles. The independent bumper was added in front of barrier face without change the shape of whole barrier face with a purpose of fitting the deformation mode to the actual vehicle. Then, the tuning by chemical etching was done to fit the original corridor of the AE-MDB in the main body of the lower row of new barrier face, because the stiffness of new barrier face changed by adding the independent bumper.

We succeeded in the development of the new barrier face as a result of such process. And this new barrier face was within the required corridor of the AE-MDB completely.

After that, we carried out the full-scale side impact test to confirm the deformation mode when the new barrier face was used. The deformation mode of the full-scale test was the homogeneously like the CTC test. The injury values were compared with the results of the CTC test and the JNCAP test of same vehicle. The results of the full-scale test using this new barrier face were severe than the results of the other tests. One of the purposes of the development of this barrier face is reproduce the stiffness including the small sized sports utility vehicles. Therefore, it was presumed that the injury values of the test using this new barrier face were severe than the CTC test.

The next step, we plan the validation test using another vehicles, and/or using another dummies.

The review of the barrier face is necessary for about every ten years, because the stiffness and the dimension of the vehicles will be changing year by year to improve safety.

ACKNOWLEDGEMENTS

The support of the JAMA-SIWG members, JASIC and Showa Aircraft Industry Co., Ltd. is gratefully. JAMA and JASIC members had precious advice on the occasion of the development of this barrier face. Showa Aircraft Industry Co., Ltd. was produced this barrier face for our research.

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