INVESTIGATION FOR NEW SIDE IMPACT TEST PROCEDURES IN JAPAN
-Effect of Various Moving Deformable Barriers and Male/Female Dummies on Injury Criteria in Side Impact Test-

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ABSTRACT

The International Harmonization Research Activities Side Impact Working Group (IHRA-SIWG) focused on a new barrier face such as the Advanced European Moving Deformable Barrier (AE-MDB), which reflects recent car characteristics. Since the proportion of females severely or fatally injured in vehicle-to-vehicle crashes was greater than in males in the USA and Europe, a difference of injury criteria between male and female dummies should be investigated. Therefore, the purpose of the present study is to investigate the effect of AE-MDB on the injury criteria in male (ES-2) and female (SID-IIs) in the front seat and in female (SID-IIs) in the rear seat. In the present study, the ECE/R95 MDB or AE-MDB or car was impacted into the side of the same type of small passenger car. The present study also describes the results of the pole side impact test against the small passenger car used in the above test series according to the impact conditions proposed by the FMVSS/214 draft and E-NCAP.

INTRODUCTION

Japan introduced a side impact regulation[(1)] in 1998 for occupant protection in side collisions. As a result, the number of fatal and serious injuries in side collisions has been reduced. However, there are still many side collision accidents, and further effective countermeasures are needed to reduce fatalities and serious injuries in side impacts. It is known that occupants in cars are inclined to sustain serious injuries when struck by vehicles with high front stiffness and high ground clearance such as Sport Utility Vehicles (SUVs), Multi-Purpose Vehicles (MPVs) and minivans[(2)(3)]. It is also necessary to consider improving the protection of occupants against side collisions with narrow objects such as trees and poles in single collisions.

The proportion of females severely or fatally injured in vehicle-to-vehicle crashes was greater than in males[(2)] in the USA and Europe. A difference of injury criteria between male and female dummy should be investigated.

In this paper, new side impact test procedures using AE-MDB were investigated, which have been discussed in IHRA SIWG and EEVC/WG13. The side impact test procedure using pole proposed by the United States and E-NCAP was also investigated. These tests consist of (1) MDB-to-car test: AE-MDB test in which the current vehicle specifications and front stiffness are taken into consideration, ECE/R95 MDB test and car-to-car test, and (2) Car-to-pole test: procedure of FMVSS/214 draft and E-NCAP.

In the tests of the present research, SID-IIs and ES-2 were used in order to investigate the difference in injury criteria between female and male.

TEST CONDITIONS

Moving Deformable Barriers-to-Car Test

Table 1 shows the test configurations and conditions in the moving deformable barriers (MDBs) to car test and the car-to-car. In the present study, one type of Japanese bonnet-type 4 door sedan was used as the struck car. The specification of the tested car is listed as Table 2. This car is one of the representative models of the small car fleet in Japan. The striker (MDB or car) impact velocity was 50 km/h.

The test configuration of Test No. 1 and 2 was according to the ECE/R95 test procedure. In Test No.1, the ECE/R95 MDB was used, and the ES-2 was placed in the front seat and SID-IIs in the rear seat. In Test No. 2, only the SID-IIs was placed in the front seat.

In Test No. 3, 4 and 5, the AE-MDB version 2[(4)] was used as an MDB. The AE-MDB is an MDB that was developed based on the car dimensions, mass and front stiffness in the current vehicle fleet[(5)]. It also considers both-vehicle traveling and loading

of the rear seat occupants. The AE-MDB face was made in Japan according to the specification[4] required by EEVC/WG13. The AE-MDB tests were conducted under two conditions: The center line of the AE-MDB was aligned with the driver Seat Reference Point (SRP) (Test No. 3), 250 mm behind the front seat SRP (Test No.4 and 5).

In Test No. 3, the two SID-IIs were placed in a front seat and a rear seat, respectively. The center line of the AE-MDB was aligned with the driver Seat Reference Point (SRP). In Test No. 4, the two SID-IIs were placed in the front and rear seat, respectively. In Test No. 4, the two ES-2 were placed in the front and rear seat, respectively. The center line of the AE-MDB was 250 mm behind the driver SRP. In Test No. 5, the two SID-IIs were placed in the front and rear seat, respectively. The center line of the AE-MDB was 250 mm behind the SRP.

In Test No. 6, a car was used as a striker. The specifications of the car are the same as those used for the struck car. The two ES-2 were placed in the front and rear seat, respectively. The center line of the striking car was aligned with the driver SRP in the front seat.

Car-to-Pole Test

Table 3 shows the test configurations and conditions in the car to pole test. The same type of car employed in the moving deformable barrier to car test was used (Table 2) except for the optional equipment with curtain air bag. In Test No. 7, 8 and 9, a curtain airbag was installed in the tested car.

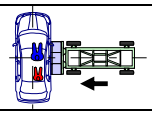
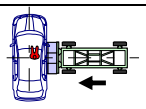
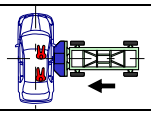
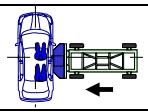
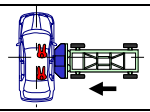
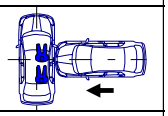
The test configuration of Test No. 7 and 8 was according to the car-to-pole test proposed by NHTSA (FMVSS/214 Draft), where the impact velocity is 32 km/h and the impact angle is 75 degrees. The pole diameter is 254 mm. The ES-2 was placed in the front seat in Test No. 7 according to the FMVSS/214 Draft. When the ES-2 is used, the seat was set in the midway position in the seat slide range. In Test No. 8, the SID-IIs was placed in the front seat in order to investigate the injury criteria difference between the ES-2 and SID-IIs. When the SID-IIs is used, the seat was set in the forward most position in the seat slide range (hereafter referred to forward-most). In both tests, the gravity center of the dummy head in a front seat was in alignment with the center of the pole.

The test configuration of Test No. 9 was according to the car-to-pole test proposed by Euro-NCAP, where the impact velocity is 29 km/h and the impact angle is 90 degrees. The pole diameter is 254 mm. The ES-2 was placed in the front seat. The gravity center of the dummy head in the front seat was aligned with the center of the pole.

Table 2. Specification of tested car

Kurb Mass	1100 kg
Wheel base	2600 mm
Engin Displacement	1498 cc
Passenger	5

Table 1. Impact conditions in moving deformable barriers or car-to-car test

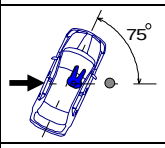
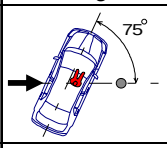
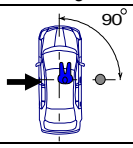
Test No.		*1*	*2*	*3*	*4*	*5*	*6*
Test config.							
Impact Verocity		50 km/h	50 km/h	50 km/h	50 km/h	50 km/h	50 km/h
Impact Point	Striker	Vehicle C/L	Vehicle C/L	Vehicle C/L	Vehicle C/L	Vehicle C/L	Vehicle C/L
	Struck Car	SRP	SRP	SRP	SRP+250 mm	SRP+250 mm	SRP
Striker	Type	ECE/R95 MDB	ECE/R95 MDB	AE-MDB	AE-MDB	AE-MDB	Car
	Mass	948 kg	948 kg	1503 kg	1503 kg	1503 kg	1269 kg
	Ground Height	300 mm	300 mm	300 mm	300 mm	300 mm	300 mm
Struk Car	Curtain air bag	without	without	without	without	without	without
	Mass	1194 kg	1249 kg	1251 kg	1304 kg	1256 kg	1317 kg
	Front Dummy	ES-2	SID-IIs	SID-IIs	ES-2	SID-IIs	ES-2
	Rear Dummy	SID-IIs	-	SID-IIs	ES-2	SID-IIs	ES-2

C/L: Center line
SRP: Seat reference point of driver in front seat
SRP + 250 mm: 250 mm behind the SRP

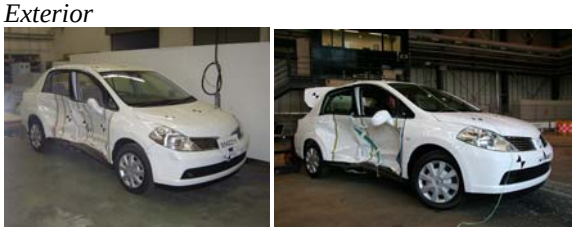
Figure 1. ECE/R95 MDB.

Figure 2. AE-MDB ver.2.

Table 3. Impact conditions in car-to-pole test

Test No.		*7*	*8*	*9*
Test configuration				
Impact Verocity		32 km/h	32 km/h	29 km/h
Impact Point		Pole center to Front Dummy Head center	Pole center to Front Dummy Head center	Pole center to Front Dummy Head center
Pole	Size	254 mm (10 in)	254 mm (10 in)	254 mm (10 in)
	Impact Angle	75°	75°	90°
Struk Car	Curtain air bag	with	with	with
	Mass including Dummy	1194 kg	1161 kg	1195 kg
	Front Dummy	ES-2	SID-IIs	ES-2
	Rear Dummy	–	–	–

Exterior

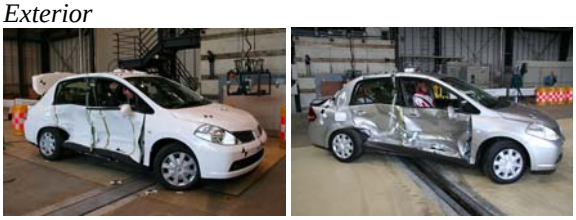


MDB

Test No. 1 (ECE/R95) Test No. 2 (ECE/R95)

Figure 3a. Deformation (Test No. 1 and 2).

Exterior



MDB

Test No. 3 (AE-MDB) Test No. 4 (AE-MDB, SRP+250 mm)

Figure 3b. Deformation (Test No. 3 and 4).

Exterior

MDB or car (striker)

Test No. 5 (AE-MDB SRP+250 mm) Test No. 6 (Car-to-car)

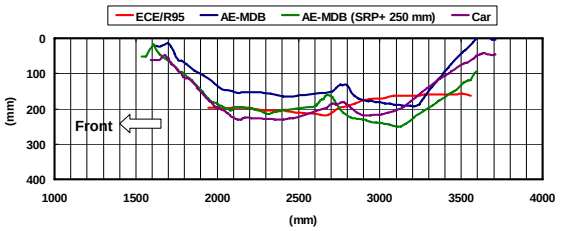
Figure 3c. Deformation (Test No. 5 and 6).

TEST RESULTS

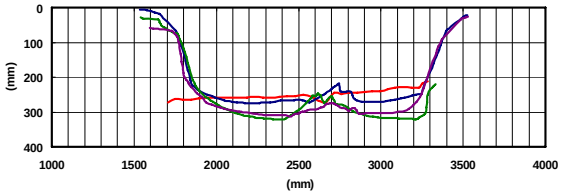
1. Moving Deformable Barriers To Car Test

Car and MDB Deformation - The deformations of struck car (outer panel) and striker (MDB or car) in all test cases (Test No.1, 2, 3, 4, 5 and 6) are presented in Figures 3a, 3b and 3c.

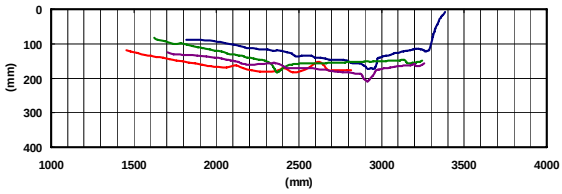
The deformations of the outer door panel of the struck car at the level of (a) dummy thorax, (b) dummy hip point and (c) side sill in moving deformable barriers-to-car test with ECE/R95 MDB (Test No.1), AE-MDB (Test No. 3), AE-MDB SRP+250 (Test No. 4) and car-to-car test (Test No. 5) are shown in Figure 4. The door panel deformation shapes struck by car, AE-MDB and AE-MDB SRP+250 are similar. Especially, the deformation of rear door panel struck by AE-MDB SRP+250 is larger than that by car or AE-MDB at thorax level. On the other hand, the door panel deformation shapes struck by ECE/R95 are different from those by AE-MDB, AE-MDB SRP+250 and car. The door panel deformation did not create the cavity shape due to impact with the B-pillar in the car struck by the ECE/R95. Thus, the MDB characteristics at the location contacting the B-pillar are more rigid than the AE-MDB characteristics or car.



(a) Thorax Level



(b) Hip Point Level

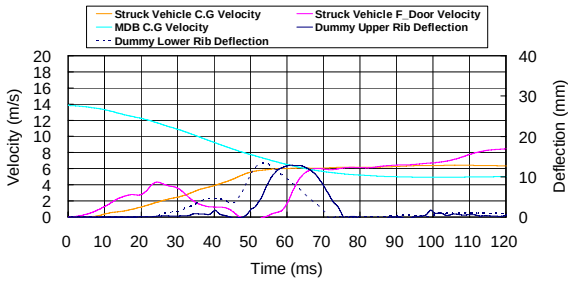


(c) Side Sill Level

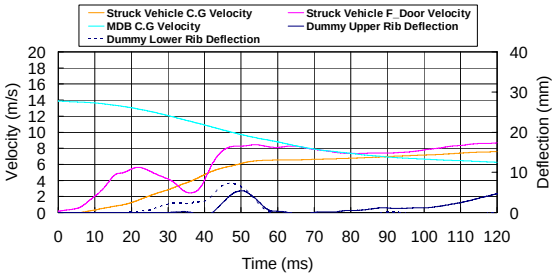
Figure 4. Deformation of outer door panel of struck car in moving deformable barriers-to-car test and car-to-car test (Test No. 1, 3, 4 and 6).

Velocity-time histories of the struck car at the gravity center, front door, MDB and dummy upper and lower rib deflections in Test No. 1 (ECE/R95 MDB, ES-2), No. 3 (AE-MDB, SID-IIs), No. 4 (AE-MDB, SID-IIs) and No. 6 (Car-to-car, ES-2) are shown in Figure 4.

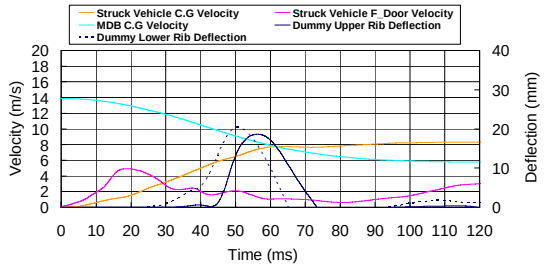
The maximum velocities of the front door are different in each test case. Furthermore, the time of the maximum velocity of the front door and dummy rib deflection are different. Especially, the timing of the maximum dummy rib deflections in the car-to-car test is faster than in moving deformable barrier tests, because the bumper equipped in the striking car front might intrude into the struck car door at the level of the dummy chest.



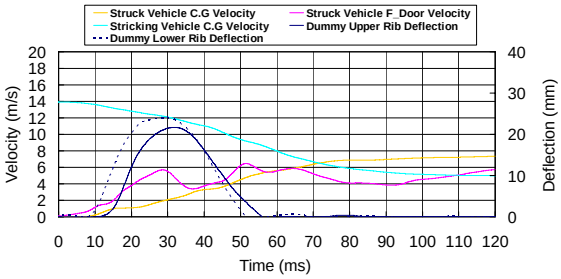
(a) Test No. 1 (ECE/R95 MDB, ES-2)



(b) Test No. 3 (AE-MDB, SID-IIs)



(c) Test No. 4 (AE-MDB, SRP+250 mm, ES-2)



(d) Test No. 6 (Car-to-car, ES-2)

Figure 5. Velocity-time histories of struck car and striker (MDB or car).

Dummy Injury Criteria

Front seat dummy (ES-2) - Using the results of Test No. 1, 4 and 6, the injury criteria of ES-2 sit in a driver seat in the struck car by ECE/R95 MDB, the AE-MDB SRP+250 and actual car were compared.

HPC (head performance criteria) of ES-2 in each test are shown in Figure 6. The HPC of the dummy in three test cases were close to 700, due to the fact that the dummy head grazed the edge of the roof-side-rail. The HPC 700 is under the injury threshold of 1000.

Thoracic rib deflections at upper, middle and lower of the ES-2 are shown in Figure 7. The thoracic deflections are in descending order of lower, middle and upper rib in the AE-MDB SRP+250 test and car-to-car test. The thoracic rib deflection is the smallest in the test using ECE/R95 MDB. When we focus on the maximum deflection, the thoracic deflections are in descending order of car-to-car test, AE-MDB SRP+250 test, and ECE/R95 MDB test.

The thoracic rib V*C of ES-2 are shown in Figure 8. The V*C are in descending order of lower, middle and upper rib in the ECE/R95 MDB test and car-to-car test. The V*C in middle rib is the smallest in the test using AE-MDB SRP+250 test. When we focus on the maximum V*C, the thoracic rib V*C are in descending order of car-to-car test, AE-MDB SRP+250 test, and ECE/R95 MDB test.

The abdominal force and pubic force of ES-2 are shown in Figure 9. The abdominal force shows similar values among the three tests, whereas the pubic force is higher in the AE-MDB SRP+250 test than the ECE/R95 MDB test and car-to-car test.

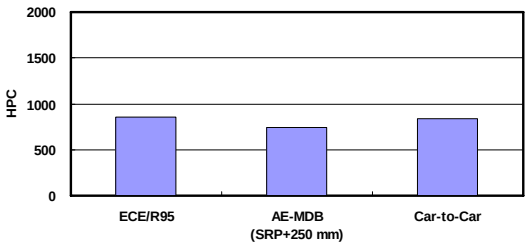


Figure 6. HPC of ES-2 sit in front driver seat in struck car by ECE/R95 MDB, AE-MDB SRP+250 and car.

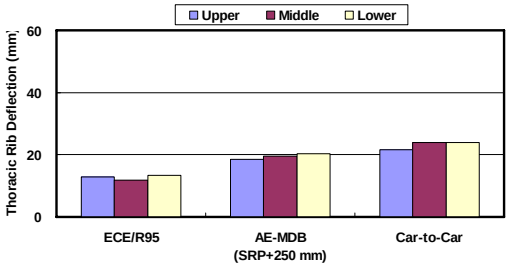


Figure 7. Thoracic rib deflection of ES-2.

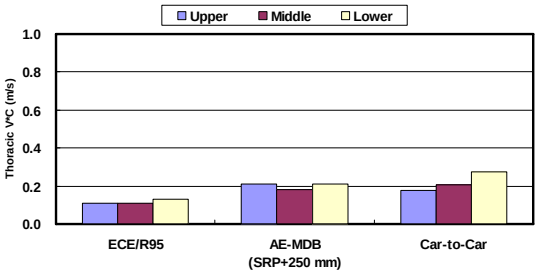


Figure 8. Thoracic rib V*C of ES-2.

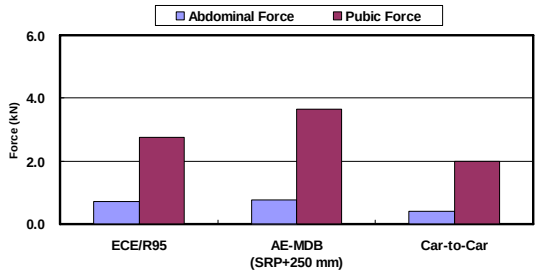


Figure 9. Abdominal and pubic forces of ES-2.

Front seat dummy (SID-IIs) - Using the results of Test No. 2, 3 and 5, the injury criteria of SID-IIs sit in a driver seat in the struck car by ECE/R95 MDB, AE-MDB (AE-MDB center was aligned with the target car front seat SRP), and AE-MDB SRP+250 were compared.

HPC of SID-IIs in each test are shown in Figure 10. The HPC in AE-MDB test is higher in three test cases. However, they were less than 500, due to the fact that the dummy head did not impact the interior. Thus, the HPC of SID-IIs are smaller than that of ES-2.

Thoracic rib deflections at upper, middle and lower of the SID-IIs are shown in Figure 11. When we focus on the maximum deflection, the thoracic deflections are in descending order of ECE/R95 MDB test, AE-MDB SRP+250 test, and AE-MDB test. The order is different from that observed in HPC results.

The thoracic rib V*C of SID-IIs are shown in Figure 12. When we focus on the maximum V*C, the thoracic rib V*C are in descending order of ECE/R95 MDB test, AE-MDB test and AE-MDB SRP+250 test.

The pubic force of SID-IIs is shown in Figure 13. The pubic forces are in descending order of AE-MDB SRP+250 test, AE-MDB test and ECE/R95 MDB test.

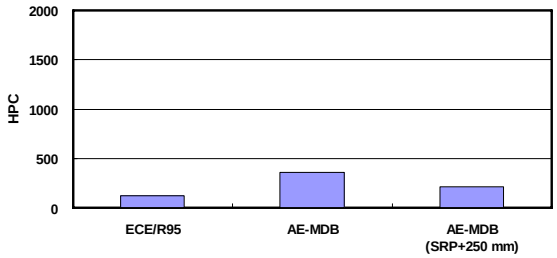


Figure 10. HPC of SID-IIs sitting in front driver seat in struck car by ECE/R95 MDB, AE-MDB and AE-MDB SRP+250.

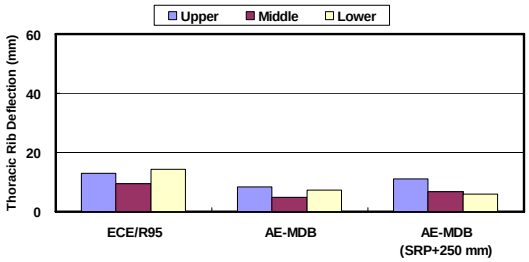


Figure 11. Thoracic rib deflection of SID-IIs.

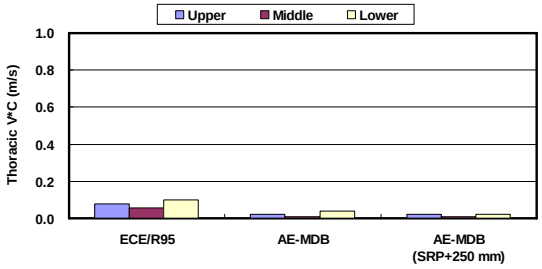


Figure 12. Thoracic rib V*C of SID-IIs.

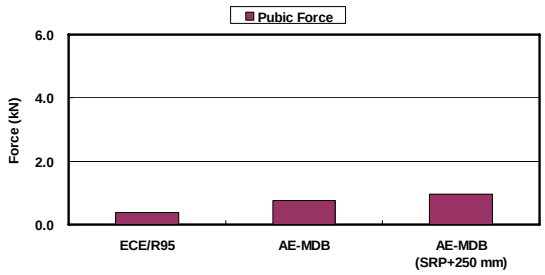


Figure 13. Pubic force of SID-IIs.

<u>Rear seat dummy (SID-IIs)</u> - The injury criteria of the rear seat dummy (SID IIs) in struck car by ECE/R95 MDB, AE-MDB and AE-MDB SRP+250 were compared from the results of Test No. 1, 3 and 5.

HPC of SID-IIs in each test is shown in Figure 14. The HPC are in descending order of AE-MDB SRP+250 test, AE-MDB test and ECE/R95 MDB test.

Thoracic rib deflections at upper, middle and lower SID-IIs are shown in Figure 15. The thoracic deflections are in descending order of AE-MDB SRP+250 test and AE-MDB test as with the order observed in HPC results. In the present study, thoracic rib deflections were not measured in ECE/R95 MDB test.

The thoracic rib V*C of SID-IIs are shown in Figure 16. The V*C are in descending order of AE-MDB SRP+250 test and AE-MDB test as with the order observed in HPC and thoracic rib deflection results. In the present study, V*C were also not measured in ECE/R95 MDB test.

The pubic forces of SID-IIs are shown in Figure 17. The pubic forces are in descending order of AE-MDB SRP+250 test and AE-MDB test as with the order observed in HPC, thoracic rib deflection and thoracic rib V*C results.

In the impact configuration in the present research, the distance between the dummy in rear seat and left edge of the MDB are close order of AE-MDB SRP+250 test, AE-MDB test and ECE/R95 MDB test, which would affect the injury criteria of the dummy in the rear seat.

In ECE/R95 MDB test, thoracic rib deflections were not measured, on the other hand, thoracic rib accelerations were measured (Figure 18). When we focus on the maximum acceleration, the thoracic accelerations are in descending order of AE-MDB SRP+250 test, AE-MDB test and ECE/R95 MDB test. Since thoracic rib deflections would connect to the thoracic rib accelerations, the descending order of the thoracic rib deflections could be the same as for thoracic rib accelerations.

Overall, the injury criteria measured in SID-IIs in rear seat are in descending order of AE-MDB SRP+250 test, AE-MDB test and ECE/R95 MDB test.

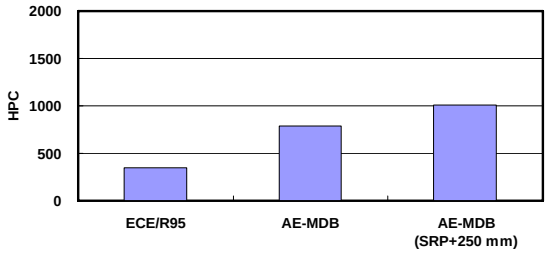


Figure 14. HPC of rear seat dummy (SID-IIs) in struck car by ECE/R95 MDB, AE-MDB and AE-MDB SRP+250.

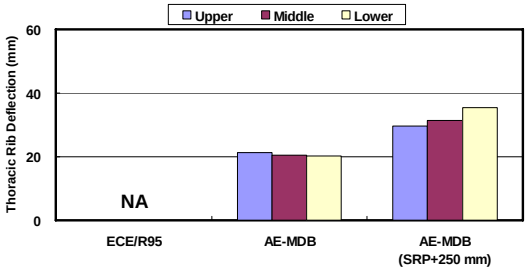


Figure 15. Thoracic rib deflection of rear seat dummy (SID-IIs).

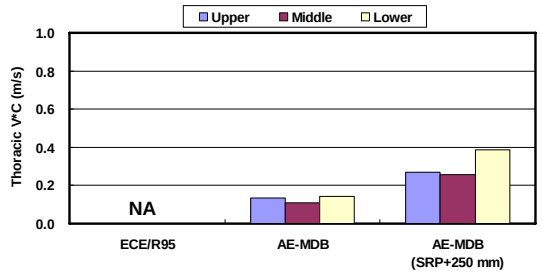


Figure 16. Thoracic rib V*C of rear seat dummy (SID-IIs).

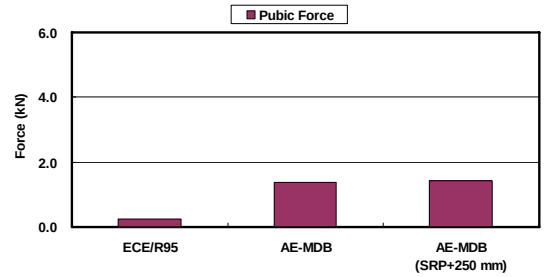


Figure 17. Abdominal and pubic forces of rear seat dummy (SID-IIs).

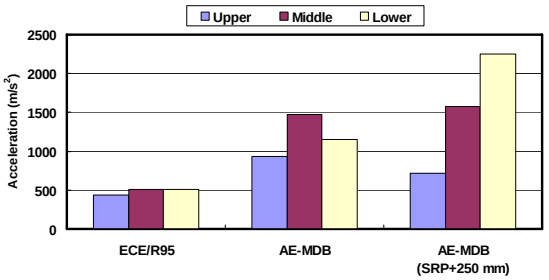


Figure 18. Thoracic rib acceleration of rear seat dummy (SID-IIs).

2. Car-To-Pole Test

Car Deformation - The deformations of struck car in all test cases (Test No. 7, 8 and 9) are presented in Figures 19a and 19b. ES2 dummy heads contacted the curtain airbag in Test No. 7 and 9. On the other hand, in Test No. 8, the SID-IIs dummy head did not contact the curtain air bag as shown in Figure 19b right.

The deformation of outer door panel of struck car at the level of (a) dummy thorax, (b) dummy hip point and (c) side sill in a car to pole test are shown in Figure 20. The intrusions are in descending order of Test No. 7 (32 km/h, 75 degrees, ES-2), Test No. 8 (32 km/h, 75 degrees, SID-IIs) and Test No. 9 (29 km/h, 90 degrees, ES-2). Thus, the intrusion in the car-to-pole test conducted at 32 km/h (Test 7 and 8) are larger than that in the car-to-pole test conducted at 29 km/h. The contact location of the outer door panel to the pole in Test 8 (SID-IIs in forward-most seating position) is 250 mm forward comparing to the location in Test 7 (ES-2 in middle seating position), since the contact location of the dummy head was aligned with the center of the pole.

Exterior

Interior

Test No.7 (ES-2) Test No.8 (SID-IIs)

Figure 19a. Deformation of test car struck by pole at 32 km/h and 75 degrees.

Exterior

Interior

Test No.9 (ES-2)

Figure 19b. Deformation of test car struck by pole at 29 km/h and 90 degrees.

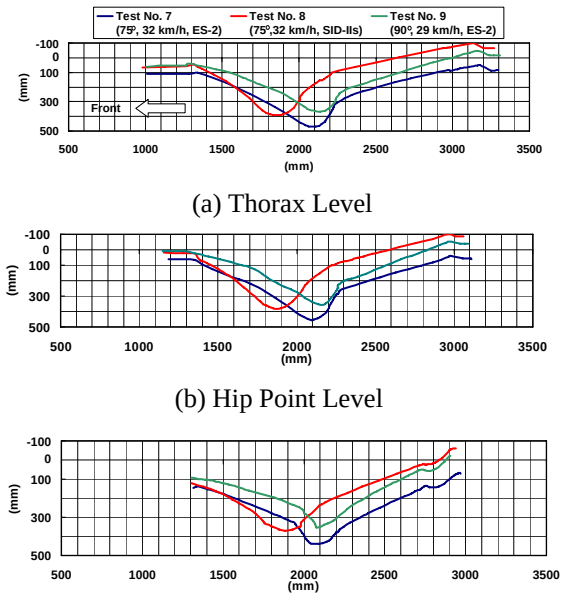


Figure 20. Deformation of outer panel of struck car in the pole test (Test No. 7, 8 and 9).

Dummy Injury Criteria - The injury criteria of ES-2 (Test No. 7 and 9) and SID-IIs (Test No. 8) in a driver seat in the car struck by a pole were compared.

HPC measured in each test are shown in Figure 21. Although the equipped curtain airbag deployed in all tested cars, the HPC of the SID-IIs dummy (Test No. 8) was far higher (over 7832) in the car-to-pole test compared with the other two tests with ES-2 (Test No. 7 and 9). At the moment of impact, the curtain airbag did not cover the SID-IIs dummy head, due to the forward-most seating position.

Although the curtain airbag deployed, the HPC in ES-2 measured in Test No. 7 (75 degrees, 32 km/h) was 1964. The HPC in ES-2 in Test No. 9 (90 degrees, 28 km/h) measured 783.

Thoracic rib deflections at upper, middle and lower are shown in Figure 22. When we focus on the maximum deflection, the thoracic deflections are in descending order of Test No. 9 (ES-2, 90 degrees, 29 km/h), Test No. 7 (ES-2, 75 degrees, 32 km/h) and Test No. 8 (SID-IIs, 75 degrees, 32 km/h). Furtheremore, the thorax upper, middle and lower rib deflections were larger in the car-to-pole test than in the ECE/R95 MDB test or AE-MDB test because the door intrusion at the thorax was large in the car-to-pole test (Figures 4 and 20).

The thoracic rib V*C are shown in Figure 23. When we focus on the maximum V*C, the thoracic rib V*C are in the same descending order of the one observed in thoracic rib deflections.

The abdominal and pubic forces are shown in Figure 24. The pubic forces are in descending order of Test No. 7 (ES-2, 75 degrees, 32 km/h), Test No. 9 (ES-2, 90 degrees, 29 km/h) and Test No. 8 (SID-IIs, 75 degrees, 32 km/h).

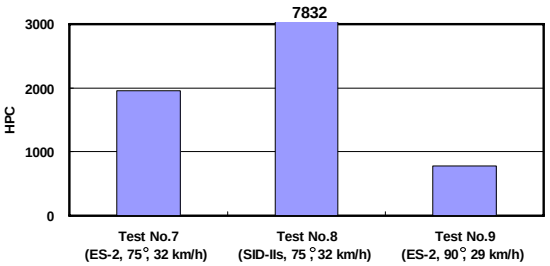


Figure 21. HPC of ES-2 (75 degrees, 32 km/h), and SID-IIs (75 degrees, 32 km/h) and ES-2 (90 degrees, 29 km/h) in car-to-pole test.

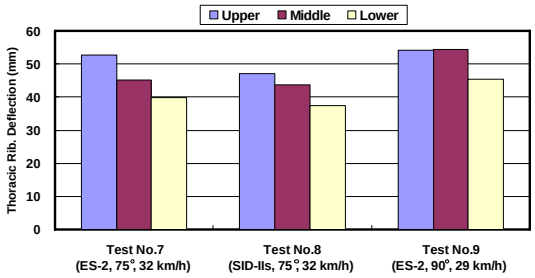


Figure 22. Thoracic rib deflection in car-to-pole test.

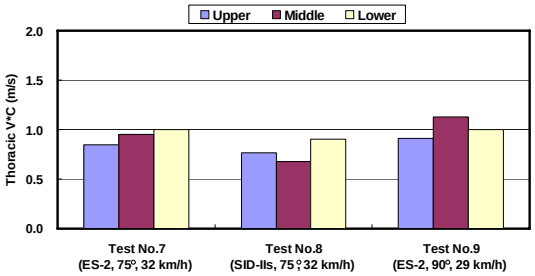


Figure 23. Thoracic rib V*C of ES-2 in car-to-pole test.

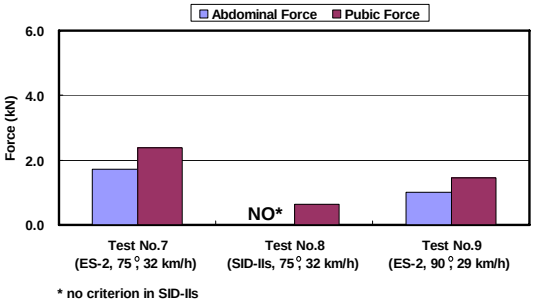


Figure 24. Abdominal and pubic forces in car-to-pole test.

DISCUSSION

In the moving deformable barriers-to-car test, the injury criteria measured in SID-IIs (Figures 6, 7, 8 and 9) were lower than in ES-2 (Figures 10, 11, 12 and 13). Following reasons could be considered.

1) Stiffness of impacted area in car: Fundamentally, the seating position of the SID-IIs was set to the forward-most, while the ES-2 was set to the middle position. Since the door panel corresponding to the SRP was impacted by the MDB, the impact position of the car using SID-IIs was different from the impact position of car using ES-2. For example, when the MDB is impacted against the door using SID-IIs, the cabin stiffness could be more rigid than the cabin stiffness using ES-2 test (Figure 20). Furthermore, the seat back can prevent intrusion of the door in the test using SID-IIs. On the other hand, the door intruded directly toward the dummy in ES-2 test.

2) Distance between dummy and door inner panel: A distance between dummy and door inner panel using ES-2 was smaller than that using SID-IIs. Thus, greater force was applied to the ES-2 than the SID-IIs. Therefore, the distance between dummy and door inner panel also affected the injury criteria in ES-2 and SID-IIs.

Regarding the injury criteria of ES-2 in the front seat, the thoracic deflection and thoracic rib V*C measured in car-to-car test are larger than those in the AE-MDB SRP+250 test or AE-MDB test. On the other hand, the abdominal force and pubic force in the AE-MDB SRP+250 test or AE-MDB test were larger than those in car-to-car test. Each MDB has different compressive characteristics in height. Hence, the above-mentioned phenomena could be owing to different force distribution due to the type of MDB.

In moving deformable barriers-to-car test, the present study used AE-MDB version 2. On the other hand, the AE-MDB has been under development and the current version of AE-MDB was 3. When the development of AE-MDB is finished, the present research should be modified using the final version.

In a car-to-pole test, although the curtain airbag deployed, the HPC measured by ES-2 in Test No. 7 (75 degrees, 32 km/h) was higher (HPC 1964) than by ES-2 (HPC 783) in Test No. 9 (90 degrees, 28 km/h). The first reason for this phenomenon was the different impact energy in these tests. The impact energy of Test No. 7 is roughly 22% higher than that of Test No. 9. The second reason was the different air bag deployment timing due to the different impact angle in these tests. Therefore, the deployment timing and volume of the curtain air bag may be the key factors influencing the driver injury criteria.

In a car-to-pole test with an impact angle of 75 degrees and impact velocity of 32 km/h, the thoracic rib deflection, thoracic rib V*C and pubic force measured by ES-2 (Test No. 7) were higher than those measured by SID-IIs (Test No. 9). The main reason was the different intrusion in these tests. The intrusion in the pole test at thorax level, hip joint level, and side sill level conducted with ES-2 were larger (471 mm, 455 mm, 440 mm) than those with SID-IIs (391 mm, 381 mm, 371 mm), respectively. Those intrusion differences were due to different impact locations on the door panel in these tests. The contact locations of the outer door panel in relation to the pole in Test 8 (SID-IIs in forward-most seating position) is 250 mm forward of the location in Test 7 (ES-2 in middle seat position), since the contact location of the dummy head was aligned with the center of the pole.

SUMMARY

In the present study, the ECE/R95 MDB or AE-MDB was impacted onto the side of one Japanese small passenger car which was not equipped with a curtain air bag. The injury criteria in ES-2 and SID-IIs on the front passenger seat, and the injury criteria in SID-IIs on the rear passenger seat were investigated. Pole side impact tests against the same type of small passenger car equipped with a curtain air bag were conducted according to the FMVSS/214 draft (75 degrees, 32 km/h) to investigate the injury criteria in ES-2 and SID-IIs. Furthermore, a pole side impact test according to E-NCAP (90 degrees, 29 km/h) was conducted to investigate the injury criteria in ES-2. The results are summarized as follows.

(1) Moving Deformable Barriers-To-Car Test

(i) Regarding the injury criteria of ES-2 in front seat, the thoracic deflection and thoracic rib V*C measured in the car-to-car test are larger than those in the AE-MDB SRP+250 (AE-MDB test with rearward target point) test or AE-MDB test. On the other hand, the abdominal force and pubic force in the AE-MDB SRP+250 test or AE-MDB test were larger than those in car-to-car test.

(ii) The injury criteria, HPC, thoracic deflection and thoracic rib V*C measured in SID-IIs in front seat were smaller than those measured in ES-2 in front seat.

(iii) The injury criteria, HPC, thoracic deflection and thoracic rib V*C and pubic force of SID-IIs in rear seat, are in descending order of AE-MDB SRP+250 test, AE-MDB test and ECE/R95 MDB test.

(2) Car-To-Pole Test

(i) The injury criteria of the head and chest of the dummy in the pole test were far higher than in the MDB test.

(ii) Although the curtain airbag deployed, the HPC measured by ES-2 in the test according to the FMVSS/214 draft (75 degrees, 32 km/h) was higher (HPC 1964) than the injury reference value HPC 1000. On the other hand, the HPC

measured by ES-2 in the test according to the E-NCAP (90 degrees, 29 km/h) was 783.

(iii) The injury criteria of thoracic rib deflection, thoracic rib V*C, abdominal force and pubic force measured by ES-2 in the test according to the FMVSS/214 draft (75 degrees, 32 km/h) were higher than by ES-2 in the test according to the E-NCAP (90 degrees, 29 km/h).

(iv) Although the curtain airbag deployed, the HPC of the SID-IIs dummy was far higher (over 7832) in the pole test compared with the other two tests using ES-2. At the moment of impact, the curtain airbag did not cover the SID-IIs dummy head, due to the forward-most seating position of the SID-IIs dummy. On the other hand, the HPC in ES-2 measured in the test (75 degrees, 32 km/h) was 1964.

(v) In the test according to the FMVSS/214 draft (75 degrees, 32 km/h), the injury criteria of thoracic rib deflection, thoracic rib V*C, abdominal force and pubic force measured by SID-IIs dummy were lower than those measured by ES-2.

In Japan, a side impact regulation for occupant protection in side collisions was introduced in 1998. As a result, the side protection safety performance of current production cars has reached the level five score according to the J-NCAP (Japan New Car Assessment Program). On the other hand, the current barrier face employed in ECE/R95 side impact test procedure referred to in European regulation, Japanese regulation and J-NCAP, was developed based on the front characteristics of production cars in the 1970s. Since the stiffness of front characteristics and mass of recent cars have increased drastically compared to those of cars in the 1970s, it is necessary to develop a new barrier face reflecting the current car accident situation.

In the present study, we used the Advanced European Moving Deformable Barrier (AE-MDB) version 2, which was developed by IHRA-SIWG. The AE-MDB was developed based on the current accident situation in several countries. Our research objective is to continue fundamental research[6] [7] [8] in order to introduce a new Japanese side impact test procedure reflecting the current accident situation with a high level of occupant protection.

In the present study, we used the SID-IIs, because the proportion of females severely or fatally injured in vehicle-to-vehicle crashes has been greater than for male[2] in the USA and Europe.

In addition to car-to-car collisions, occupant protection in single-car crashes is also important. In the present research, the pole test proposed by NHTSA was carried out, and the influences of the curtain air bag on the dummy injury criteria were investigated. In Japan, basic research on occupant protection in side collisions will be continued, and side impact test procedures will be developed in the near future.

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