JAPANESE RESARCH ACTIVITY ON FUTURE SIDE IMPACT TEST PROCEDURES

Hideki Yonezawa
Traffic Safety and Nuisance Research Institute
Takeshi Harigae
Japan Automobile Research Institute
Yukihiro Ezaka
Ministry of Land, Infrastructure and Transport
Japan
Paper No. 267

ABSTRACT

This paper summarizes a future side impact test procedure based on the Japanese presentation at the recent IHRA Side Impact WG meeting. Under current Japanese regulations, the MDB specifications and test procedures were determined based on a market study more than ten years ago. Thus, they may not reflect current automobile characteristics, the actual accident situation, and crash test results. In this study (1) the vehicle types, velocity of striking and struck vehicles, body injury regions, causes of injuries, etc. are reviewed with reference to the latest Japanese side impact accident data. The occupant percentages for the non struck-side, rear seat and for female occupants as well as the injury levels were analyzed. (2) To determine the MDB specifications, based on data from passenger car models registered in 1998, the curb mass, geometry and stiffness were examined. (3) For factorial analysis, side impact tests were performed as for real accidents. Issues for future side impact test procedures include protection of the non struck-side and rear seat occupants, the female occupants and the comparison of the dummy injury severity with or without crabbed angle, along with comparison between EuroSID-1 responses and ES-2 prototype responses. We have conducted full-scale tests in these areas. Based on these results, we present the Japanese view regarding future side impact test procedures.

INTRODUCTION

Currently, the International Harmonized Research Activities (IHRA) side impact working group (SIWG) is discussing an internationally harmonized side impact test procedure(s) incorporating the latest information on side impact accidents and the status quo of the automobile market. Their study activities are ongoing both from short-term and long-term viewpoints. Further, side impact dummies to be used for an internationally harmonized side impact test procedure are being developed by the World-SID task group under ISO/TC22/SC12/WG5, which is called World-SID. In Europe, similar efforts are being made to develop the ES-2 Prototype, an improved version of the current dummy EUROSID-1, as an interim harmonized side impact dummy.

Under these circumstances, Japan considers the activities of the IHRA-SIWG as critically important research by taking it "as a study for supporting the development of a future side impact test procedure to fulfill international harmonization." Japan has been actively carrying out research to make contributions to this project. This report contains a summary of the results of the activities conducted by Japan so far, namely (1) analysis of side impact accidents, (2) investigation of the front-end geometry and front-end stiffness of Japanese car models, and (3) results of side impact full-scale tests using compact passenger cars.

STUDY ON SIDE IMPACT ACCIDENTS IN JAPAN

Analysis of side impact accidents in Japan was conducted based on the National Police Agency Traffic Accident Statistics (hereinafter the "Statistics") in 1997, which cover all traffic accidents that involved a minimum of one injured person. According to the Statistics, the number of traffic accidents in 1997 was 780,399 with 958,925 injuries and 9,640 fatalities. In the Statistics, passenger injuries are categorized into four types: fatalities (persons who died within 24 hours of the accident), serious injury (requiring medical treatment for 30 days or more), slight injury (requiring medical treatment for less than 30 days), and no injury. In cases incurring no injury, only driver-related data are reported. No specific data are provided as to the sitting location (right, center, or left) of the rear seat passengers at the time of an accident

General Side Impact Accidents

Side impact accidents were extracted from the statistical data in 1997. Only data on front seat passengers whose sitting location was identified were used. According to the results of data extraction, there were 63,658 vehicle-to-vehicle side impact accidents and 1,815 single vehicle side impact accidents. The types of vehicles involved in vehicle-to-vehicle side impact accidents and single vehicle side impact accidents are shown in Figure 1, while the types of struck objects involved in single vehicle side impact accidents are shown in Figure 2.

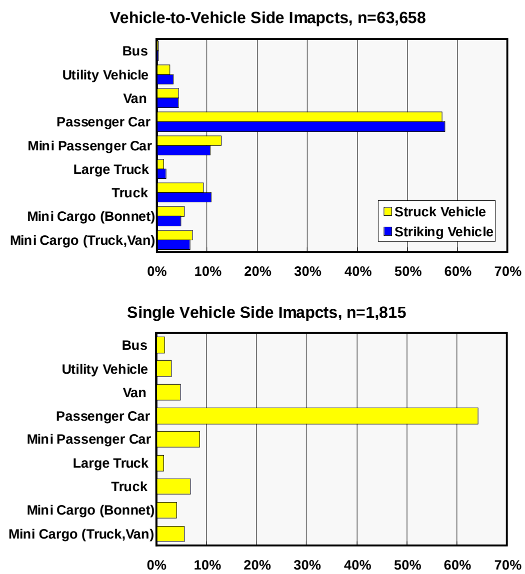


Figure 1. Types of vehicles involved in vehicle-to-vehicle side impact accidents and single vehicle side impact accidents.

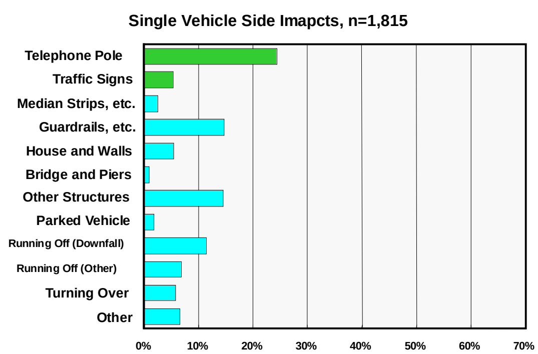


Figure 2. Types of struck objects involved in single vehicle side impact accidents.

Passenger cars account for the greatest percentage of vehicles involved in vehicle-to-vehicle side impacts, accounting for about 57% of all striking and struck vehicles. As for single vehicle side impact accidents, passenger cars account for about 64% of all vehicles involved. As for struck objects involved in single vehicle side impact accidents, pole-type structures, such as telephone poles or traffic sign poles, account for about 30%. Considering these results, the following analysis was conducted only for passenger car side impact accidents.

Passenger Car-to-Passenger Car Side Impact Accidents

Injuries by Struck-side or Non-struck Side - Figure 3 shows the number of injuries for both the struck-side and non struck-side passengers in passenger car-to-passenger car side impact accidents by injury severity. The "Slight +" shown in Figure 3 means the sum of slight injuries, serious injuries and fatalities, while "Serious +" means serious injuries and fatalities. As the severity of injury worsens, the rate of struck-side passengers and the rate of unbelted passengers tend to increase.

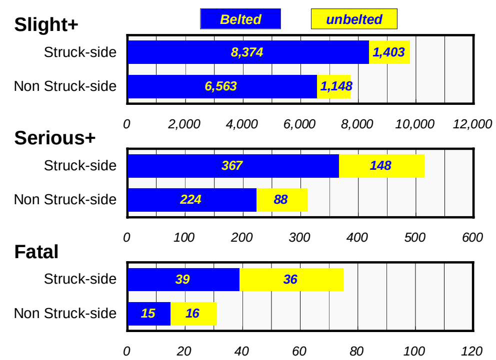


Figure 3. Number of injuries in passenger car-to-passenger car side impact accidents.

Velocity Distribution - Velocity distribution by injury severity for passengers was studied, and the results shown in Figure 4 and Figure 5.

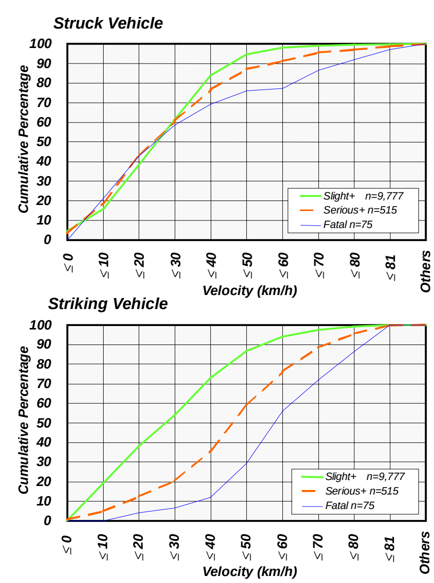


Figure 4. Velocity distribution in passenger car-to-passenger car side impact accidents by struck-side occupant injuries.

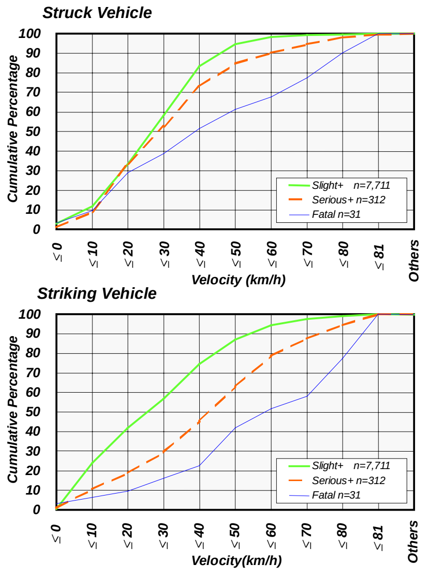


Figure 5. Velocity distribution in passenger car-to-passenger car side impact accidents by non struck-side occupant injuries.

The definition of the term "velocity" is taken from the "danger recognition speed" (the travel speed before a driver perceives a danger and takes avoidance procedures), which was defined by the Statistics. As a general tendency, the velocity curve of a struck vehicle shows a small variation depending on the severity of passenger injuries, while that of striking cars tends to be distributed more in a higher velocity range as the severity of struck vehicle passenger injuries intensifies. The velocity corresponding to the 50 percentile of struck-side passengers who suffered serious injuries and fatalities is 20 to 30 km/h for struck vehicles and 40 to 50 km/h for striking vehicles.

<u>Injured Body Region and Contact Parts</u> - The injured body regions and contact parts for "Serious +" injuries in passenger car-to-passenger car side impact accidents are shown in Figure 6 and Figure 7, respectively. There is a relatively similar tendency for injured body regions for both struck-side and non struck-side passengers in general. Injured body regions are widely distributed, or over the head, neck, thorax, and pelvis, for "Serious+". For struck-side "Serious+" injuries, "door and window" is the most frequent contact part. Regarding the contact parts for non struck-side "Serious+" passengers, the rates of steering wheel, windshield, and other structures in the front part of the car interior are higher than those for struck-side passengers..

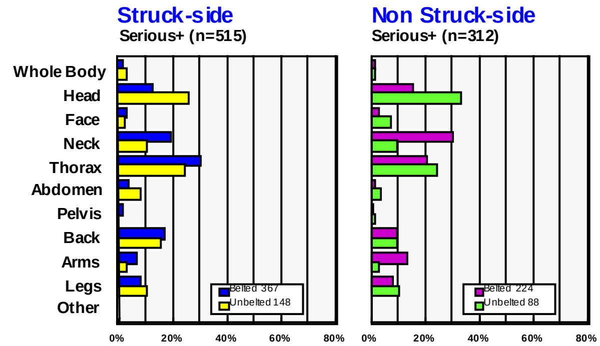


Figure 6. Injured body regions for "Serious +" injuries in passenger car-to-passenger car side impact accidents.

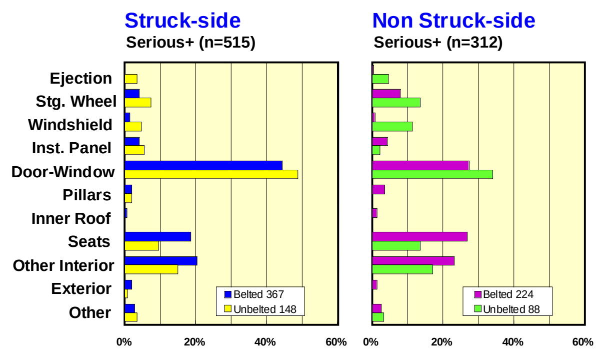


Figure 7. Contact parts for "Serious +" injuries in passenger car-to-passenger car side impact accidents.

Single Passenger Car Side Impact Accidents

<u>Injuries by Struck-side or Non struck-side</u> - The number of struck-side and non-struck-side passengers injured in single passenger car side impact accidents is shown in Figure 8.

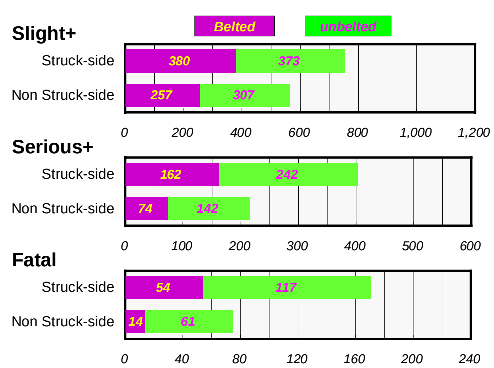


Figure 8. Number of passengers injured in single passenger car side impact accidents classified by use or non-use of belts.

As the severity of injury worsens, the rate of struck-side passengers and non-belt users tends to increase, which is similar to the case of passenger car-to-passenger car side impact accidents. What is characteristic of single passenger car side impact accidents is an extremely high rate of unbelted passengers in the injured.

Injured Body Region and Contact Parts - Figure 9 and Figure 10 show the injured body regions and contact parts for "Serious +" injuries involved in single passenger car side impact accidents.

The general inclination for struck-side passengers is similar to that of non-struck-side passengers. The most frequent injured body region is the head regardless of the use or non-use of seatbelts. However, injured body regions also tend to be distributed widely over various body parts. Regarding the contact parts for struck-side passengers, the "door-window" is most frequent, but also widely distributed among other parts. For non struck-side passengers, the contact parts show a wider distribution than for struck-side passengers.

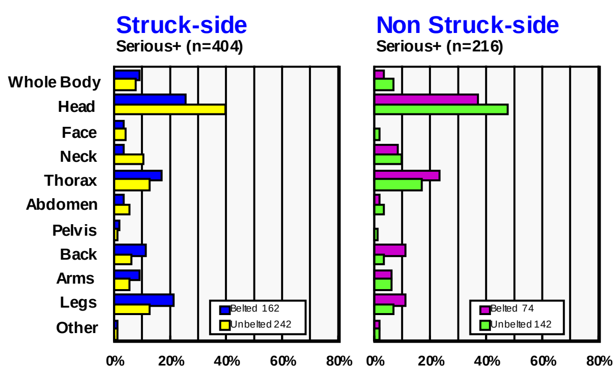


Figure 9. Injured body regions for "Serious +" injuries in single passenger car side impact accidents.

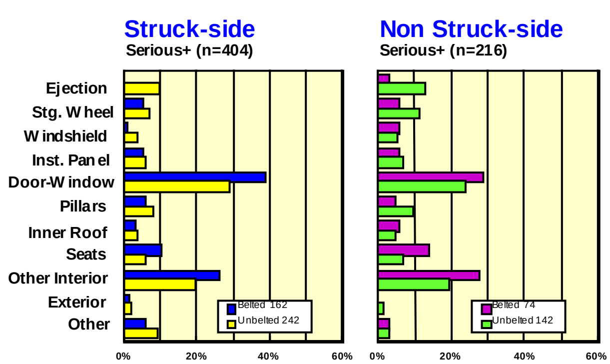


Figure 10. Contact parts for "Serious +" injuries in single passenger car side impact accidents.

Additional Analysis for Side Impact Accidents

Injuries by Gender - Injuries in side impact accidents were analyzed by gender based on the three-year data on passenger car -to-passenger car side impact accidents from 1996 to 1998 in the Statistics, and the results are shown in Figure 11. As for "Serious +" injuries, male passengers were slightly more injured than female passengers, for both struck-side and non struck-side passengers.

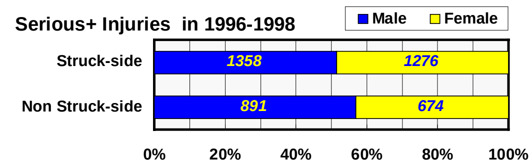


Figure 11. Injuries by gender in side impact accidents.

Injuries by Seating Location - Seating locations of passengers involved in side impact accidents were analyzed based on the eight-year data in the Statistics from 1990 to 1997. As the results in Figure 12 indicate, 85% of the fatalities and 88% of the injuries occur to front seat passengers, while the ratio of rear seat passengers is very small.

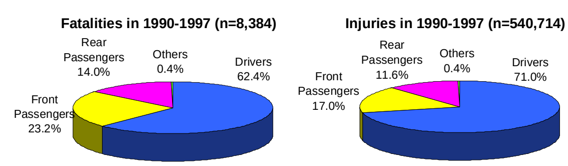


Figure 12. Injuries by seating locations in side impact accidents.

Summary of Side Impact Accident Study

The following information was obtained from our side impact accident study.

- Passenger cars are the type of vehicle most frequently involved in side impact accidents.
- The pole-shaped structures account for about 30% of struck objects in single vehicle side impact accidents.
- A tendency common to both passenger car-to-passenger car side impacts and single passenger car side impacts is that as injury severity increases the proportion of struck-side passengers and unbelted passengers becomes higher .
- In passenger car-to-passenger car side impact accidents, the velocity corresponding to the 50 percentile of struck-side

"Serious +" injuries is 20 to 30 km/h for struck vehicles and 40 to 50 km/h for striking vehicles

- Head, neck and thorax are the most injured body regions, and "door - window" is the most frequent contact part in passenger car-to-passenger car side impact accidents.
- In single passenger car side impact accidents, many occupants sustained head injuries. There were many cases in which the "door - window" was the contact part, although various other contact parts were involved.
- Male passengers were slightly more injured than female passengers in "Serious +" injuries in side impact accidents.
- Front seat passengers account for 85% of the fatalities and 88% of the injuries in side impact accidents.

INVESTIGATION ON VEHICLE FRONT-END CHARACTERISTICS

IHRA SIWG plans to adopt specifications for MDB and its barrier face, which will be used as 'striking vehicles' in the MDB-to-car test procedure, considering the status quo of the recent market conditions in various countries of the world. Based on these conditions, we investigated 1) vehicle mass, 2) front-end geometry, and 3) front-end stiffness of vehicles newly registered in 1998 in Japan and the number of each car model sold annually. We selected three types of vehicles, passenger car, mini van and SUV, taking into account the results of the side impact accident analysis discussed above. Table 1 shows the effective number of cars investigated by study item and vehicle type.

Table 1. Effective number of cars investigated

	Passenger Car	Mini-Van	SUV	Total
Vehicle Mass	2,391,569 (59.4%)	1,297,705 (32.2%)	337,196 (8.4%)	4,026,470 (100.0%)
Front-end Geometry	2,391,569 (59.4%)	1,297,705 (32.2%)	337,196 (8.4%)	4,026,470 (100.0%)
Front-end Stiffness	2,027,119 (66.3%)	760,565 (24.9%)	269,665 (8.8%)	3,057,349 (100.0%)

Vehicle Mass

Figure 13 shows the cumulative percentage of vehicle curb mass. The curb mass corresponding to the 50 percentile of the cumulative percentage was 1,150 kg, as shown in Figure 14. It was an increase of 70 kg from our previous study result of 1,080 kg for 1993 car models. Major causes of this increase are that vehicles tend to become larger in size as well as heavier to incorporate improved safety countermeasures, and that sales of heavier vehicles, such as mini vans and SUVs, have been growing recently. In order to determine the mass of MDB, it was necessary to add the mass of passengers to the vehicle mass with due consideration as to where passengers actually seated themselves.

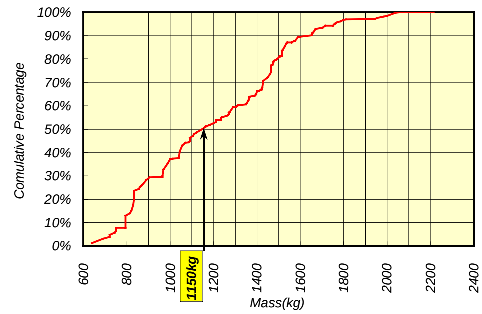
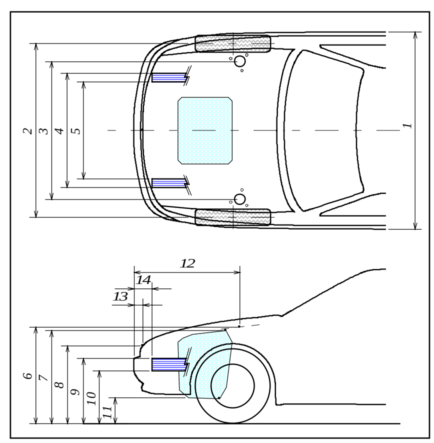


Figure 13. Cumulative percentage of vehicle mass

Front-end Geometry

For the front-end geometry, dimensions of a vehicle front-end structural component were measured. The results were weighted by the number of each car model sold to obtain the "weighted average." Figure 14 shows the measuring points and the weighted average for each dimension, while the front-end structural component height distribution with the vehicle curb mass as a parameter is shown in Fig.15.



	Measurement Point	(mm)
1	Overall Width	1652
2	Tread	1428
3	Front Shock Absorber Fixing Width	1007
4	Longitudinal Member Width(Inner Surface)	982
5	Longitudinal Member Width(Outer Surface)	853
6	Front Shock Absorber Fixing Height	788
7	Engine Top Height	735
8	Bonnet Front-end Height	736
9	Longitudinal Member Top Height	504
10	Longitudinal Member Bottom Height	376
11	Engine Bottom Height	267
12	Front Shock Absorber Fixing from Vehicle Front-end	804
13	Bonnet Front-end from Vehicle Front-end	99
14	Longitudinal Member Front-end from Vehicle Front-end	138

Figure 14. Measuring points and weighted average for each dimension.

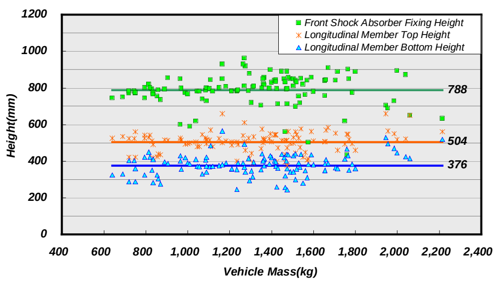


Figure 15. Distribution of vehicle front-end structural component height.

According to the calculation results, the weighted average of the front shock absorber fixing height is 788 mm, slightly lower than 800 mm (i.e., the top of the Japanese and European barrier face). On the other hand, the weighted average of the longitudinal member bottom height is 376 mm, higher than 300 mm, the bottom of the barrier face.

Front-end Stiffness

Front-end stiffness was studied in 86 car models for which the barrier force was measured in frontal impact tests. Of the force-deformation characteristics revealed from the study, the force values for deformation at every 50 mm were summed up. The forces were adjusted in term of surface area ratio to a six-block structure of a barrier face used in the Japanese and European side impact test procedures. To obtain the weighted average, the force values were weighted by the number of cars sold in 1997.

Figure 16 shows the front-end stiffness and the corridor specified for the Japanese and European current barrier face. There is a general tendency for the stiffness of the vehicle upper part to almost correspond to the corridor. However, the vehicle lower part is different from the corridor whereby the stiffness of the left and right parts is higher and that of the central part is lower. The total vehicle stiffness values turned out to be higher than the upper limit of the corridor. It is supposed that this tendency reflects well the results of the incorporation of the offset frontal impact countermeasures into vehicles.

Summary of Vehicle Front-end Characteristics Investigation

The following information was obtained from investigation of the vehicle front-end characteristics:

- Vehicle curb mass that corresponds to the 50 percentile of the cumulative percentage is 1,150 kg, an increase of 70 kg from the 1993 car model study result.
- Front shock absorber fixing height is slightly lower than the top of the current barrier face, and the height of the longitudinal member bottom edge is slightly higher than the bottom of the current barrier face.
- Upper part of the vehicle almost corresponds to the corridor of the current barrier face. As for stiffness of the lower part, the stiffness of the right and left part is higher while that of the central part is lower. It is presumed that the effect of incorporation of offset frontal impact countermeasures into recent vehicles reflected this tendency.

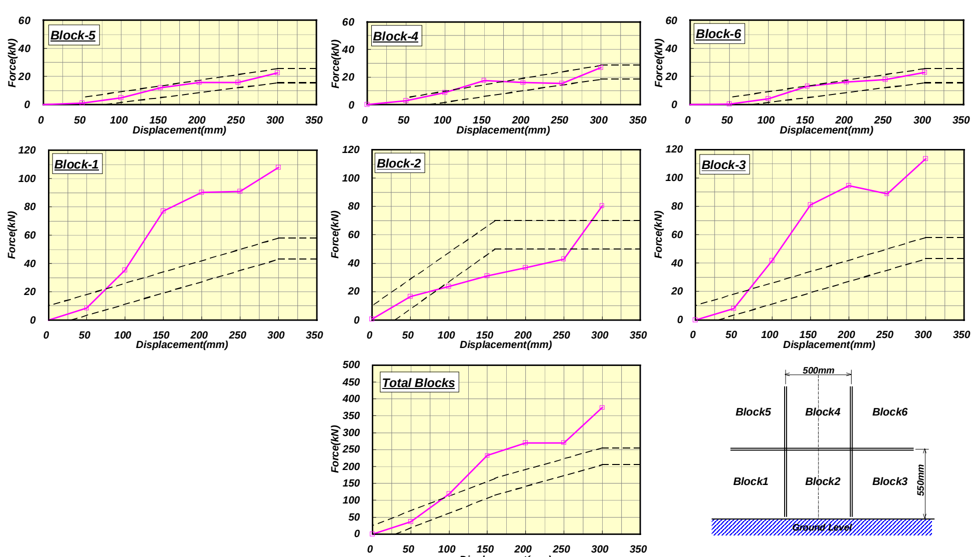


Figure 16. Vehicle front-end stiffness (weighted average based on 1998 car models)

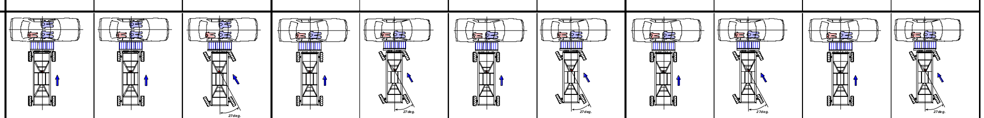
FULL-SCALE SIDE IMPACT TEST

We conducted 11 full-scale side impact tests using two types of Japanese compact passenger cars. The purpose of these tests was to obtain basic data to review the test conditions of the proposed internationally harmonized MDB-to-car test discussed by IHRA SIWG. Major study items include: 1) comparison between struck-side dummy responses and non-struck-side dummy responses, 2) comparison between front dummy responses and rear dummy responses, 3) a review of the impacts of a crab angle on dummy responses, and 4) comparison between EUROSID-1 responses and ES-2 prototype responses. The tests were conducted under the following two conditions: those for the side impact test procedure ECE R95 currently adopted by Japan and Europe and those based on the US side impact test procedure FMVSS214. The details of the test conditions and the peak responses of the dummies are shown in Table 2.

Discussion of Full-scale Side Impact Test Results

Comparison between Struck-side Dummy Responses and Non-Struck-side Dummy Responses – Analytical results of the side impact accidents also revealed that the injury frequency for passengers sitting on seats opposite the side of impact was not lower. The aim of the present study was to assess the capability of the test to evaluate the performance of a tested car's protection of its passengers both on the struck-side and non struck-side. Figure 17 compares the dummy responses between the struck-side and the non struck-side in both the ECE R95 non-crabbed test and 27-degree crabbed test. As shown in Figure 18, the non struck-side dummy responses are lower than those of the struck-side dummies except for HPC in the non-crabbed test. For rib deflection and V*C in particular, their values were very small for non-struck-side dummies, indicating a very low input to the thorax. These tendencies are almost the same as in the FMVSS214-based test. We analyzed this result and concluded that any measurement of injury values using a dummy on the non struck-side is almost meaningless under the current test procedure.

Table 2.
Full-scale side impact test matrix and dummy peak responses

	F991201	F00_0401	F00_0402	F00_0801	F00_0802	F00_0803	F00_0804	F00_1001	F00_1002	F00_1003	F00_1004
Impact Configuration											
Impact Velocity	50 km/h	50 km/h	53.9 km/h	50 km/h	53.9 km/h	50 km/h	53.9 km/h	50 km/h	53.9 km/h	50 km/h	53.9 km/h
MDB Mass	950 kg	950 kg	950 kg	950 kg	950 kg	1368 kg	1368 kg	950 kg	950 kg	1368 kg	1368 kg
Barrier Face Height	300 mm	300 mm	300 mm	300 mm	300 mm	279 mm	279 mm	300 mm	300 mm	279 mm	279 mm
MDB Impact Point	ECE/R95	ECE/R95	ECE/R95	ECE/R95	ECE/R95	FMVSS214	FMVSS214	ECE/R95	ECE/R95	FMVSS214	FMVSS214
Barrier Face Type	ECE/R95	ECE/R95	ECE/R95	ECE/R95	ECE/R95	FMVSS214	FMVSS214	ECE/R95	ECE/R95	FMVSS214	FMVSS214
Struck Vehicle	4drSD-A	4drSD-A	4drSD-A	4drSD-A	4drSD-A	4drSD-A	4drSD-A	4drSD-B	4drSD-B	4drSD-B	4drSD-B
Struck Vehicle Mass	1285 kg	1282 kg	1283 kg	1210 kg	1211 kg	1210 kg	1212 kg	1433 kg	1430 kg	1432 kg	1431 kg
Front Struck-side Dummy	EUROSID-1	SID-IIs β+	EUROSID-1	ES2 Proto.	ES2 Proto.	ES2 Proto.	ES2 Proto.	ES2 Proto.	ES2 Proto.	ES2 Proto.	ES2 Proto.
HPC	138	702	85	172	81	355	196	222	157	448	203
Thoracic Rib Defl.(mm) *1	42.0	51.3	21.7	40.5	25.1	49.3	29.9	42.0	23.4	49.5	41.3
Thoracic Rib V*C(m/s) *1	0.55	0.96	0.14	0.71	0.18	0.99	0.57	0.84	0.22	1.57	0.53
Abdominal Force(kN)	2.45	-	1.55	2.02	1.16	1.22	1.22	1.90	1.29	1.96	1.83
Abdominal Rib Defl(mm) *2	-	60.30	-	-	-	-	-	-	-	-	-
Pubic Force(kN)	3.10	0.51	1.81	3.31	1.73	4.93	3.67	4.10	2.43	4.52	3.29
Iliac Force(kN)	-	5.48	-	-	-	-	-	-	-	-	-
Acetabulum Force(kN)	-	1.86	-	-	-	-	-	-	-	-	-
Rear Struck-side Dummy	SID-IIs β+	EUROSID-1	SID-IIs β+	SID-IIs β+	SID-IIs β+	SID-IIs β+	SID-IIs β+	SID-IIs β+	SID-IIs β+	SID-IIs β+	SID-IIs β+
HPC	154	351	344	127	345	249	423	455	471	731	421
Thoracic Rib Defl.(mm) *1	29.2	17.3	39.4	33.6	39.4	31.9	39.8	20.2	27.4	17.6	34.9
Thoracic Rib V*C(m/s) *1	0.25	0.08	0.62	0.50	0.62	0.31	0.59	0.15	0.21	0.16	0.62
Abdominal Rib Defl(mm) *2	33.3	-	47.1	35.6	44.4	33.9	48.4	17.7	31.0	18.2	33.8
Abdominal Force(kN)	-	1.27	-	-	-	-	-	-	-	-	-
Pubic Force(kN)	N.M. *3	3.60	0.24	0.31	0.30	0.77	0.97	0.43	0.29	0.80	1.17
Iliac Force(kN)	N.M. *3	-	0.52	3.62	0.33	0.95	2.73	0.05	0.08	0.05	0.08
Acetabulum Force(kN)	N.M. *3	-	1.50	1.30	1.87	1.27	3.47	1.42	1.09	1.70	2.22
Front Non Struck-side Dummy	EUROSID-1	EUROSID-1	EUROSID-1	No Dummy	No Dummy	No Dummy	No Dummy	No Dummy	No Dummy	No Dummy	No Dummy
HPC	233	215	21	-	-	-	-	-	-	-	-
Thoracic Rib Defl.(mm) *1	2.5	5.0	0.6	-	-	-	-	-	-	-	-
Thoracic Rib V*C(m/s) *1	0.00	0.01	0.00	-	-	-	-	-	-	-	-
Abdominal Force(kN)	0.48	0.34	0.48	-	-	-	-	-	-	-	-
Pubic Force(kN)	1.40	1.43	1.27	-	-	-	-	-	-	-	-

*1 ; Max of three Thoracic Ribs *2 ; Max of two Abdominal Ribs *3 ; N.M. = not measured

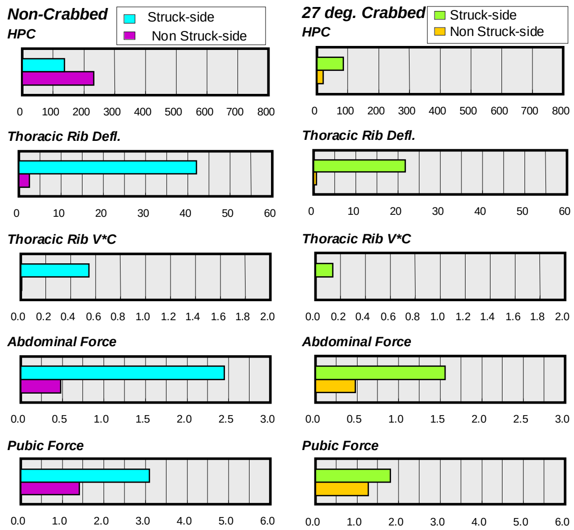


Figure 17. Comparison between struck-side and non struck-side dummy responses.

<u>Comparison between Front and Rear Dummy Responses</u> -Dummy responses in the front seat were compared to those in the rear seat in the ECE R95 non-crabbed test to assess if the test was capable of evaluating rear seat dummy responses in the current test conditions. The comparison results for front and rear seat dummy responses for EUROSID-1 and SID-IIs are shown in Figure 18.

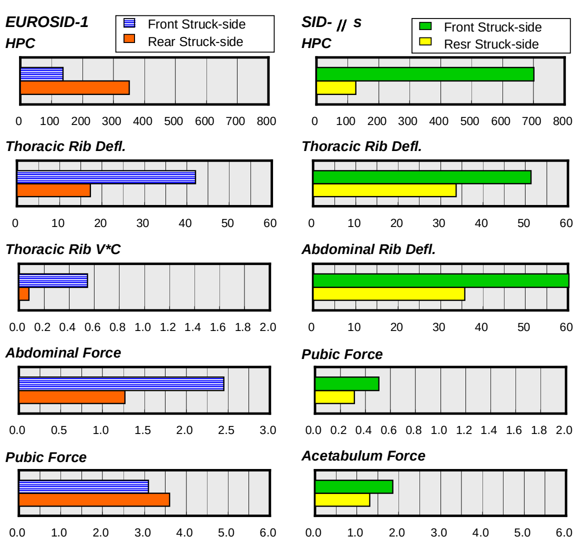


Figure 18. Comparison between front and rear dummy responses in ECE R95 non-crabbed test.

The values for the thorax and abdomen for both types of dummies are higher for front seats, while those for the head and pelvis show a different inclination depending on the anthropometry of the dummy. It is revealed from this finding that rear seat dummy responses can be higher than front ones even in the non-crabbed test depending on the anthropometry of the dummy used.

<u>Effect of Crab Angle for Dummy Responses</u> - Here, effects of the MDB with or without a crab angle on front and rear dummy responses in a striking vehicle were studied.

A sample of front and rear dummy response comparison based on the ECE R95-based test condition with or without a crab angle is shown in Figure 19 and Figure 20. It is clearly seen for front dummies, that the responses are lower in the 27-degree crabbed test than the non-crabbed test for both Vehicle A and Vehicle B. An almost similar inclination is also seen in the FMVSS214-based test. For rear dummies, the results are different from front dummies. With respect to rib deflection values for the thorax and abdomen, the responses are higher in the 27-degree crabbed test than non-crabbed test for both Vehicle A and Vehicle B. For the FMVSS214-based test, the responses are higher in the 27-degree crabbed test than in the non crabbed test for not only the thorax and abdomen rib deflection values but also the pubic force and acetabulum force.

For ECE R95 27-degree crabbed test, it was originally feared that the adhesion surface of the barrier face would cause peeling. However, no such problem arose for the multi-layer type barrier face used in our tests. The post-test condition of the barrier face is shown in Figure 21.

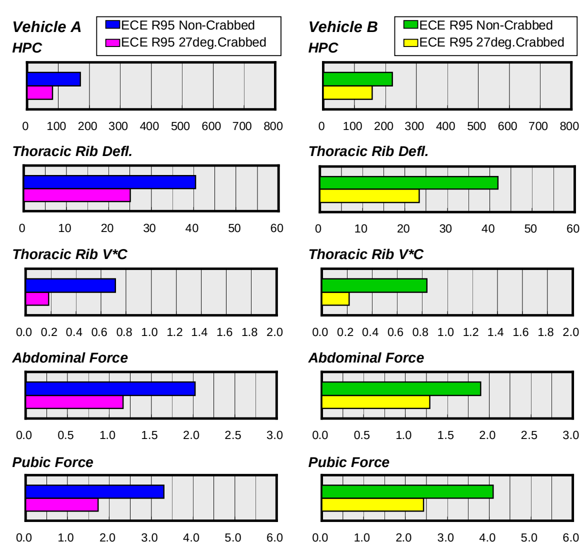


Figure 19. Comparison between non-crabbed test with 27-degree crabbed test - front dummy responses.

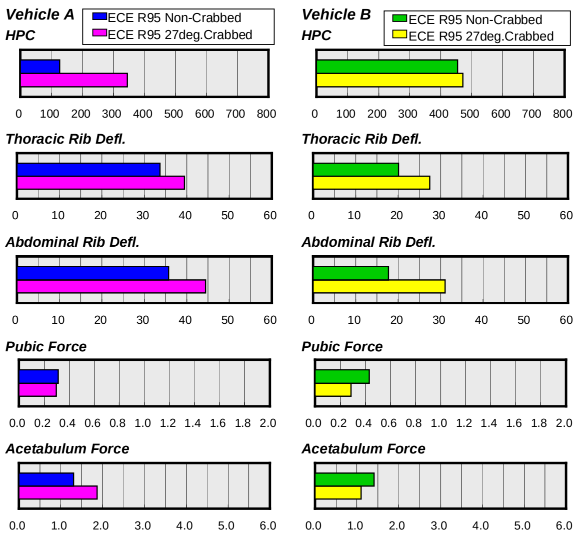


Figure 20. Comparison between non-crabbed test with 27-degree crabbed test - rear dummy responses.

Figure 21. Barrier face deformation - ECE R95-based tests.

Comparison between EUROSID-1 Responses with ES-2 Prototype Responses – Responses of the EUROSID-1 and ES-2 prototype were compared under the same test conditions to evaluate the improvement effect and to study the differences in their characteristics.

Figure 22 shows the responses of the EUROSID-1 and ES-2 prototype in the ECE R95 non-crabbed test and the ECE R95 27-deg. crabbed test using vehicle A.

In the non-crabbed tests, the maximum rib deflection values of both dummies were almost the same, while vibration was generated after deflection occurred only in the ES-2 prototype responses. Depending on the difference in rib deflection rate, V*C of the ES-2 prototype is higher than that of the EUROSID-1. Although the abdomen showed no modification, abdominal force of the ES-2 prototype is lower than that of the EUROSID-1. This is probably because the modification of the thorax and pelvis regions generated some side effects. It appears that the ES-2 prototype showed some improvement in the second peak of pubic force, which was very apparent with the EUROSID-1.

In the 27-deg. crabbed test, the flat top phenomenon that occurred in the EUROSID-1 rib deflection responses appears to have been slightly attenuated with the ES-2 prototype. However, it is supposed to be a phenomenon almost similar to the flat top in the upper rib deflection response in 27-deg. crabbed test using another vehicle (i.e.,Vehicle B) as shown in Figure 23. ES-2 prototype shows a lower abdominal force than that of the EUROSID-1 as in the case of the non-crabbed test.

From these results, it seems the ES-2 prototype has been improved in terms of the flat top phenomenon and the generation of the second peak in pubic force. However, further consideration based upon on many test results is needed to improvements in the flat top phenomenon and the rib deflection oscillation phenomenon.

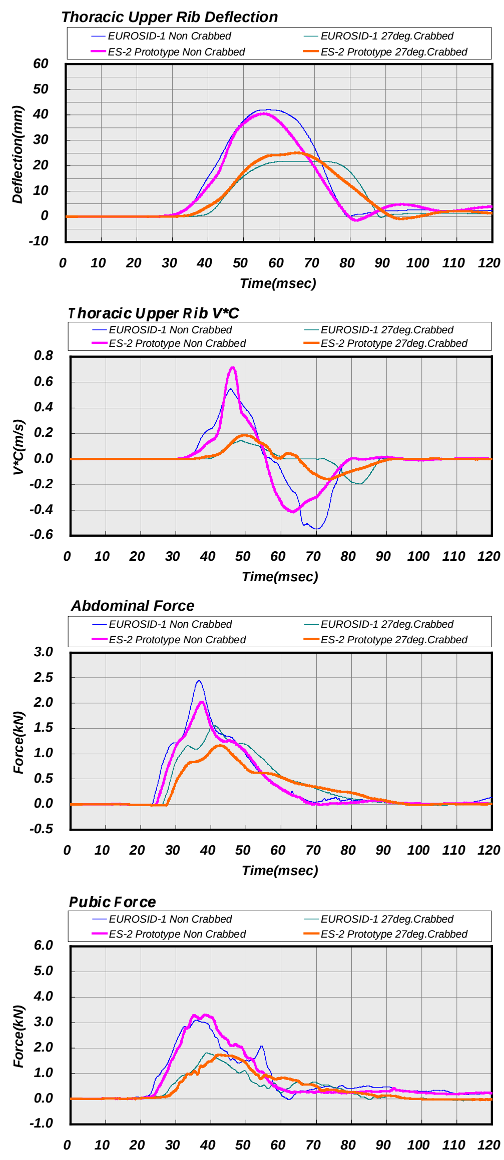


Figure 22. Comparison of EUROSID-1 responses and ES-2 Prototype responses in ECE R95-based tests (Vehicle A).

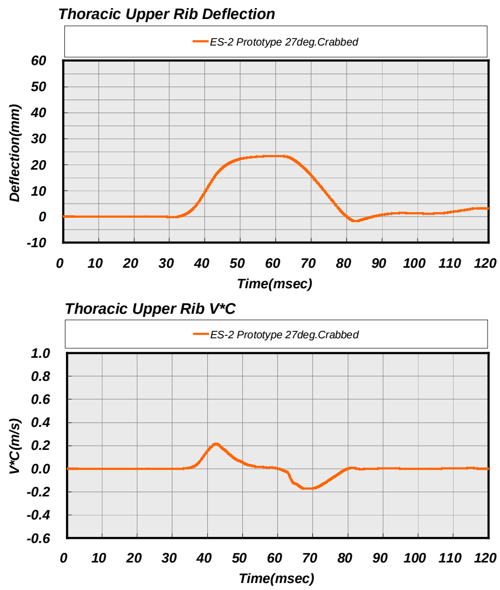


Figure 23. ES-2 Prototype thoracic responses in ECE R95 27-deg. Crabbed test (Vehicle B).

Summary of Full-scale Side Impact Test Results

The results of 11 cases in a full-scale side impact test series were as follows:

- The current test procedures have difficulty in evaluating non struck-side passenger protection. Therefore, a different evaluation procedure should be developed or used.
- Rear seat dummy responses can be higher than front ones depending on the anthropometry of the dummy used in a test. The current test procedure makes it possible to evaluate rear seat passenger protection.
- Non-crabbed test condition is more severe for front seat dummies and crabbed test condition is more severe for rear seat dummies. A test with or without a crab angle should therefore be considered in the light of these results and the priority of passenger protection in actual accidents.
- The ES-2 prototype has been slightly improved with regard to some structural problems of the EUROSID-1. However, these improvement effects need to be validated by further testing.

CONCLUSION

The Japanese view of the internationally harmonized side impact test procedure in the future has been developed as explained above. Here is an overview:

- Impact velocity - Based on the results of accident analysis, it is concluded that the appropriate MDB longitudinal impact velocity is 50 km/h.
- MDB specifications – There were some differences between the front-end characteristics of current vehicles and those of the current MDB and barrier face. Therefore, the specifications of the MDB should be dividable into six blocks. In conclusion, the appropriate MDB should have 1150 (+100 to 150) kg in mass, 1,600 to 1,800 mm in width, 500 to 550 mm in effective height, and 300 to 350 mm in ground clearance. It is also considered the stiffness of MDB should simulate the stiffness distribution of recent vehicles.
- Dummy – At this writing, only the 50th percentile adult male dummy has the possibility of being internationally harmonized. Therefore, it is necessary to continue using the 50th percentile adult male dummy until a more appropriate dummy size is specified worldwide.
- Protection of rear passengers - For the protection of rear seat passengers, a comprehensive review needs to be made on the size of the dummies and the geometry and stiffness of MDB. However, it was found that even in the non-crabbed test condition, evaluation of vehicle performance for rear seat passengers would still be possible.
- Protection of non struck-side passengers – Non struck-side passenger protection is considered difficult to evaluate by the current dummy-based test procedures.

REFERENCES

1) 49 CFR Part 571, "FMVSS214; Side Impact Protection" (1990).
2) ECE Regulation No. 95, "Uniform provisions concerning the approval of vehicles with regard to the protection of the occupants in the event of a lateral collision" (1995).
3) 96/27/EC, "Directive 96/27/EC of the European parliament and of the Council of 20 May 1996 on the protection of occupants of motor vehicles in the event of a side impact and amending Directive 70/156/EEC" (1996).
4) EEVC WG12, "Status of Side Impact Dummy Development in Europe" (2000).
5) ISO/TC22/SC12/WG5-N597, "ISO World-SID Task Group Status Report to ISO/TC22/SC12/WG5", April 2000