RESEARCH OF CRS SIDE IMPACT TEST PROCEDURES USING AN ACCELERATION TYPE SLED SYSTEM

Yoshinori Tanaka
Naruyuki Hosokawa
Daisuke Yamaguchi
Yasuhiro Matsui
National Traffic Safety and Environment Laboratory
Japan
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ABSTRACT

Accident data show that the injury risks to children seated in child restraint systems (CRSs) are higher in side collisions than those in any other types of collisions. Accordingly, NHTSA [1] reported about CRS side impact test methods. In WG29/GRSP, the ISOFIX type CRS new regulation [2] was accepted at the 2011 December GRSP. Adding side impact sled test is one of the topics for a new regulation.

In Europe, the deceleration type sled system is most commonly available, and consequently most studies regarding CRS side impact tests are done by the deceleration type sled system. But NTSEL, the type approval test department in Japan, has an acceleration type sled system, so it is necessary to confirm that the CRS side impact test procedure of new regulation can be tested by the acceleration type sled test system.

In this present research, NTSEL conducted CRS side impact sled test series for evaluating the CRS side impact test procedure by using an acceleration type sled system. The test methods using our acceleration type sled system are almost same as those published in NHTSA's 2009 ESV technical paper [1]. The tests series we conducted are as follows: (1) We conducted tests to confirm that the test conditions of new regulation can be satisfied by an acceleration type sled system. (2) We conducted tests to confirm that the severities of the CRS side impact test used by the deceleration sled and the acceleration sled are similar or not. (3) We conducted tests to confirm whether there are any problems with the specified CRS side impact test procedures or not.

(1) The CRS side impact test conditions specified by the new regulation were defined to be the relative velocity and the intrusion between the door and seat. We confirmed that the tests using an acceleration type sled system could satisfy the relative velocity corridor and intrusion as proposed in new regulation.

(2) Test data measured by the deceleration type sled systems from European test laboratories were obtained in order to compare the severities between the different types of sled systems. We then compared the 2 different CRSs test data. As for the dummy injury measures, the coefficients of variation were less than 10% with the exception of that for the neck. As a result, the severities of the CRS side impact tests conducted using a deceleration sled and an acceleration sled were determined to be similar.

(3) We confirmed the main test parameters which determine dummy injury measures to evaluate whether test conditions of the new regulation were specific enough or not for evaluating the CRS performance. So we conducted tests under 2 different conditions which both satisfy the test conditions of new regulation (i.e., the relative velocity and intrusion between the door and seat), and we collected the different dummy injury measures. These test data indicated that additional conditions are needed for the CRS side impact test procedure of the new regulation to make the conditions the same in various tests. We studied the parameters which influenced the dummy injury measures. We confirmed that the relative velocity between the door and dummy had a large influence on the dummy injury measures. Therefore, we propose to add the door velocity condition to the CRS side impact test procedure.

INTRODUCTION

Accident data show that the injury risks to children seated in child restraint systems (CRSs) are higher in side collisions than those in any other types of collisions. Accordingly, there have been a number of reports published about CRS side impact. Arbogast et al. [3] have shown the side impact accident data in which occupants restrained in a CRS were injured. Sullivan et al [1] (NHTSA) reported about CRS side impact test methods using an acceleration type sled. Yoshida et al [4] have presented test results of CRS occupant behavior for oblique car-to-car side impact tests and for sled tests. Johannsen et al [5] have published an update of the CRS side impact test procedure.

Consumers internationally want to revise the UN R44 (Standard of CRS) and introduce a side impact test. Therefore, an informal working group on CRS was convened for the purpose of making a new CRS

regulation. After having been studied by the informal group in WG29/GRSP, the ISOFIX type CRS new regulation was accepted at the 2011 December GRSP. Adding side impact sled test is one of the topics of the new regulation.

In the research of informal group, most studies about CRS side impact test were conducted using a deceleration type sled system. But in the regulation, the sled type is not defined. So it is necessary to confirm that the CRS side impact test procedure specified in the new regulation can be conducted using an acceleration type sled test system. National Traffic Safety and Environment Laboratory (NTSEL), the type approval test department in Japan, only has an acceleration type sled system, so we especially need to confirm that is an appropriate system to use for conducting the testing.

METHOD

Test condition in new regulation

In the CRS new regulation accepted by the GRSP, there are no specified sled systems which are to be used for conducting the dynamic tests, for example frontal impact test or side impact test. Only the relative velocity between the door and seat and the door maximum intrusion relative to the seat are defined with respect to the dynamic specifications for side impact test.
Figure 1 shows the size of the test bench seat and Figure 2 shows the definition of 'T=0ms' and door maximum intrusion, which are defined in the CRS new regulation [2].

'T = 0 ms' is defined as the time when the door is at a 350 mm distance from the center of CRS. The maximum door intrusion is 250 mm movement from the position at T = 0 ms, (at an 100 mm distance from the CRS center).

Figure 3 shows the corridor of the relative velocity between the door and seat (defined as the 'Curve of relative velocity between the trolley and door panel as a function of time' in the regulation [2]). In our test plan using the acceleration type sled, the door is fixed at the trolley and the seat is moved on the rail fixed at the trolley, so we think that the relative velocity between the door and seat need to be within the specified corridor.

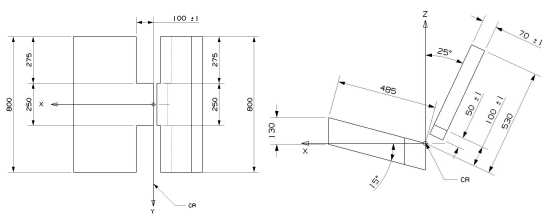


Figure1. Tested bench seat

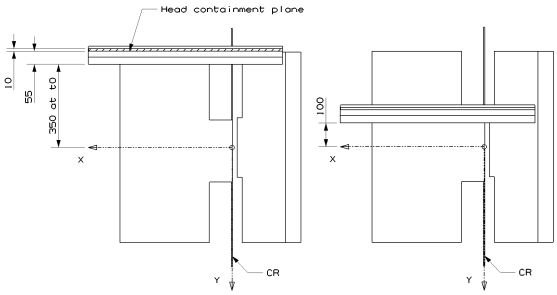


Figure2. Definition of 'T = 0 ms' and Door maximum intrusion

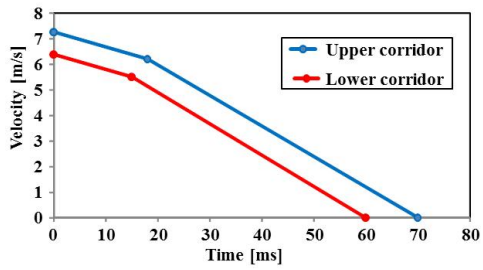


Figure3. Relative velocity corridor

Test Jig

Figure 4 shows the CRS side impact test jig using an acceleration type sled system. This is the same as the system presented in NHTSA's ESV paper [1].

Figure4. Test jig

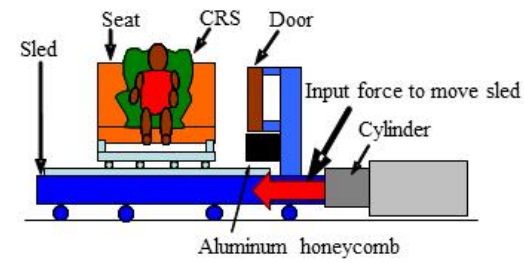
Figure 5 shows the process of our CRS side impact test. Figure 6 shows the velocity time histories of our test.

Figure 5 (a) shows the condition from T = -80ms to T = 0ms. The sled is accelerated by a cylinder until the sled velocity reaches the specified velocity. Then the sled velocity remains constant. The door is fixed at the sled; hence the door velocity is the same as the sled velocity. In the new regulation, the relative velocity corridor is specified to be greater than 6.375 m/s and less than 7.25 m/s at T = 0ms.

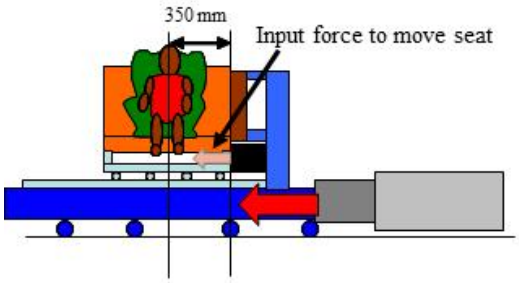
Figure 5 (b) shows the T = 0 ms condition, which is defined as to when the door is at a 350mm distance from the CRS center. The aluminum honeycomb pushes the seat at T = 0 ms. At that time, the seat starts to move.
Figure 5 (c) shows the time duration from the time T = 0 ms to the time when the intrusion is maximum.

The aluminum honeycomb pushes the seat, so seat is accelerated. The door moves at a constant velocity and the relative velocity between the seat and door changes. When the seat velocity becomes the same as the door velocity, the relative velocity between the door and seat is 0 m/s and the door intrusion reaches a maximum. In Figure 6, the seat velocity catches up with the door velocity at T = 62 ms, and at that time the relative velocity is 0 m/s.

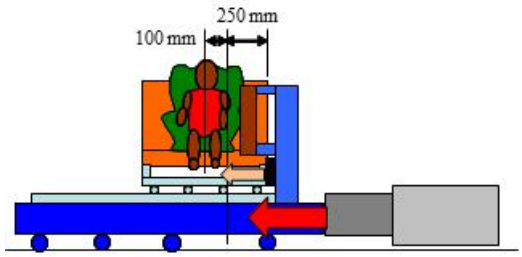
In this test procedure, the relative velocity is kept within the specified corridor under the condition that the door velocity is greater than 6.375 m/s and less than 7.25 m/s for the time period starting at T = 0 ms and stays within the corridor up to the time at which the door incurs its maximum intrusion. See Figure 6. The seat acceleration is able to be controlled during this time.



(a) -80ms < t < 0ms



(b) T = 0ms



(c) 0 < t

Figure5. Test process

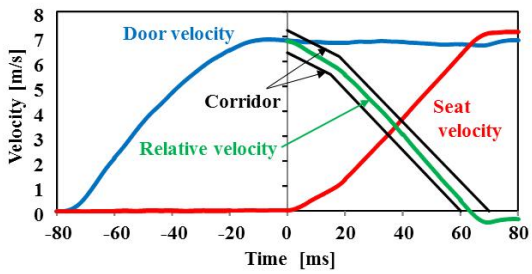


Figure6. Velocities time histories

Figure 7 shows the locations of the uni-axial accelerometers attached to the test jig. Door and seat velocities are calculated by integrating the acceleration data measured with the accelerometers.

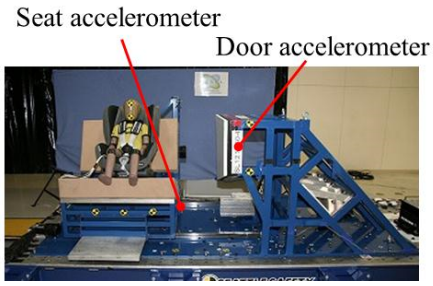


Figure7. Attachment locations of accelerometers

Used dummy

Figure 8 shows the dummy used in this test series. We used the Q3 dummy which is specified for use by the regulation.

Figure8. Tested dummy

Tested CRS

Figure 9 shows the tested CRS. We used 3 CRS which are sold in Japan. All the CRS are attached to the vehicle by ISOFIX. CRS A uses a top tether to limit the pitch rotation of the CRS. CRS B and C use a support leg to limit the pitch rotation of the CRS. In the new regulation, the support leg is also recognized as ISOFIX universal; though in the UN Regulation No.44 which is current CRS standard, the support leg is not recognized as ISOFIX universal.

CRS A is able to be attached to vehicle not only by ISOFIX but also by a seatbelt.

(a) CRS A (b) CRS B (c) CRS C

Figure9. Tested CRSs

RESULTS

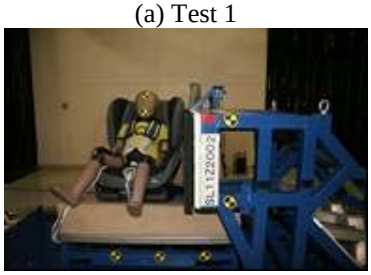
Sled Tests

Repeatability

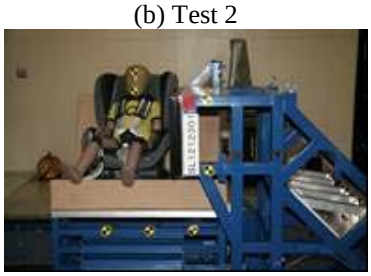
We conducted 5 CRS side impact tests using CRS A under the same conditon for in order to study repeatablity. The test condition used was the same as that specified in the CRS new regulation.

Figure 10 shows post-test photographs of the CRS and dummy. The conditions were almost same in all of the tests. There were no broken CRSs resulting from this test series.

(a) Test 1

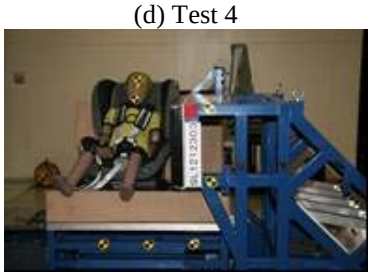


(b) Test 2



(c) Test 3

(d) Test 4



(e) Test 5

Figure10. Post-test photographs

Figure 11 shows the door velocities time histories. Figure 12 shows the seat velocites time histories. Figure 13 shows relative velocity time histories between the door and seat. The relative velocity is calclated by subtracting the seat velocity from the door velocity.

Door velocities, seat velocities, and relative velocities were very similar in all 5 tests. The maximum difference of the door velocity for the time duration from T = 0 ms to the time when the door intrusion was maximum was 0.16 m/s. The maximum difference of the seat velocity during the same time period was 0.27 m/s. The maximum difference of the relative velocity during the same time period was 0.33 m/s. The differences were very small so the test procedure using our test facility was deemed to provide a good repeatability performance.

In this test series, the relative velocities were within the specified corridors. The door intrusions were almost 250 mm in this test series. So we confirmed that our test procedure using an acceleration type sled system could satisfy the relative velocity corridor and intrusion as proposed in the new regulation.

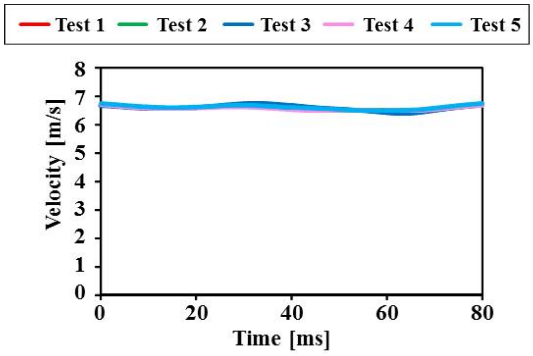


Figure11. Door velocities time histories

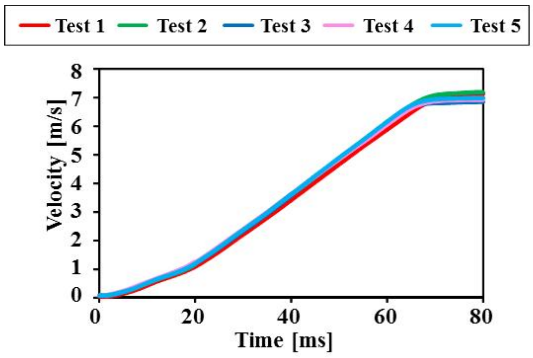


Figure12. Seat velocities time histories

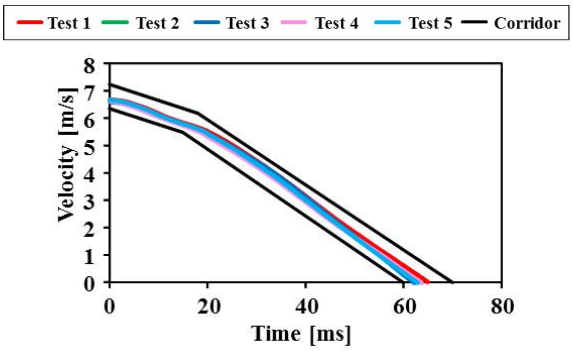


Figure13. Relative velocities between door and seat time histories

Table 1 shows the maximum injury measures. HPC15, head resultant maximum acceleration (3 ms), thorax rib deflection, thorax resultant maximum acceleration (3 ms), and pelvis resultant maximum acceleration (3 ms) were measured in this test series. Figure 14 shows deviation to means of maximum injury measures and coefficient values.

The maximum deviation to the means for HPC15 was 7%. That for the head resultant maximum acceleration (3 ms) was 3%. That for the thorax rib deflection was 8%. That for the thorax resultant maximum acceleration (3 ms) was 4%. That for the pelvis resultant maximum acceleration (3 ms) was 12%. The deviations to the means were less than 10% except for the pelvis resultant maximum acceleration (3 ms) in Test 2. The deviation to mean for the pelvis resultant maximum acceleration was nearly 10%.

The coefficient value of HPC15 was 4%. That of the head resultant maximum acceleration (3 ms) was 2%. That of the thorax rib deflection was 6%. That of the thorax resultant maximum acceleration (3 ms) was 3%. That of pelvis resultant maximum acceleration (3 ms) was 8%. So the coefficient values were less than 10%. So as for the maximum injury measures, the repeatability was good in this test procedure.

Table1. Maximum Injury measures

	unit	Test 1	Test 2	Test 3	Test 4	Test 5
HPC15		410	432	430	419	460
Head resultant maximum acceleration (3ms)	m/s2	730	751	742	733	767
Thorax rib deflection	mm	22	23	20	21	20
Thorax resultant maximum acceleration (3ms)	m/s2	566	583	544	572	576
Pelvis resultant maximum acceleration (3ms)	m/s2	796	670	799	719	804

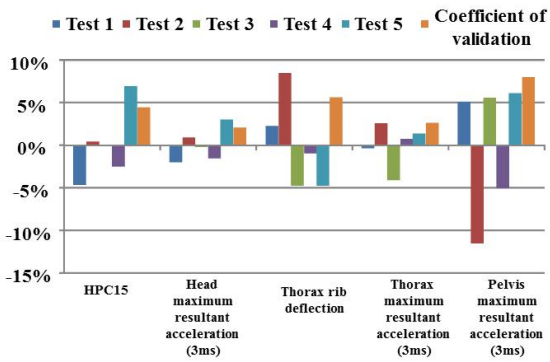


Figure14. Deviation to the means of the maximum injury measures

Figure 15 shows the dummy head resultant acceleration time histories. Figure 16 shows the thorax resultant acceleration time histories. Figure 17 shows the pelvis resultant acceleration time histories. As for the head and thorax, the shapes of the resultant accelerations were very similar in this test series. As for the pelvis, there were observed differences. There is the possibility that a small difference in the dummy leg positioning resulted in the difference in the shapes of the pelvis accelerations. But even though there were observed differences in the pelvis resultant accelerations, the head resultant accelerations were very similar. So, it was concluded that the pelvis acceleration had little influence on the dummy head behavior and resulting injury measures. Furthremore, the head injury measures were the most important compared to the other body regions because the most injured region was the head in fatal or serious injury accidents.

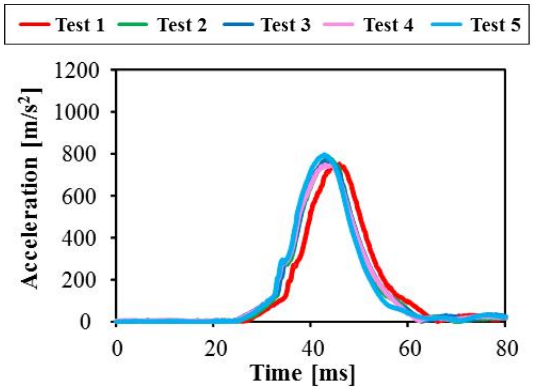


Figure15. Dummy head resultant acceleration time histories

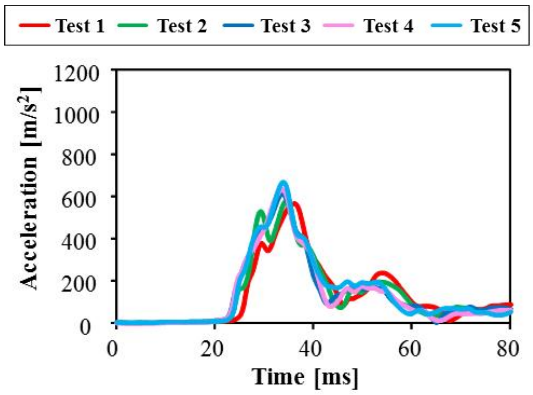


Figure16. Dummy thorax resultant acceleration time histories

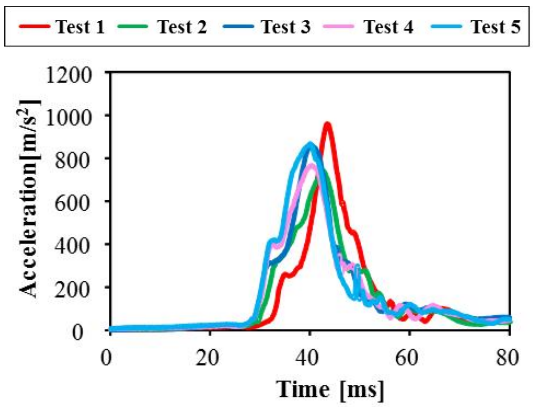


Figure17. Dummy pelvis resultant acceleration time histories

Comparison test data between an acceleration type sled and a deceleration type sled

We conducted CRS side impact tests using CRS A and B under the same conditions as the deceleration type sled test, the data for which we received from a member of CRS informal group under WP29/GRSP. The purpose was to confirm that the severity of the test provided by an acceleration type sled was same as that provided by a deceleration type sled. The dummy, door pad material, and CRS used in the test series were the same in both types of sled tests.

Table 2 shows the maximum injury measures. HPC15, head resultant maximum acceleration (3 ms), thorax resultant maximum acceleration (3 ms) and pelvis resultant maximum acceleration (3 ms) were measured in this test series. The thorax deflection was not measured in the test used by deceleration type sled, so thorax deflection was not included in the Table 2 since there were no data available for making comparisons.

Figure 18 shows the deviation to the means of the maximum injury measures and the coefficient values for CRS A. Figure 19 shows the deviation to the means of the maximum injury measures and the coefficient values for CRS B.

The maximum deviation to the means for HPC15 was 1.1% in CRS A and 2.0% in CRS B. That for the head resultant maximum acceleration (3 ms) was 1.5% in CRS A and 0.3% in CRS B. That for the thorax resultant maximum acceleration (3 ms) was 1.9% in CRS A and 6.1% in CRS B. That for the pelvis resultant maximum acceleration (3 ms) was 3.1% in CRS A and 0.1% in CRS B. The deviations to the means were less than 10% in all of the tests.

The coefficient value of HPC15 was 1.6% in CRS A and 2.9% in CRS B. That of the head resultant maximum acceleration (3 ms) was 2.2% in CRS A and 0.5% in CRS B. That of the thorax resultant maximum acceleration (3 ms) was 2.7% in CRS A and 8.6% in CRS B. That of the pelvis resultant maximum acceleration (3 ms) was 4.4% in CRS A and 0.1% in CRS B. So the coefficient values were less than 10%. Hence, with respect to the maximum injury measures, it was determined that the test severities were very similar for both the acceleration type sled and the deceleartion type sled.

Table2. Maximum Injury measures

	unit	CRS-A		CRS-B	
		Acceleration type sled	Deceleration type sled	Acceleration type sled	Deceleration type sled
HPC15		410	401	328	315
Head resultant maximum acceleration (3ms)	m/s2	719	697	597	601
Thorax resultant maximum acceleration (3ms)	m/s2	497	479	618	547
Pelvis resultant maximum acceleration (3ms)	m/s2	730	685	868	867

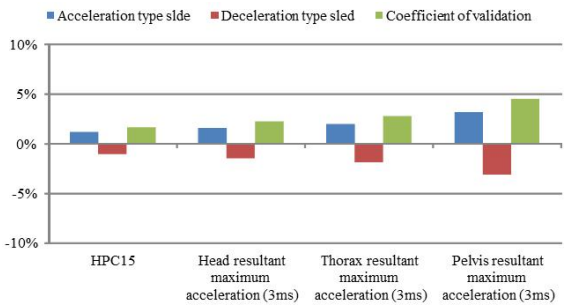


Figure18. Deviation to means of maximum injury measures in CRS A

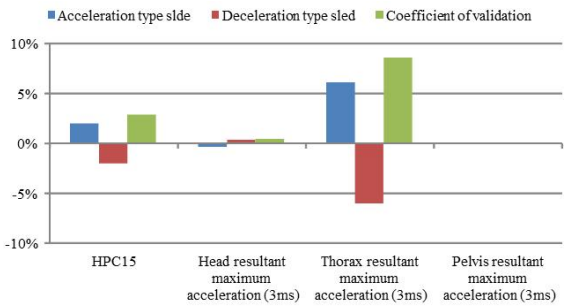


Figure19. Deviation to means of maximum injury measures in CRS B

Figure 20 shows the dummy head resultant acceleration time histories for CRS A. Figure 21 shows the thorax resultant acceleration time histories for CRS A. Figure 22 shows the pelvis resultant accelerations time histories for CRS A.

Figure 23 shows the dummy head resultant acceleration time histories for CRS B. Figure 24 shows the thorax resultant acceleration time histories in CRS B. Figure 25 shows the pelvis resultant accelerations time histories for CRS B.

All the shapes of the accelerations were very similar, though the initiation times of the pulses were different. It was observed that the dummy behaviors were very similar in the tests conducted for both the acceleration type sled and deceleartion type sled.

It was judged that the timing differences probably were due to the difference from the the variability of the T = 0 ms.

From these results, the test severities were determined to be almost the same for the acceleration type sled system and for the deceleration type sled system when the tests were conducted under the conditions specified by the new test regulation.

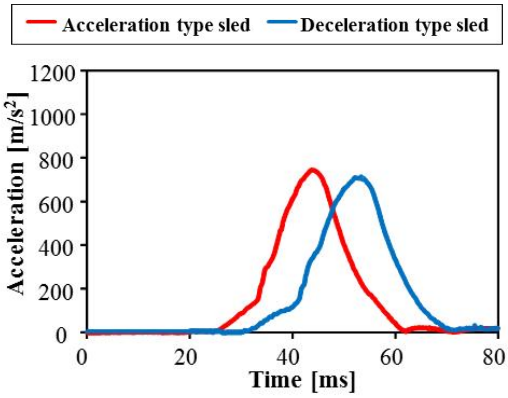


Figure20. Dummy head resultant accelerations time histories for CRS A

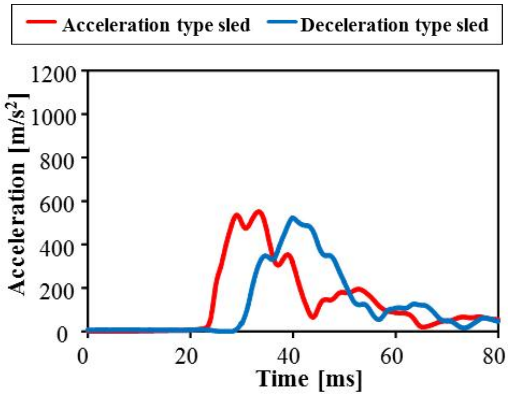


Figure21. Dummy thorax resultant accelerations time histories for CRS A

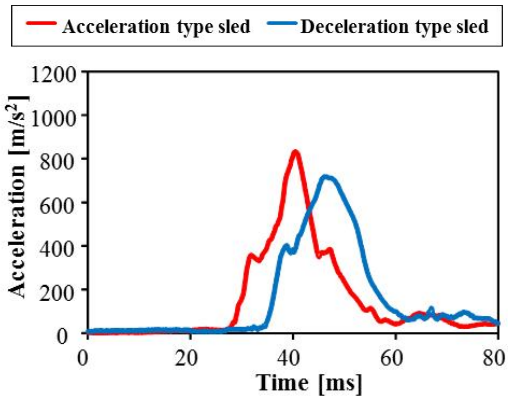


Figure22. Dummy pelvis resultant accelerations time histories for CRS A

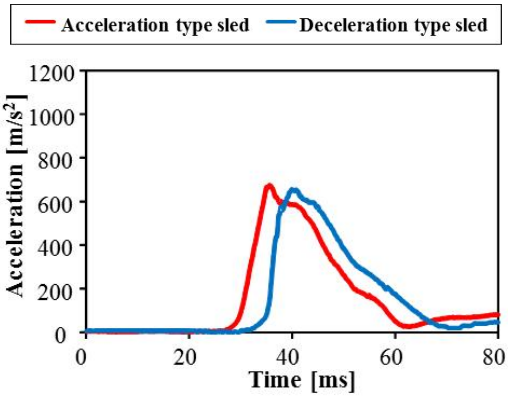


Figure23. Dummy head resultant accelerations time histories for CRS B

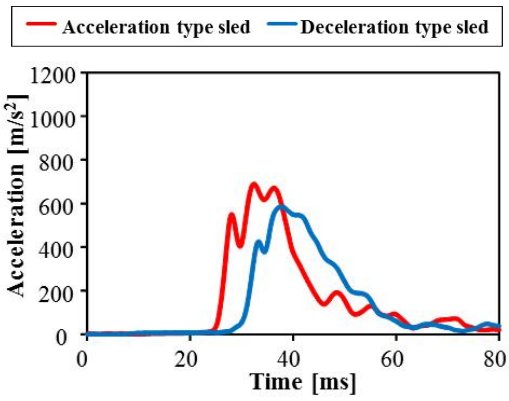


Figure24. Dummy thorax resultant accelerations time histories for CRS B

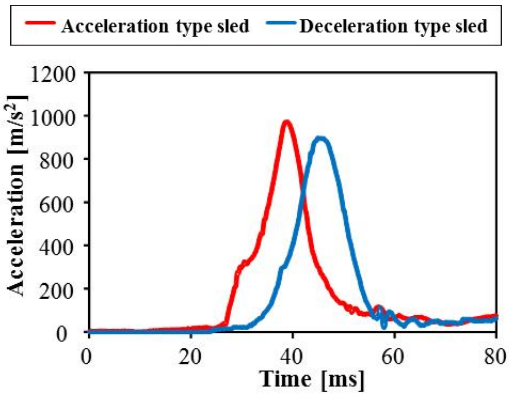


Figure25. Dummy pelvis resultant accelerations time histories for CRS B

Research for the test parameters which influenced to dummy injury measures

Door velocity

We conducted a CRS side impact tests series using CRS A to study the influence of changing the door velocity on dummy injury measures.

The door velocities were changed to attain 3 levels, 6.6 m/s, 6.0 m/s and 5.3 m/s. The door intrusion was 250 mm, and was kept the same in all tests.

Figure 26 shows the relative velocity time histories between the door and seat. The cases for which the door velocities were 6.0 m/s and 5.3 m/s were not within the specified corridors.

This was because the door velocity at time T = 0 ms was outside of the corridor. Because that the door intrusions were same, the seat velocities were different when the door velocities were different.

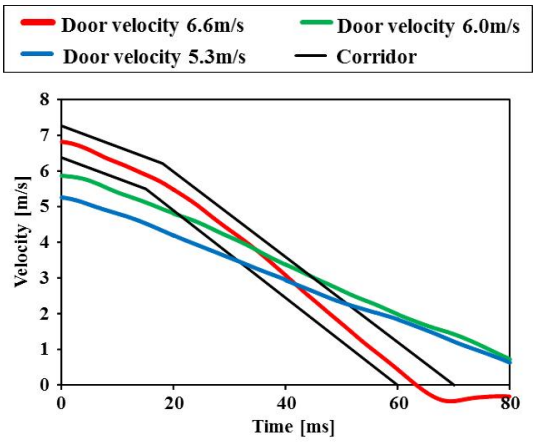


Figure26. Relative velocity time histories

Table 3 shows the maximum injury measures. The HPC15, head resultant maximum acceleration (3 ms), thorax rib deflection, thorax resultant maximum acceleration (3 ms), and pelvis resultant maximum acceleration (3 ms) were measured in this test series. All the dummy injury measures were the highest when the door velocity was 6.6 m/s. The next highest injury measures were for the case for when the door velocity was 6.0 m/s. The injury measures for when the door velocity was 5.3 ms were the lowest.

So it is highly likely that the door velocity has a large influence on the dummy injury measures. Please recall that the door intrusions were the same in all of the tests. So it is a possibility that the door intrusion has little influence on the dummy injury measures.

Table3. Maximum Injury measures

	unit	Door velocity		
		6.6m/s	6.0m/s	5.3m/s
HPC15		430	234	173
Head resultant maximum acceleration (3ms)	m/s2	742	560	511
Thorax rib deflection	mm	20	15.9	12.1
Thorax resultant maximum acceleration (3ms)	m/s2	544	396	332
Pelvis resultant maximum acceleration (3ms)	m/s2	799	525	445

Figure 27 shows the dummy head resultant acceleration time histories. Figure 28 shows the thorax resultant acceleration time histories. Figure 29 shows the pelvis resultant accelerations time histories.

The dummy accelerations for each body region became higher when the door velocity was larger. So it is highly likely that the door velocity has a large influence on the dummy‘s kinematic behavior.

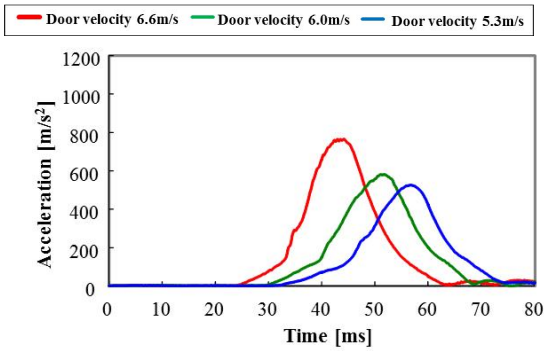


Figure27. Dummy head resultant accelerations time histories

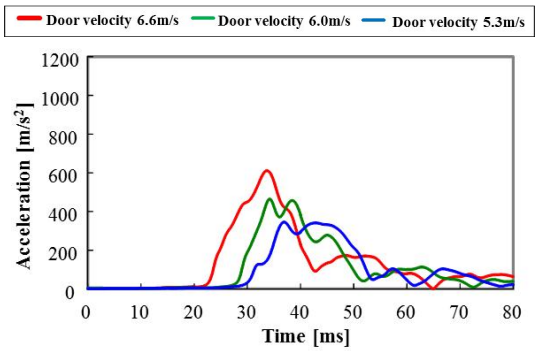


Figure28. Dummy thorax resultant accelerations time histories

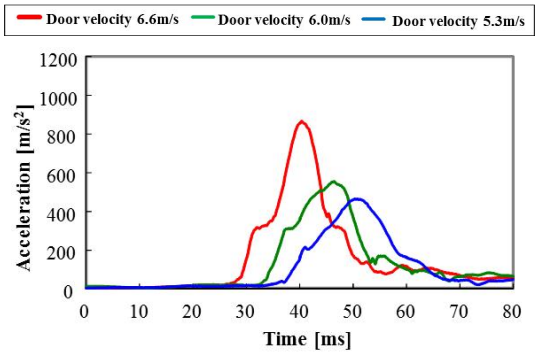


Figure29. Dummy pelvis resultant accelerations time histories

Door intrusion

We conducted a CRS side impact tests series using CRS A to study the influence of changing the door intrusion on the dummy injury measures.
The door intrusions were changed to 2 levels, 250 mm and 200 mm. The door velocities were 6.6 m/s, and kept the same in all tests.

Figure 30 shows the time histories for the door velocity, seat velocity, and relative velocity between the door and seat for the case that the door intrusion was 250 mm. Figure 31 shows the time histories of the door velocity, seat velocity, and relative velocity between the door and seat for the case that the door intrusion was 200 mm. Note that the case for when the door intrusion was 200 mm was not within the specified corridors. The relative velocity was out of corridor because the door intrusion was controlled by changing the seat velocity, and to change the door intrusion from 250 mm to 200 mm, the seat velocity therefore needed to be changed to a higher value.

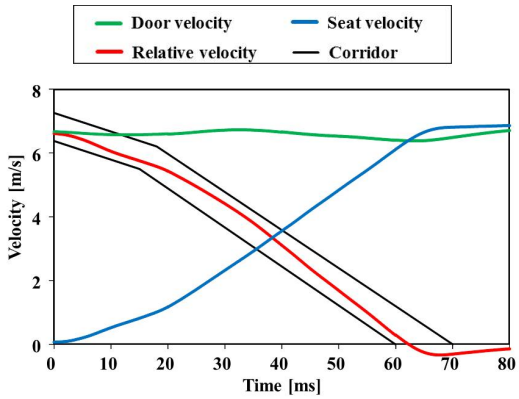


Figure30. Velocities time histories when door intrusion was 250 mm

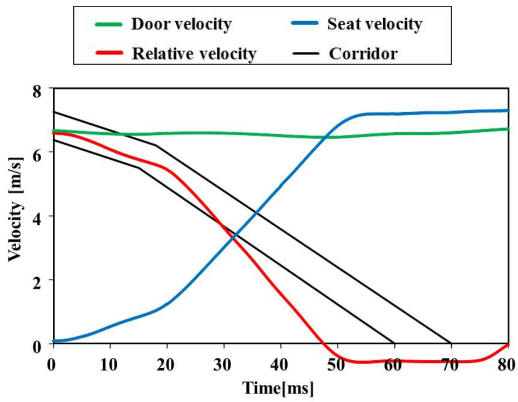


Figure31. Velocities time histories when door intrusion was 200 mm

Table 4 shows the maximum injury measures. The HPC15, head resultant maximum acceleration (3 ms), thorax rib deflection, thorax resultant maximum acceleration (3 ms), and pelvis resultant maximum acceleration (3 ms) were measured in this test series.

Figure 32 shows the deviations to the means of the maximum injury measures and coefficient values. The maximum deviation to the mean for the HPC15 was 1.9%. That for the head resultant maximum acceleration (3 ms) was 1.7%. That for the thorax rib deflection was 5.0%. That for the thorax resultant maximum acceleration (3 ms) was 3.2%. That for the pelvis resultant maximum acceleration (3 ms) was 1.7%. All of the deviations to the means were less than 5%.

The coefficient value of the HPC15 was 2.7%. That of the head resultant maximum acceleration (3 ms) was 2.4%. That of the thorax rib deflection was 7.1%. That of the thorax resultant maximum acceleration (3 ms) was 4.6%. That of the pelvis resultant maximum acceleration (3 ms) was 2.4%. So, all of the coefficient values were less than 10%. Overall, the maximum injury measures in these 2 test cases were almost the same. Hence, it is a possibility that the difference of door intrusion between 200 mm and 250 mm had little influence on the dummy injury measures.

Table4. Maximum Injury mesures

	unit	Door intrusion	
		250mm	200mm
HPC15		430	414
Head resultant maximum acceleration (3ms)	m/s2	742	718
Thorax rib deflection	mm	20	18.1
Thorax resultant maximum acceleration (3ms)	m/s2	544	581
Pelvis resultant maximum acceleration (3ms)	m/s2	799	773

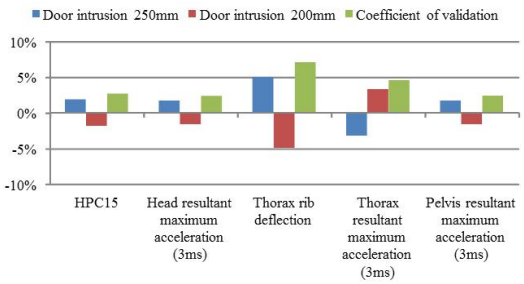


Figure32. Deviation to means of maximum injury measures

Figure 33 shows the dummy head resultant acceleration time histories. Figure 34 shows the thorax resultant acceleration time histories. Figure 35 shows the pelvis resultant accelerations time histories. The shapes of dummy accelerations for each of the body regions were very similar. So it is a possibility that the difference of door intrusion between 200 mm and 250 mm had little influence on the dummy kinematic behavior.

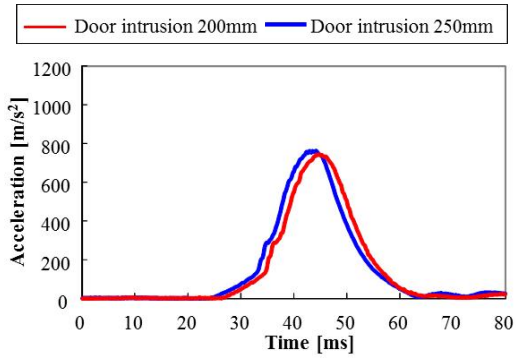


Figure33. Dummy head resultant accelerations time histories

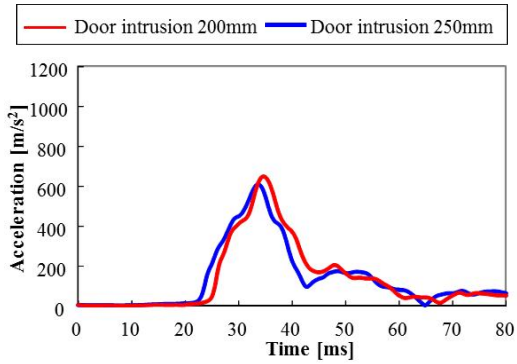


Figure34. Dummy thorax resultant accelerations time histories

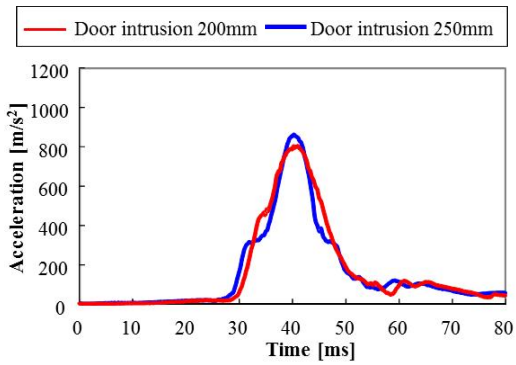


Figure35. Dummy pelvis resultant accelerations time histories

<u>Relative velocity between door and seat</u>

In the CRS new regulation, the relative velocity between the door and trolley (in this test series, we use the seat instead of the trolley) is specified as a test condition. But note that, if the door velocity and seat velocity can be controlled, it is possible to generate various situations though the relative velocity is within the specified corridors. The methods are as follows:

(A) Door velocity kept constant and only the seat velocity is increased (Door velocity constant).

(B) Seat velocity kept constant (0 m/s) and the door velocity changed to satisfy the corridors (seat velocity constant (0 m/s)).

(C) Door velocity decreased and the seat velocity increased, and the relative velocity is controlled to stay within the corridors.

For Method (C), it also is possible to make various situations by changing the rate of the change of velocity.

Our tests already described above were done by Method (A).

Figure 36 shows the velocity time histories model of Method (A) (door velocity constant). Figure 37 shows the velocity time histories model of Method (B) (seat velocity constant (0 m/s)). Figure 38 shows the velocity time histories model of Method (C).

At the time of the impact of the door and dummy, the door velocity is highest in Method (A) and lowest in Method (B). The door velocity in Method (C) is between those of Method (A) and Method (B).

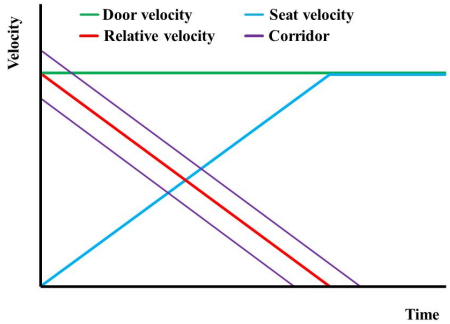


Figure36. Velocities time histories model of Method (A) (door velocity constant)

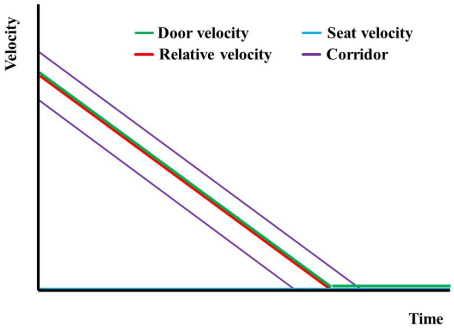


Figure37. Velocities time histories model of Method (B) (seat velocity 0 m/s)

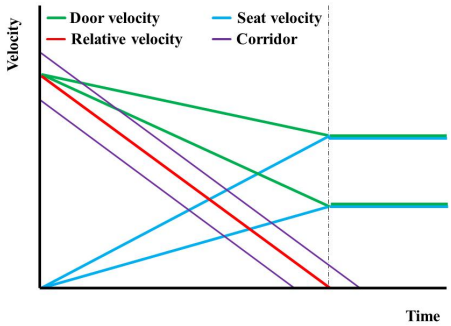


Figure38. Velocities time histories model of Method (C) (door and seat velocity change)

We conducted CRS side impact tests using Method (A) (door velocity constant) and Method (B) (seat velocity 0 m/s) with the CRS A for studying the influence of the relative velocity on the dummy injury measures.

Figure 39 shows the time histories of the door velocity, seat velocity, and the relative velocity between the door and seat for the case that the door velocity was constant. Figure 40 shows the time histories of the door velocity, seat velocity, and relative velocity between the door and seat for the case that the seat velocity was 0 m/s.

Relative velocities stayed within the corridors in both tests. Both tests satisfied the conditions of new regulation.

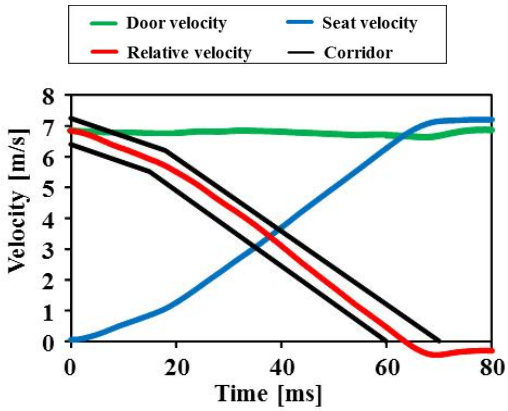


Figure39. Velocity time histories when door velocity was constant

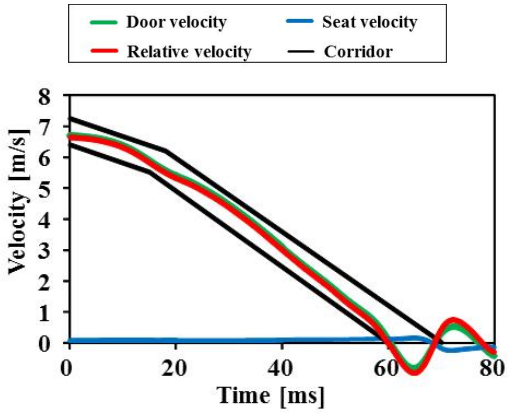


Figure40. Velocity time histories when seat velocity was 0 m/s

Table 5 shows the maximum injury measures. The HPC15, head resultant maximum acceleration (3 ms), thorax rib deflection, thorax resultant maximum acceleration (3 ms), and pelvis resultant maximum acceleration (3 ms) were measured in this test series.

The maximum injury measures in these 2 tests were different. Those in the test when the door velocity was constant were much higher than those in the test for which the seat velocity was 0 m/s. The relative

velocities were very similar; hence it was judged that the relative velocity had little influence on the maximum injury measures. Both tests satisfied the conditions of the new regulation. So it was necessary to add another condition to make the same severity in the various tests.

Table5. Maximum Injury mesures

	unit	Door velocity constant	Seat velodity 0m.s
HPC15		410	5
Head resultant maximum acceleration (3ms)	m/s2	719	112
Thorax rib deflection	mm	21.3	7.2
Thorax resultant maximum acceleration (3ms)	m/s2	497	207
Pelvis resultant maximum acceleration (3ms)	m/s2	730	207

Figure 41 shows the dummy head resultant acceleration time histories. Figure 42 shows the thorax resultant acceleration time histories. Figure 43 shows the pelvis resultant accelerations time histories.

The shapes of the dummy accelerations for the each of the different body regions in these 2 tests were different. Those in the test when the door velocity was constant were much higher than those in the test for which the seat velocity was 0 m/s. Relative velocities also were similar, so the relative velocity had little influence on the dummy kinematic behavior. Both tests satisfied the conditions of the new regulation. So it was necessary to add another condition to make the same severity in the various tests.

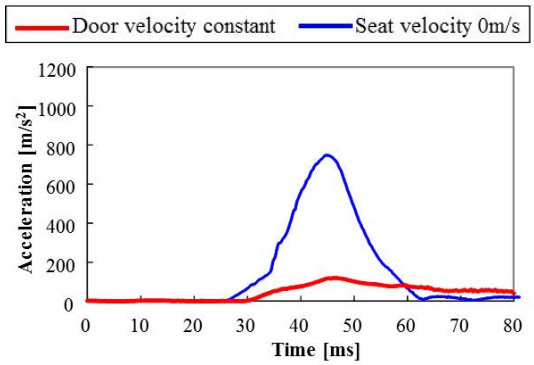


Figure41. Dummy head resultant accelerations time histories

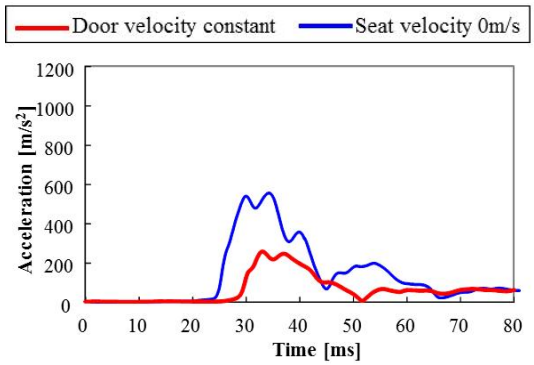


Figure42. Dummy thorax resultant accelerations time histories

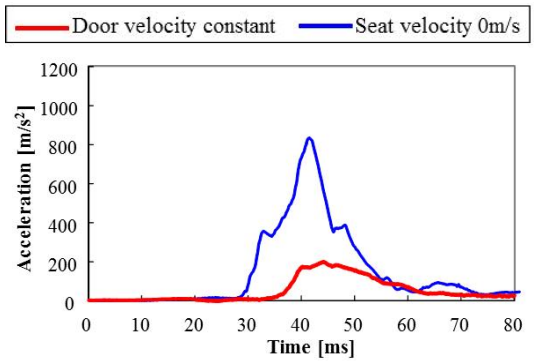


Figure43. Dummy pelvis resultant accelerations time histories

DISCUSSION

In the CRS new regulation, the relative velocity was specified as a test condition. But only the relative velocity was defined, such that various test conditions could be utilized as described in the preceding sections. This is the same situation not only for the test using an acceleration type sled, but also for the test using a deceleration type sled. As for the deceleration type sled, the same situations would be made if the door jig was made such that it could be moved. So, to make the same severity condition in various tests, additional conditions are necessary.
From the study of door velocity, it was found that the door velocity had a large influence on the dummy

injury measures and kinematic behavior. This was probably because to catch up with door velocity, the dummy needed to develop enough energy. So, under the same conditions (except for the door velocity) in our tests, the relative velocity between the door and dummy influenced the dummy injury measures.

Figure 44 shows the door velocity and dummy velocity time histories for the test series that involved changing the door velocity. When the door velocity was higher, the dummy final velocity was higher. Therefore, the resulting energy input to dummy was larger when the door velocity was higher.

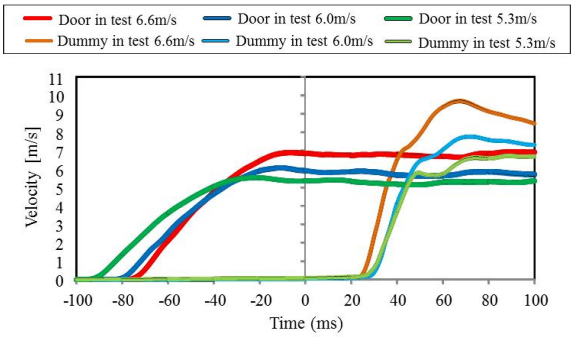


Figure44. Door and dummy velocities time histories

From these data, one of the most important parameters which had an in influence on the dummy injury measures was the relative velocity between the door and dummy.

The dummy injury measures recorded by the acceleration type sled and the deceleration type sled were very similar. Additionally, in the tests with the acceleration type sled, the dummy remained in place and the door velocity was constant. So the relative velocity between the door and dummy was the same as the door velocity. For the test with a deceleration type sled, the dummy velocity was the same as the trolley velocity, and the door remained stationary. So the difference of the door and dummy velocity was the same as the dummy velocity. Both tests satisfied the specifications of the new regulation. So the door velocity of the test conducted using the acceleration type sled and the dummy velocity of the test conducted using the deceleration type sled were almost the same, and as a result the severity of the tests were very similar.

Hence, Japan proposed the additional conditions at the 51st GTSP meeting as follows:

"Add door ground velocity to define one test condition

- In a test for which the door is moving at T = 0 ms, (i) the door ground velocity shall be between 6.375 m/s and 7.25 m/s at least the time when the door intrusion is maximum, and (ii) dummy is stationary at T = 0 ms.
- In a test which the door is stationary at T = 0 ms, (i) the door shall be fixed, and (ii) the dummy's ground velocity shall be between 6.375 m/s and 7.25 m/s at T = 0ms.

Figure 45 shows our proposal for additional condition.

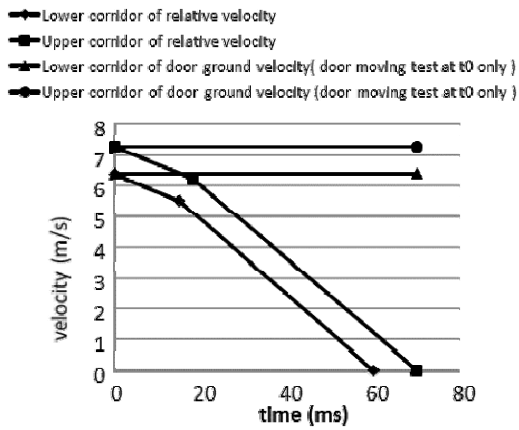


Figure45. Japanese proposal of additional condition for the CRS new regulation

This proposal was already recognized at the 52nd GRSP meeting.

SUMMARY/CONCLUSIONS

We conducted CRS side impact test series using an acceleration type sled system. The results are summarized as follows:

1. We confirmed that our test procedure using an acceleration type sled system could satisfy the conditions of the new regulation.

2. The severity of the CRS side impact tests conducted using a deceleration sled and an acceleration sled was very similar.

3. The door velocity has a large influence on the dummy injury measures in this test series.

4. The door intrusion had little influence on the dummy injury measures in this test series.

5. The relative velocity between the door and seat had little influence on the dummy injury measures in this test series.

6. We confirmed that the CRS side impact test conditions specified by the CRS new regulation were not enough to ensure the same severity for the various tests.

7. Additional conditions are necessary. We think the door velocity is valid as an additional condition.

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The authors thank Prof. Dr. Heiko Johansen, Mr. François Renaudin.
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