REAR OCCUPANT PROTECTION JNCAP TEST
– TEST RESULTS AND FINDINGS –

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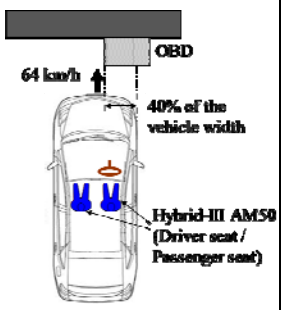
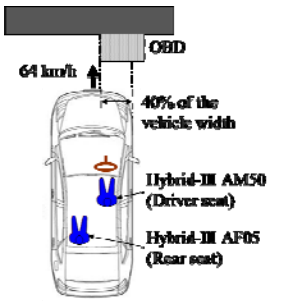
ABSTRUCT

Since its start in 1995, Japanese New Car Assessment Program (JNCAP) has conducted full-wrap frontal collision test (since 1995), side collision test (since 1999) and offset frontal collision test (since 2000), aiming for enhancing collision safety performance for drivers and front seat passengers. Safety performance of rear seat passengers had long been outside the scope of evaluation in JNCAP; however, as it became mandatory in 2008 for rear seat occupants to wear a seat belt, and the seat belt wearing rate has begun to improve, the safety assessment for rear seat occupants with seat belts has increasing its significance.
Under the above circumstances, JNCAP has amended the protocol of offset frontal crash test and introduced occupant protection methods for rear seat passengers in 2009. We adopted Hybrid III AF05 (female dummy) in rear seat instead of AM50 (male dummy) in front passenger seat, considering that women are more likely to become the rear seat occupant. And JNCAP developed its own rear seat dummy evaluation method referring to the FMVSS208[1] and new US-NCAP[2].
JNCAP has publicized this unique test result of 11 models so far. As this is a relatively new method, we have experienced some difficulties in evaluating safety performance of rear seat occupants accurately. In this paper, we will provide the latest results and findings during our experience in the rear occupant protection JNCAP tests.

OUTLINE OF REAR SEAT OCCUPANT PROTECTION PERFORMANCE EVALUATION

In an effort to improve the performance of rear seat occupant protection based on the results of the new car assessment program, JNCAP changed in 2009 the position of the dummy from the passenger seat so far used to the rear seat (passenger's seat side). It also changed the male adult dummy for a female adult dummy (Hybrid-III AF05), considering the results of analysis of traffic accidents that, on the rear seat, there were much more female casualties than male. Table 1 shows the outline of the tests, and Table 2 shows injury indicators, sliding scale, and weighting factors used in the rear seat occupant protection performance evaluation in those tests. For the background that led to the introduction of this evaluation and detail, please see paper in the last ESV conference[3].

Table 1. Outline of the offset frontal collision test by JNCAP

From FY2000 to FY2008	From FY2009
	

For the head, evaluation with HIC15 was made only when a secondary collision occurred, considering the fact that, on the rear seat, the occupant's head is very likely to strike at the air. For the neck, evaluation was made in terms of tensile load if there was not any secondary collision. For the abdomen, we could not directly evaluate abdomen injuries with dummies currently available, so, when the decrease ratio of ilium bone load was 1,000 N/ms or more, we assumed that there was an injury caused by the lap belt sliding up from the ilium bone of the pelvis (so called submarine phenomenon) and evaluation to that effect (points deducted).
In calculating the total score, the rear seat occupant's head, neck, chest, abdomen, and lower extremities were first weighted at a ratio of 4:1:4:4:2, based on casualties data for each region of injury and taking into account average human damages for each level of injury. Then, the total score (on a 12-point scale) was calculated by multiplying the score of each region by a factor weighted as above, and evaluated in five-levels.

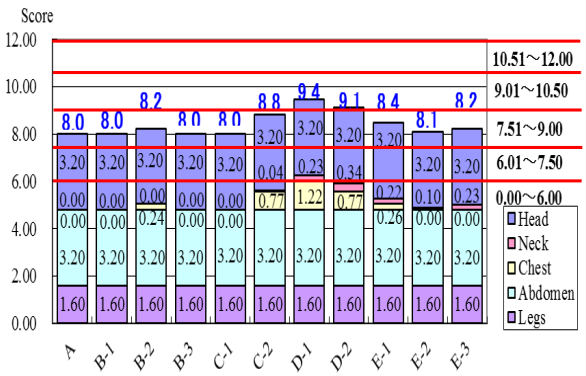
Table 2 Evaluation items, reference values, and weighting in the rear seat occupant protection performance evaluation

Body region	Injury criteria (Lower / Upper)	Score (a)		Modifier	Score (b)		Weight (c)		Weighted score ((a)+(b))×(c)
Head	HIC15* (500 / 700))	4**	+	Hard contact with car interior	-1	×	0.8	=	3.2
Neck	Tension(1.70kN/2.62kN) Shear*(1.20kN/1.95kN) Extension moment* (36Nm/49Nm)	4				×	0.2	=	0.8
Chest	Chest deflection (23mm/48mm)	4				×	0.8	=	3.2
Abdomen	n/a	4***	+	Pelvis restraint condition	Two pelvis: 0 One pelvis: -2 None: -4	×	0.8	=	3.2
Lower extremity	Femur force (4.8kN/6.8kN)	4				×	0.4	=	1.6

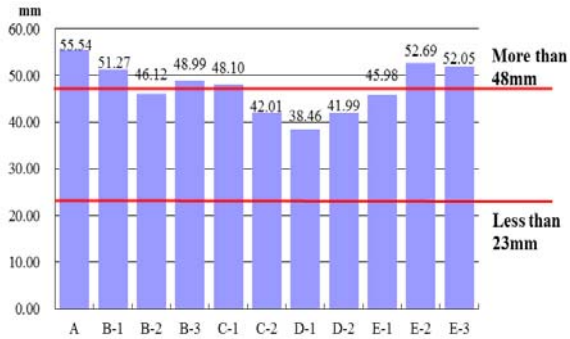
*: Calculation is done if secondary hard contact exists. Total: 12 points
**: Without secondary hard contact, 4 points are given by default.
***: 4 points are given by default.

RESULTS OF PAST TESTS AND THEIR TENDENCY

JNCAP published the results of the rear seat occupant protection performance evaluation tests it conducted in 2009 for eleven models of vehicles [4]. Figure 1 shows the result of those tests. Nine models were at Level 3 and two models at Level 4. Looking at the results by region of injury, we can see that the score of the chest injury most influences the level evaluation.
In FY 2010, the Program is conducting tests on fourteen models. While the number of models at Level 4 increased, one model dropped to Level 2. On some models, the head suffered a secondary collision and the pelvis slid up.



(Overall score)



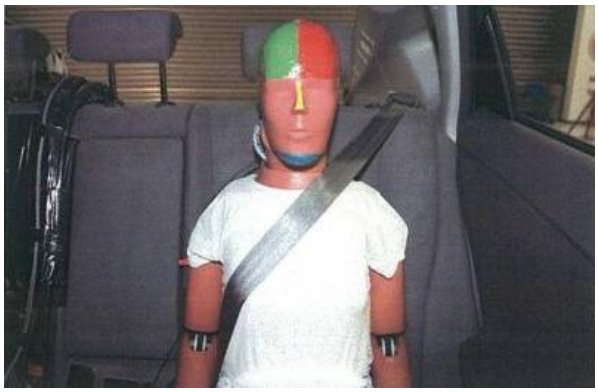
(Chest displacement)
Figure 1. Result of front-collision rear seat occupant protection performance tests in 2009

PROBLEMS ENCOUNTERED IN THE TESTS AND EXAMINATION

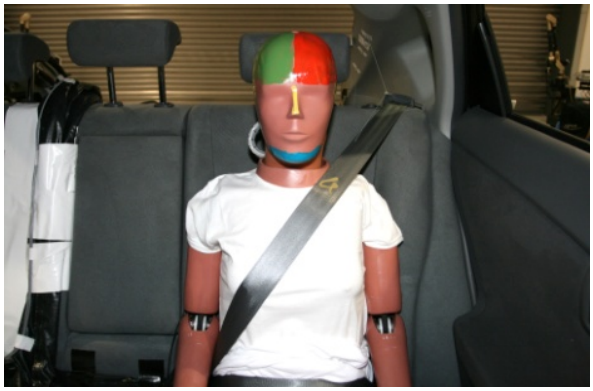
Influence of the belt path on the chest injury value

One of the offset frontal collision tests conducted in 2009 was done with a belt path for the rear seat occupant dummy set significantly differently from the normal path. According to the test procedure of JNCAP, the belt path was supposed to be set at the designed standard position designated by the vehicle manufacturer. Although there was not any prescription as to the error range, there was a vertical difference of 35 mm between the designed standard position and the actual position at the center of the dummy (between the

bottom of the jaw and the center of the belt). The difference of the belt path was visually noticeable, too, as the belt passed through the upper right chest and where it touched the neck (Fig. 2).



(Initial test)



(Retest)

Figure 2. Difference of belt paths

In normal use, it was inconceivable that the belt could take such "a path over the upper right chest." Further, if the belt took such a path, the injury value (chest deflection) would presumably be smaller than when it took other paths, given the structural factors of the ribs of the dummy (fixture of the potentiometer, ribs, etc.). Therefore, after consulting with the vehicle manufacturer, we decided to conduct a retest for this vehicle.

Table 3 shows the results of the initial test and the retest of the test vehicle. As predicted, the initial test showed smaller injury values than the retest, thus confirming that the belt path influences the injury value of the chest deflection.

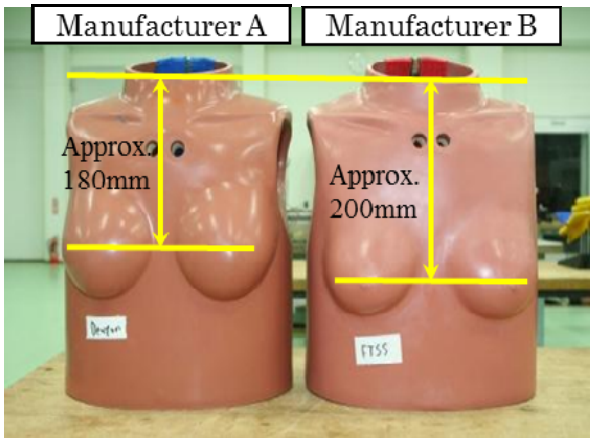
In response to the above examples, JNCAP test procedure for FY 2010 was revised so that the seat belt passed between the breasts, as it was supposed to do in normal use.

Table 3. Difference of test results between the initial test and the retest

		Initial test	Retest
Head	Secondary collision	None	None
	HIC15	584.8	635.2
Neck	Tensile load (kN)	2.61	2.57
	Shearing load (kN)	1.80	1.63
	Extension moment (Nm)	19.02	18.86
Chest	Deflection (mm)	**23.18**	**42.01**
Abdo-men	Riding up of seatbelt from pelvis	None	None
Femur load	Right (kN)	0.08	0.10
	Left (kN)	0.07	0.13

Influence of differences among dummy manufacturers

JNCAP conducts its tests using AF05 from two dummy manufacturers. During the examination entailed above, it was found that the form of the chest and the internal structure of the jacket were different between those manufacturers of the dummies used: In addition to the sizes being slightly different, the combinations of the jacket and the dummy's body (ribs, etc.) resulted in different rigidity among dummies. (Fig. 3)



A: material of lower/top part of breast are harder
B: inside of breast is hollow

Figure 3. Difference among dummy manufactures

The difference of injury values between dummy manufacturers had already been the subject of discussion at ISO. A universal specification has not agreed yet, but the two manufactures was collaborated to make the "universal jacket," with which the dummies of each manufacturer verifies the calibration tests. Since the use of this jacket allows it to conduct its tests under the same conditions as to belt path and belt slipping out of the shoulder (see below), JNCAP has

conducted its tests with the universal jacket starting FY2010.

SAE is developing the procedure for a test procedure simulating a low-energy collision, namely hybrid III AF05 dummy low-speed thorax impact test. In conducting tests using the above universal jacket, JNCAP conducted calibrations at low-speed thorax test on four cases in the form of reference measurements in FY2010. Table 4 shows the results of those tests.

Table 4. Result of the AF05 low speed thorax impact test

		Test probe velocity	Chest deflection	Thorax force	Internal hysteresis ratio
Specification		3.00+/-0.05m/s	17.4 ～ 21.8mm	1.78 ～ 2.07kN	65 ～ 72%
Case 1	30min	3.01	21.9	1.97	68.9
	24 h	3.03	21.7	1.98	69.1
Case 2	30min	3.03	22.2	1.98	72.3
	24 h	3.00	21.9	1.98	72.6
Case 3	30min	3.03	22.6	1.98	69.6
	24h	3.00	21.8	1.96	70.0
Case 4	30min	3.02	21.5	1.98	71.0
	24h	3.01	22.3	1.99	72.1

*Case 1: Passenger car
Case 2, 3: Light vehicle
Case 4: Minivan

In the calibration procedure, no alteration was made to the dummy to shift from the high-speed side to the low-speed side, leaving the dummy to restore itself.
As to the calibration intervals, in addition to doing the low-speed test 30 minutes after the calibration at high-speed following the provision of the test procedure: “Wait at least 30 minutes between successive tests on the same thorax,” we repeated the test after an interval of 24 hours to check the possibility of different rate of restoration of the dummy over time.
The above calibrations were conducted with the main purpose of calibrating the high-speed side, which aims at the median of the high-speed side. So it would be difficult to strike the balance between high-speed and low-speed calibrations of thorax by the calibration procedure used in the above reference measurement procedures.

Evaluation of the Belt Slipping Out of the Shoulder

In evaluating the rear seat occupant collision protection performance, a high-speed video camera was installed in the compartment at a side of the rear seat occupant dummy in order to check whether or not the dummy had a secondary collision. In tests conducted in FY2009, the behaviors of the rear seat occupant dummy during the crash recorded by the camera revealed that, in more than one case, the seat belt seemed to have slipped out of the shoulder of the dummy.
There were opinions that it was a problem if the seat belt slipped out of the clavicle of the dummy during the test. So, from FY2010 we started checking whether the seat belt slipped out of the clavicle of the dummy during the test.
Since it is difficult for the time being to define the the criteria of slipping out of the seat belt from the shoulder and how to assess it quantitatively, we decided for this year to limit ourselves to assess it based on the video record of the tests. Further, we installed another high-speed camera in upper front of the dummy, for it was delicate to determine whether or not the seat belt slipped out of the shoulder.

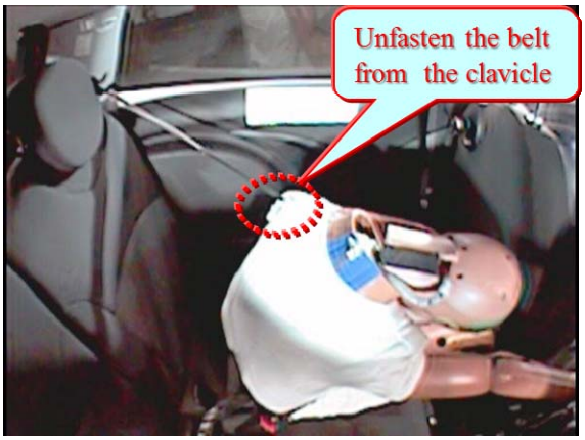


Figure 5. Case where the shoulder belt was judged to be slipped out moved from the clavicle toward the shoulder joint

Figure 6. Case where the shoulder belt was judged to be maintained over the clavicle

In the tests conducted in FY2010, taking into account of the opinions of the experts, we do assessment by checking the test video to see whether or not the seat belt keeps slipping over the clavicle while the head is shaken and also by checking whether or not the shoulder belt moves from the clavicle towards the shoulder joint during the lapse of time between the beginning of the collision and the moment the forward displacement of the head reaches maximum. When it is difficult to determine, we try to judge from a comprehensive point of view taking other factors into account.

Moreover, based on the above consideration, we decided that, if we judged that the seat belt slipped out of the clavicle of the rear seat occupant dummy, we would publish the fact of the seat belt to slip out.

In the future, it would be necessary to develop clearer judgment criteria so that subjective judgment won't be involved when determining whether or not the shoulder belt slipped out of the clavicle. Furthermore, given that we don't know at all yet to what degree the seat belt's slipping out of the clavicle influences injury values such as chest deflection, we will need to continue studying its influence on injury values.

On an actual human body, the seat belt rarely slips out of the shoulder although it may be significantly twisted, because not only is the seat belt restrained by the notch formed by the clavicle and the coracoid process, but also the shoulder blade is movable in all directions along the ribs in such a way that the restraint point moves as well. On the other hand, there are limitations to evaluating the shoulder belt's slipping out with the AF05 dummy, because not only does it restraint the seat belt solely with the over-the-clavicle part, but also the clavicle part is not movable in all directions. Therefore, to achieve an accurate evaluation of the seat belt's slipping out of the clavicle in the future, it will be necessary to use a dummy simulating the shoulder blades and the clavicle, such as THOR dummy.

REFERENCES

[1] 49 CFR Part 571
[2] US New NCAP NHTSA-2006-26555
[3] Ikari, Kawahara, "Rear Occupant Protection JNCAP Test", 21st International Technical Conference on ESV (Paper No. 09-0299)
[4] JNCAP Assessment Report (detailed edition), 2010.3, P.18-34