STUDY ON CAR-TO-CAR FRONTAL OFFSET IMPACT WITH VEHICLE COMPATIBILITY

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ABSTRACT

Euro NCAP has been developing a new car-to-car frontal offset crash test protocol including crash compatibility assessment. The current frontal offset test called ODB (Offset Deformable Barrier) test will be substituted by the new test in 2020. This new test uses a new barrier called MPDB (Mobile offset Progressive Deformable Barrier). The anthropomorphic test device (ATD) in the front seats will be changed from Hybrid-III 50th percentile male to THOR (Test Device for Human Occupant Restraint) 50th percentile male.

In this paper, two full car-to-car crash tests have been conducted. A THOR 50th percentile male dummy in the driver position and a Hybrid-III 50th percentile male dummy were seated in the front passenger position. Also, Q6 and Q10 were seated in the rear position. The test results are consisted of vehicle responses, occupant responses and crash compatibility assessment. In the second MPDB test, additional restraint systems are used to improve occupant response. The crash compatibility is assessed by standard deviation of the barrier intrusion, energy absorption and delta-V of the MPDB.

In the vehicle responses, the crash severity was increased as the relative impact speed comparison with ODB test. The vehicle deformation and Y-direction movement were similar with ODB test, but the vehicle body pulse severity was increased remarkably. The crash event timing of MPDB was faster than ODB test. So this pulse severity was similar to the full frontal impact at 50km/h.

In the occupant responses, most of injury criteria were increased. Especially, the chest compression values of front seats were significantly increased because of increased body pulse severity and THOR dummy's multi-point measurement system. In the second MPDB test, the improvement possibility of the chest compression value was identified, so it needs a study of the additional optimization method such as CAE and sled test.

In the crash compatibility assessment, final ratings were bare minimum. The causes of this result were the fracture of the front-end beam and the poor deformation of the front side member. In order to improve the crash compatibility, it needs the improved structure such as the body structure using the multi-load path system which helps distributing crash energy to various sub-structures.

INTRODUCTION

In recent years, New Car Assessment Program (NCAP) of many countries have urged automakers to improve the vehicle crashworthiness. The vehicles comply with most of the requirements of NCAP standard crash test configurations. So, passenger cars have become much safer than before.

However, the current NCAP standards don't cover all types of real traffic accidents. Also rapid-increasing market share of compact cars and SUVs has brought for both consumer and automaker to pay more attention on crash compatibility. Compact cars and SUVs are structurally different, the vehicle's body structure may not be able to absorb the impact energy sufficiently. It can also cause serious injuries to passengers on compact cars.

Figure 1 shows that the risk of getting seriously of fatally injured in a crash is approximately twice as high in very light vehicles (<950kg) (over 27%) as in very heavy vehicles (>1750kg).This shows that the light vehicles are very vulnerable to the vehicle crash compatibility. [1]

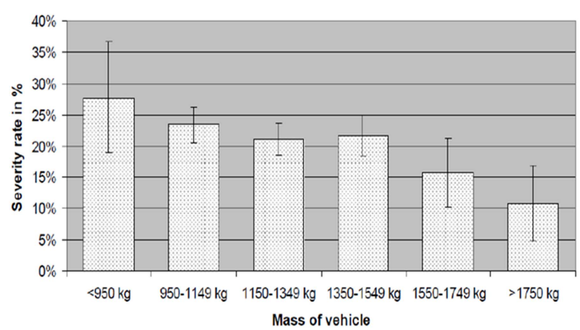

Figure 1. Percentage of severely and fatally injured in car-to-car front-end collisions by vehicle mass (ADAC accidents research data)

Therefore, many countries have tried to develop the new crash test mode and update the present crash test mode of NCAP. In Europe, Euro NCAP has been developing a new car-to-car frontal offset crash test protocol including the vehicle crash compatibility assessment.

In this paper, it is addressed that vehicle responses, occupant responses and vehicle crash compatibility performance from full vehicle crash tests using the new car-to-car frontal offset test protocol of Euro NCAP.

TEST PROTOCOL

The new car-to-car frontal offset crash test protocol of Euro NCAP, illustrated below in Figure 2, involves a Mobile offset progressive deformable barrier (MPDB) weighting 1,400 kg(with the trolley weight) which impacts a testing vehicle at a speed of 50 km/h, a zero degree angle, and a 50 percent overlap. A test vehicle also impact the trolley at a speed of 50 km/h. (100 km/h approach speed)

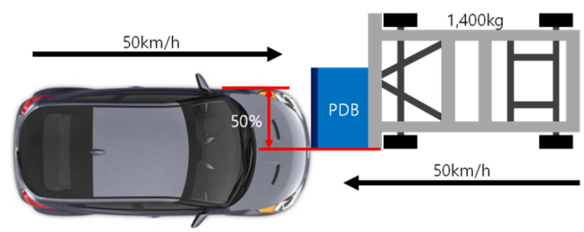

Figure 2. Euro NCAP new frontal offset impact test (MPDB test)

And this protocol uses THOR 50th percentile male anthropomorphic test device with the lower leg part of Hybrid-III 50th percentile male dummy in the driver position and child dummies (Q6 & Q10) in the rear position. (And front passenger position, to be applied)

This protocol assesses occupant responses and crash compatability. Crash compatability assessment uses the proposed protocol made by ADAC.

TEST RESULTS

In this paper, 2 full vehicle crash tests was conducted. The test vehicle was a compact car being sold in Europe now. The weight of the test vehicle was about 1,380kg, similar to the MPDB trolley's weight.

A THOR 50th percentile male dummy in the driver position and a Hybrid-III 50th percentile male dummy in the front passenger position were used. In the rear position, Q6 and Q10 dummies were seated.

Retractor pretensioners and load limiters were mounted to all seats in the test vehicle as standard. In the second test, Some additional restraint systems in the front position was added.

Vehicle Responses

Vehicle structure deformation

The body structure deformation of MPDB test was generally similar to ODB test.
Figure 3 shows the deformation of the front-end beam. The deformation occurs excessively at the end of the front-end beam stiffener.

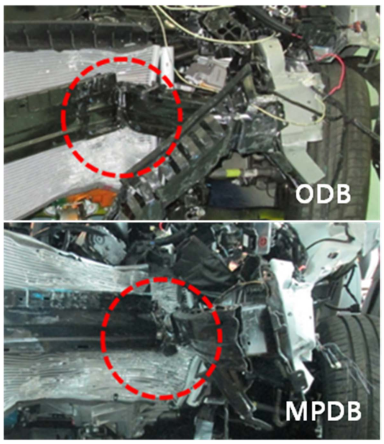

Figure 3. Comparison for the front-end beam deformation (ODB vs. MPDB)

Figure 4 shows the deformation of the front side member. It is also generally similar to the deformation of ODB test. But, The deformation of the crash box was insufficient in MPDB test. For the effective absorption of impact energy, structural improvement of the crash box will be needed.

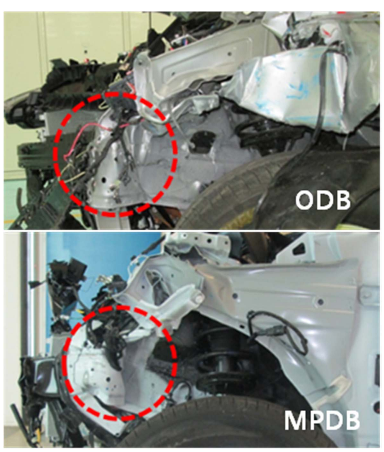

Figure 4. Comparison for the front side member deformation (ODB vs. MPDB)

Vehicle Body Pulse

The vehicle body pulse of MPDB test was relatively more severe than ODB test. The overall event occurred about 40 ms earlier and the maximum value of the pulse was increased about 18 G. These are more similar to the frontal impact at 50 km/h than ODB test. It seems that this results was occurred by the high approach speed (100 km/h) of MPDB test. Due to the change of the event time, the firing time of the restraint system was also faster than ODB test. It was also similar to the frontal impact.

Vehicle Y-direction movement

Figure 5 shows the vehicle movement in the Y-direction. When the dummies start loading on the airbag, between about 50ms and 150ms, MPDB test vehicle shifted more than ODB test vehicle. As a result, it seems that the movement of the dummies became more severe in MPDB test.

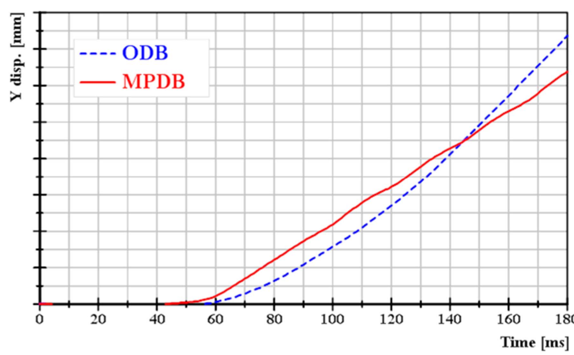

Figure 5. Vehicle movement (Y-direction)

Occupant Responses

Driver (THOR 50th percentile male)

A THOR 50th percentile male dummy was seated in the driver position. (ODB test uses a Hybrid-III 50th percentile male dummy.) Table 1 shows the result of head and neck injury in the driver position. HIC15 value has increased by 44.5% compared to ODB test, but it meets the injury requirement. Nij value also has increased by 158% compared to ODB test.

Table 1.
Driver Head/Neck Injury Results

criteria	Test result		
	ODB	MPDB#1	MPDB#2
HIC15	100%	144.5%	79.5%
Nij	100%	258.0%	178.4%

Figure 6 shows the driver's Nij value graph. In the second MPDB test, the Nij value was improved by the addition of some restraint systems.

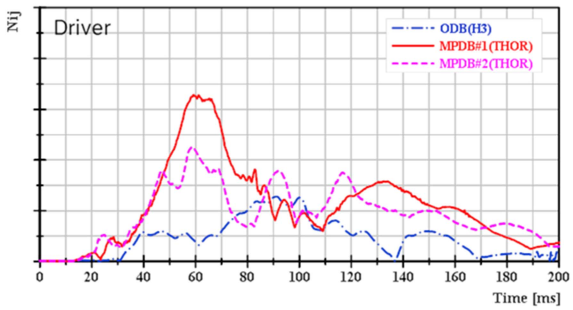

Figure 6. Driver Neck Injury result (Nij)

Table 2 shows the results of the chest and abdomen injury values in the driver position. In the first MPDB test, the chest compression value increased remarkably due to increased severity of the vehicle body pulse and changed ATD. (THOR ATD has 4 IR-TRACC for measuring the chest injury value)

Table 2.
Driver Chest/Abdomen Injury Results

Injury criteria	Test result		
	ODB	MPDB#1	MPDB#2
Chest Compression	100%	184.5%	127.3%

However, in the second MPDB test, the chest compression value was greatly improved by 31% compared to the first MPDB test. Figure 7 shows that the chest compression value improved significantly after about 40ms.

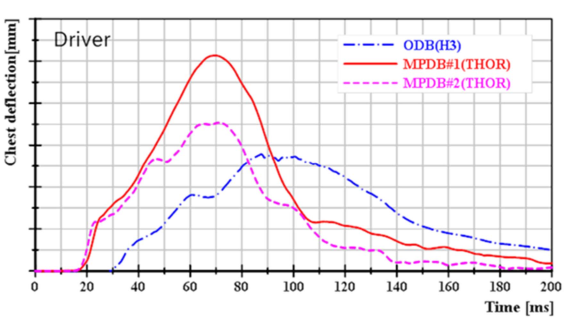

Figure 7. Driver Chest Deflection

Table 3 shows the results of the femur and knee injury value. Femur force and knee slide value increased in MPDB test, but it meets the injury requirement. Acetabulum load also measured high.

Table 3.
Driver Knee/Femur/Pelvis Injury Results

Injury criteria	Test result		
	ODB	MPDB#1	MPDB#2
Femur Force	100%	372.9%	393.8%
Knee Slide	100%	129.9%	220.6%

Table 4 shows the results of the lower leg injury value. Tibia index and Tibia compression value increased slightly due to the increased of vehicle body pulse severity and footrest deformation.

Table 4.
Driver Lower leg Injury Results

Injury criteria	Test result		
	ODB	MPDB#1	MPDB#2
Tibia Index	100%	116.1%	112.9%
Tibia Compression	100%	110.7%	125.7%

<u>Front Passenger (Hybrid-III 50th percentile male)</u>

A hybrid-III 50th percentile male dummy was seated in the front passenger position. Table 5 shows the results of the head and neck injury value. Head Injury Criterion (HIC15) increased slightly, but it meets the injury requirement. Neck injury criterion was similar to the result of ODB test.

Table 5.
Front Passenger Head/Neck Injury Results

Injury criteria	Test result		
	ODB	MPDB#1	MPDB#2
HIC15	100%	142.1%	104.2%
Neck Shear	100%	147.7%	143.2%
Neck Tension	100%	93.5%	70.7%
Neck Extension	100%	65.7%	59.2%

Table 6 shows the result of the chest injury criteria in the front passenger position. The chest compression value increased by about 14%. However, in the second MPDB test, the chest compression value was greatly improved by 27% compared to the first MPDB test.

Table 6.
Front Passenger Chest Injury Results

Injury criteria	Test result		
	ODB	MPDB#1	MPDB#2
Chest Compression	100%	113.7%	83.3%

Figure 8 shows the graph of the chest compression value.

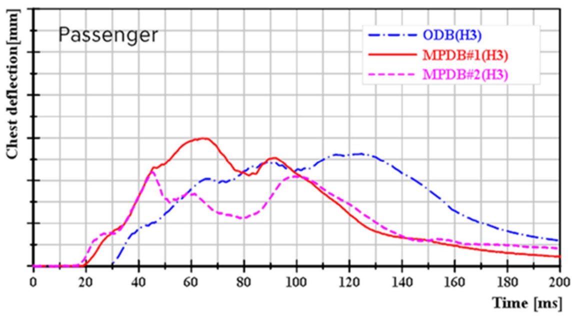

Figure 8. Front Passenger Chest Deflection

Table 7 shows the results of the femur and knee injury value in the front passenger position. Femur force and knee slide value increased in MPDB test, but it meets the injury requirement.

Table 7.
Front Passenger Femur/Knee Injury Results

Injury criteria	Test result		
	ODB	MPDB#1	MPDB#2
Femur Force	100%	337.9%	177.3%
Knee Slide	100%	33.9%	35.8%

Table 8 shows the results of the lower leg injury value in the front passenger position. Tibia index and Tibia compression value increased due to the increased severity of the vehicle body pulse.

Table 8.
Front Passenger Femur/Knee Injury Results

Injury criteria	Test result		
	ODB	MPDB#1	MPDB#2
Tibia Index	100%	202.9%	138.2%
Tibia Compression	100%	154.3%	115.0%

Rear Passenger injury (Q6/Q10)

The injury value of the child dummy in the rear position was generally increased due to the increased vehicle body pulse severity. The neck force(Fz) of Q6 increased by about 53%, and the chest acceleration of Q6 increased by about 31%. The neck force(Fz) of Q10 increased by about 31%, and the chest acceleration of Q10 increased by about 16%. (See Figure 9/10)

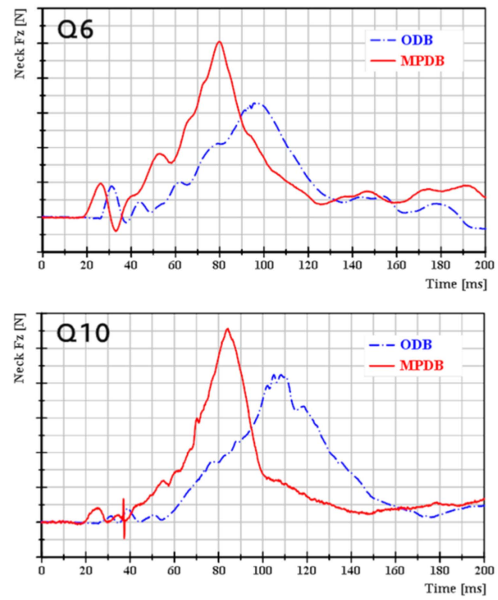

Figure 9. Upper Neck – Fz (Q6 & Q10)

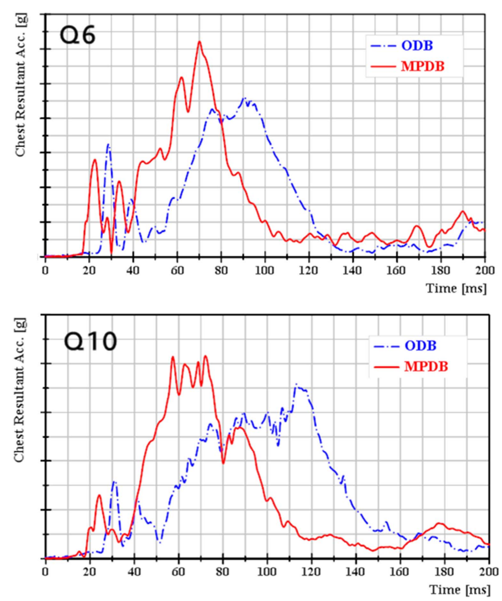

Figure 10. Chest Resultant Acc.(Q6 & Q10)

CRASH COMPATIBILITY ASSESSMENT

Test protocol

In this study, the proposed protocol made by ADAC was used.[1] This protocol includes some criteria such as standard deviation of the barrier intrusion. Figure 11 shows the test area for compatibility.

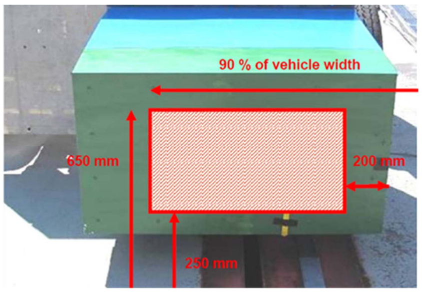

Figure 11. Test area for compatibility assessment

Table 9 shows the crash compatibility assessment criteria. The homogeneity assessment comprises a statistical evaluation of the intrusion depth in the area under assessment. The average intrusion depth and the standard deviation are determined. A greater standard deviation means a more inhomogeneous deformation of the barrier and results in a poorer homogeneity rating. This rating has 5 levels; Very Good, Good, Average, Bare minimum, and Poor.

Table 9.
Vehicle Compatibility assessment criteria

Criteria		Weighting
Geometry/Homogenity		75%
Energy Input	PDB energy (50%)	25%
	Delta-V MPDB (50%)	

Test Result

Figure 12 shows the compatibility assessment result. Rating result was bare minimum. It seems that the causes were the fracture of the front-end beam (see figure 13) and the poor deformation of the front side member.

In order to improve the compatibility assessment performance of the vehicle, it seems that the structural improvement is very important. First, it is necessary to prevent the fracture of the front-end beam through the improvement of the shape and material. And the structural improvement of the crash box is needed for absorbing impact energy efficiently. In addition, it is also necessary to control the deformation of the front side member.

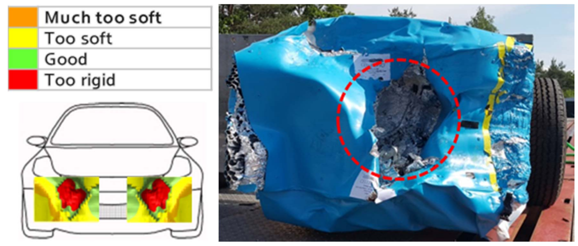

Figure 12. Compatibility assessment result

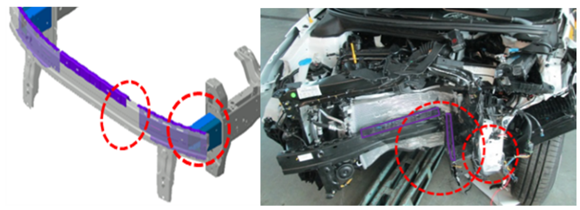

Figure 13. Front-end beam deformation

CONCLUSIONS

1) In Europe, a new frontal offset impact protocol based on real accident data will be developed and introduced in 2020 including the vehicle compatibility assessment. This protocol includes the dummies change from Hybrid-III to THOR in the front position.

2) Compared with the ODB test, the vehicle structure deformation and movement were similar, but the vehicle body pulse severity was more severe due to the increase in the relative speed of the vehicle and the MPDB trolley.

3) In occupant responses, the injury value increased generally due to the increased vehicle pulse severity and using the new frontal dummy . Especially, the chest compression value increased remarkably.

4) It seems that the chest injury value could improve from adding some restraint systems. However, to achieve additional reductions in the chest injury, extended research into restraint systems will be required.

5) In this study, Hybrid-III dummy was used in the front passenger position. But it is necessary to conduct the test using THOR dummy. Extended research will be required.

6) In order to improve the compatibility assessment performance of the vehicle, it seems that the structural improvement is very important. (The effective interaction of different vehicles and a large front-end shield are becoming increasingly important.

REFERENCES

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