Car Crashworthiness in Pole Side Impact and MDB Side Impact

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Abstract – Based on full vehicle pole side impact tests, in this paper, the side structure crashworthiness of a typical passenger car was simulated and analyzed for two patterns of side impact: pole side impact according to EuroNCAP and MDB side impact according to ECE R95. The former test focuses more on side structure crashworthiness under large intrusion while the latter focuses more on full side structure crashworthiness. Accordingly, occupant protection emphasizes on different aspects, which is to maintain passenger compartment, protect the head for the pole side impact and to protect the full human body for the side impact. When designing the car side structure, these two tests should be considered for side crashworthiness. At the same time, to do these two side impact proven tests would give us a full view of car side safety.

Keywords: Car, Side impact, Pole side impact, Crashworthiness, Finite element simulation

1 Introduction

Side impact accidents are common around the world and so in China. According to the statistic of Chinese road traffic accidents[2], more than 33% accidents are side impacts. Furthermore, it leads to high fatality for the small crash zone between occupants and vehicle structures. From 2006, side impact test, similar with ECE R95, will be taken as the proven test for all new vehicles of M1 class in China.

On the other hand, a large amount of side impacts are pole impacts, which could induce the passenger compartment to split, for which high injuries would occur on the occupants. Some pole side impact tests have been conducted in EuroNCAP, FMVSS, etc.

A typical mid-size passenger car was selected to perform the two side impact tests or simulations. The relationship between the crashworthiness under these two impacts was discussed.

2 Midsize Car Selection and Side Structures

Midsize car is more popular and has the ability to provide better protection for occupants than small car. In this research, one type of passenger car was selected according to table 1, representing the midsize class.

The selected car’s side structures are also representative, with multi-layer B-pillar and side framework, strengthened door panel, anti-impact rod in all the four doors and with not many devices between the inner and outer door panels. The framework of vehicle body is usually made of high-strength steel whose yielding stress normally above 500MPa.

Table 1. Standard for midsize car selection

Item	Length (mm)	Curb weight (kg)	Sale price (￥)
Range	4500 ~ 5000	1400 ~ 1500	150,000 ~ 200,000

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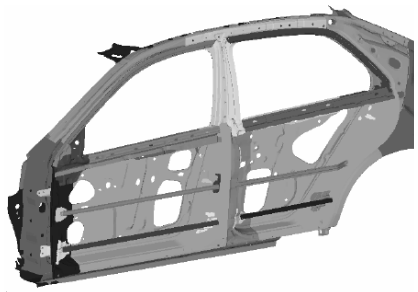


Fig. 1 Side structure of the selected car

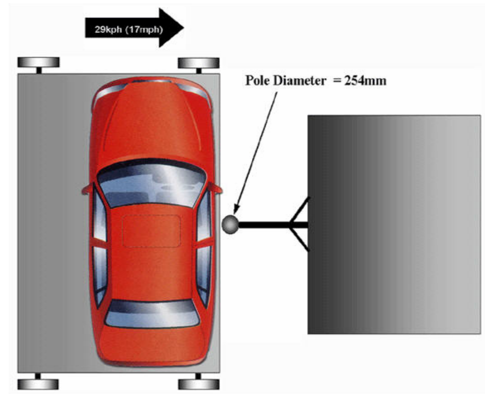


Fig. 2 Pole side impact test

The model for FEA in this research was delivered by the vehicle product company. LS-DYNA 970 [3] MPP version provided by ANSYS China was selected to do the simulations.

3 EuroNCAP Pole Side ImpactTtest and Simulation

Pole side impact test had been performed in the Vehicle Impact Laboratory in Tsinghua University, according to EuroNCAP pole side impact test protocal[4], as figure 2.

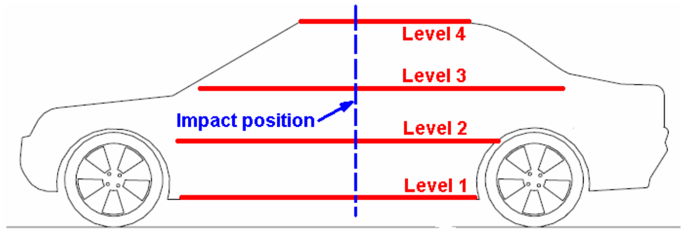
The test vehicle was placed on a large planar trolley, which was able to allow the vehicle's free motion of no less than 1 meter. The trolley and the vehicle were accelerated together to 29 km/h, impacting into a rigid cylinder whose out diameter was 254 mm. The impact position should aim at the C.G. of dummy head. For there are no side airbags, no dummies were used in the pole side impact test.

At the same time, finite element simulation of the same impact situation was conducted and the model was validated with the real world test results.

The model was validated through three comparisons: the acceleration of the required test spot (low point of unstruck B-pillar), the velocity derived from that acceleration, and the side permanent deformations. Deformation data were taken from four height levels which could represent the characteristics of car side structure, as figure 3.

All the comparisons were shown in figure 4 and 5. In the deformation curve, X-axis represented the coordinates in the longitudinal direction with the zero point defined as the impact position, and Y-axis was the deformation while zero meant no deformation. So the curves showed the deformed side profiles directly. The peak values of each deformation curves were listed in table 2. It is important to note that the maximum deformation during the whole impact was larger than the maximum permanent deformation because of the vehicle's elastic rebound behavior. The maximum deformation during the impact was 478 mm, taken from the motion image analysis.

From all these comparisons, the FE model was built accurately enough to be used in other side impact simulations.



Level	Position
4	Roof edge
3	Lower window frame
2	Middle of 1 and 3
1	Door sill

Fig. 3 Four height levels to measure the permanent deformations

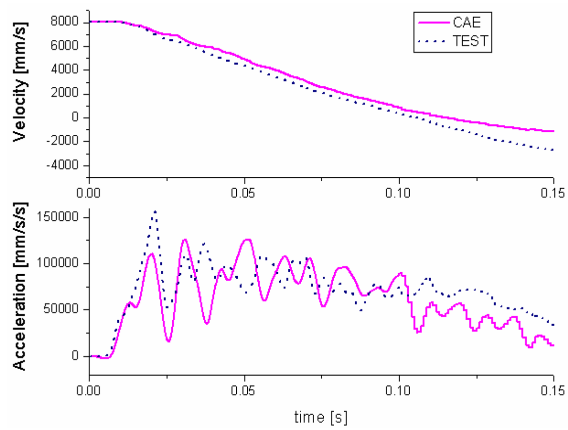


Fig. 4 Velocity and Acceleration comparison

Table 2 Maximum permanent deformation in 4 levels (mm)

Level	4	3	2	1
TEST	160	317	369	285
CAE	166	326	368	300

4 ECE R95 side impact simulation

When dealing with ECE R95 side impact simulation, the MDB model is significant. In this research, the MDB model was built by my cooperation with Jin Xin and its details can be found in Jin Xin's graduate paper[5]. Similarly, the acceleration and deformation were obtained to describe the side crashworthiness.

In MDB side impact, doors were pushed deeper than the A or B-pillar for their lower intensity. Most deformations of the car centralized in the lower part of the vehicle but distributed almost on all the side structures, which was determined by the MDB size.

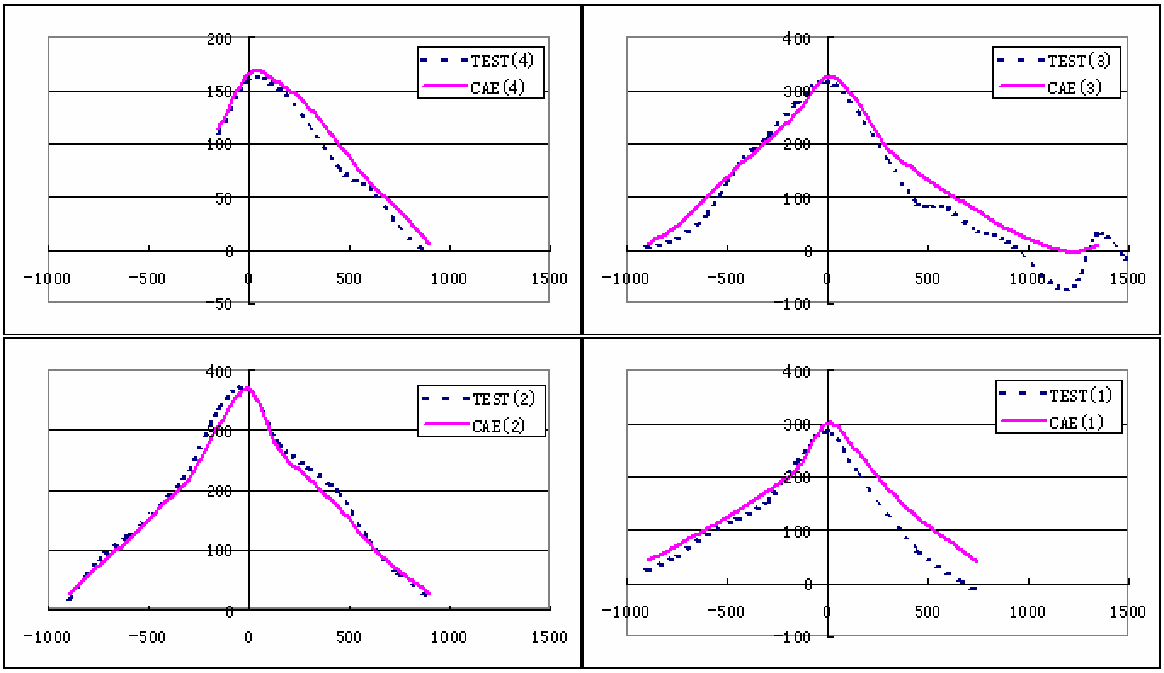


Fig.5 Permanent deformation of POLE side impact test and simulation

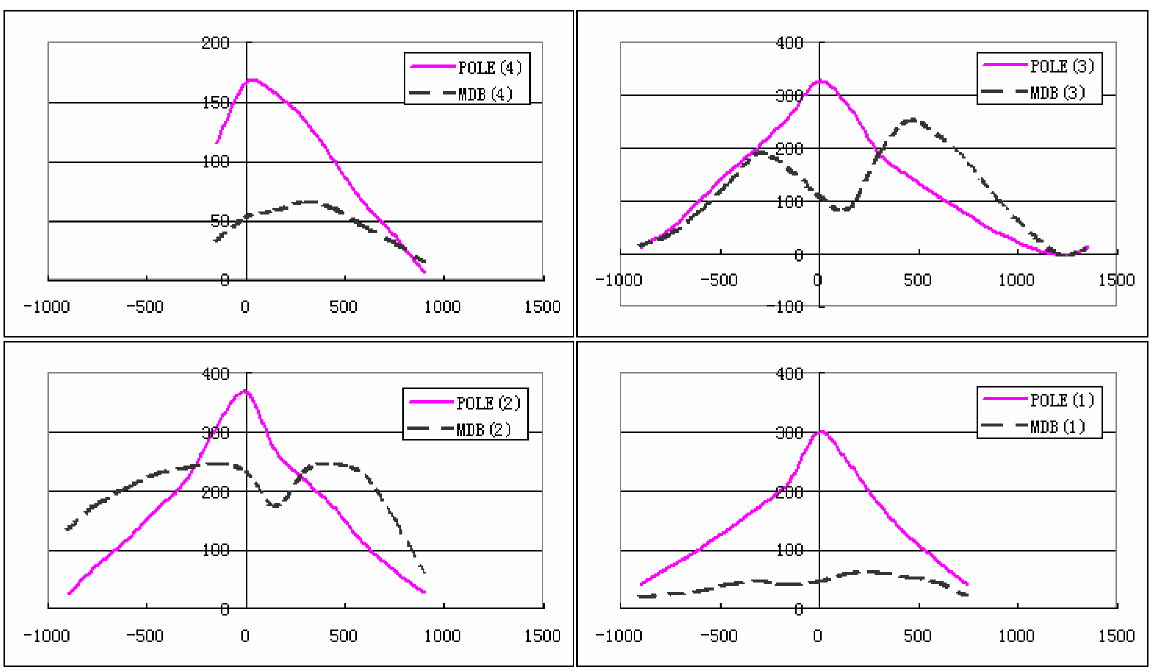


Fig. 6 Permanent deformation of POLE and MDB side impact

5 Comparison between pole side impact and side impact

5.1 Vehicle permanent deformation and energy absorption

The comparisons of the car permanent deformations after POLE and MDB side impact were as figure 6. Their peak values were listed in table 3. In MDB side impact, level 4 and 2 almost did not contact with the MDB, so their deformations were much more smaller than that in POLE impact.

Table 3 Maximum permanent deformation in 4 levels (mm)

Level	4	3	2	1
POLE	166	326	368	300
MDB	65	251	246	61
$\frac{POLE-MDB}{POLE}$	35.8%	23.0%	33.2%	79.7%

When we discussed the car deformation, the energy absorbed by the car should not be skipped. This energy in POLE side impact was 50345.23J and in MDB side impact 39202.06J, from FEA results. The two figures made the rate of $\frac{POLE-MDB}{POLE}$ to be 22.1%, which was far smaller as to those deformation ratios.

Though the amounts of energy imported into the car distinguished not so much, the deformations differ largely. This is apparently because of the energy distribution, which can be seen in figure 7. In the pole side impact, the energy centralized within a very narrow area, which lead to the same amount of energy conducing larger intrusions. As a result, this is significant to the occupant protection.

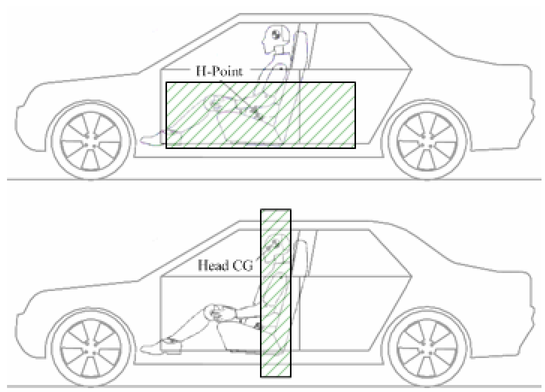


Fig.7 Side impact area

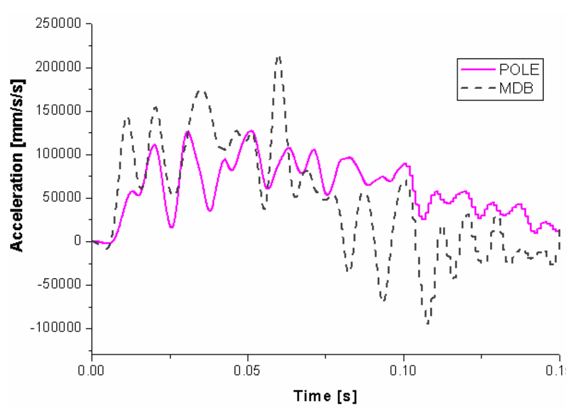


Fig. 8 Acceleration comparison

5.2 Acceleration at the lower B-pillar of unstruck side

The acceleration vs. time curves of the two patterns of side impacts were in figure 8. The acceleration level in MDB side impact was about two times than that in POLE impact.

5.3 Occupant protection

Based on the above-mentioned deformation and acceleration results, we can see that in the two patterns of impact, the occupants would be in two opposite conditions: smaller acceleration with larger intrusions and larger acceleration with smaller intrusions. However, the acceleration levels of the two conditions are low enough to ensure that the injury criteria based on acceleration would be at a low level. So in the side impact, to maintain the passenger compartment is the key point of all. Especially in the POLE side impact, intrusions of 478mm would be a menace to the occupants.

Another menace is the head impact in the POLE side impact. For the pole is just aiming at the occupant head C.G., if there were no head airbag, the head would impact into the pole directly and lead to serious injury. So the side head airbag is recommended to be added to all the cars.

6 Conclusion

The relations between pole side impact and side MDB impact were discussed and results may be summarized as follow:

1) Both the two side impact tests examine the car side crashworthiness. The acceleration environment for pole side impact is smaller than side MDB impact, while its intrusion is much more larger than the side MDB impact.
2) The two impact tests are characterized by strong complementarity, focusing on higher acceleration or larger intrusion respectively. Accordingly, the occupant protection conceptions for the two impacts are different in some degree.
3) Structure design should consider at least these two impact patterns. The more impact patterns considered, the safer a car would be. But the structure design would be more difficult.
4) Side head airbag is one kind of important occupant protection devices for side impact and is recommended to be added onto all the passenger cars.
5) From 2006, China will require the side MDB impact tests as proven test for all new cars of M1 class. For a full examination of the side structure crashworthiness, the pole side impact test is recommended as a supplement to the side MDB impact test.

7 References

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