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Vehicle performance evaluation in side impact (MDB) using ES-II dummy

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Abstract. Side impact collision is one of the leading causes of death. Protection of people during lateral collision is challenging because of relatively small space available to restraint occupant compared to front. Hence, it is imperative to protect the occupants in side collision. It is a function of vehicle type and restraints for side protection. This paper focuses on evaluation of injury parameters of the ES II dummy during the lateral collision of different vehicles with different spaces, sections and materials. Thus the comparison will enable us to understand the sensitivity of space, B-pillar section and material which affects the injury parameters. This study will help automotive engineers to design side impact crashworthy vehicles.

1. Introduction

Indian road accident statistics show that side impacts account for approximately 20% of all impacts and 35% of total fatalities. For example, side impact crashes were 26% of the total amount of fatal accidents that took place in 2012 in the US. This information has been retrieved from the road accident sampling system-India (RASSI), which has the only vehicles database in India, in relation to real-world severe crash tests in the US. A similar trend has been identified in Europe, where side impact road collisions correspond to approximately one quarter of the total amount of serious-to-fatal injuries.

It is for this reason that developing safety systems to prevent occupants from injuries during Side Impact crashes has a significant potential in terms of road fatalities reduction. Because of this, all regulations include injury criteria requirements that must be accomplished in Side Impact crash testing. These regulations intend to enhance the safety of the new vehicles to be set in the market by obliging Original Equipment Manufacturers (OEMs) to develop restraint systems based on the vehicle's behavior to Side Impact crashes. In this way, the vehicle occupants have a major protection in case of lateral accident. Side impacts also require more attention in that there is considerably less crush zone for absorbing energy in the side of passenger cars compared to the front and rear structures, and consequently the occupants sit almost within the crush zone, which often results in severe thoracic injuries. Research and development into minimizing structure intrusions during side impacts of passenger cars are done to reduce the effects of side impacts.

Most side impacts can be classified into two types they are car-to-broad-object and car-to-narrow-object. Car to narrow object are the impacts that are done with pole. In this paper car to broad object test is considered i.e. impact of car with mobile deformable barrier (MDB). Three passenger vehicles were taken for comparison and the performance of ES II dummy during the side MDB test is compared and analyzed with space, section and deformation.

2. Side Impact Test

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Side impact tests are carried out on the vehicles to observe the structural integrity of the vehicle and thereby providing safety to the occupants of the vehicle. The test is done with a deformable barrier placed perpendicular to the vehicle longitudinal axis.

2.1. Regulation
The vehicles taken for comparison are M1 category. Impact is done on the driver side using mobile deformable barrier (MDB) which has the impactor and the trolley. Impactor is a crushable section mounted on the front of the MDB and the trolley is a wheeled frame which travels along its longitudinal axis at the point of impact. The test setup is as shown in the figure 1. Impact will be done at 50kmph.

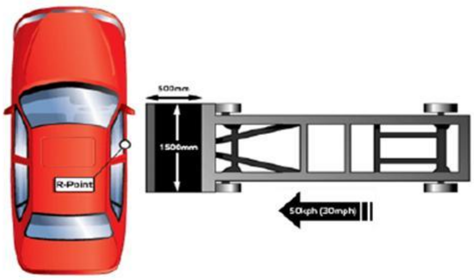

Figure 1. Test setup showing the MDB and vehicle.

2.2. Injury Criterion

2.2.1 The head performance criterion (HPC).
When head contact takes place this performance criterion is calculated for the total duration between the initial contact and the last instant of the final contact.HPC is the maximum value of the expression:

$$(t_2 - t_1)\left\{\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a.\,dt\right\}^{2.5}$$

Where a is the resultant acceleration at the centre of gravity of the head in meters per second per second divided by 9.81 recorded versus time and filtered at channel frequency class 1000 Hz; t1 and t2 are any two times between the initial contact and the last instant of the final contact. The value shall be less than or equal to1000.

2.2.2 The thorax performance criteria.
- Rib Deflection Criterion (RDC) is the maximum value of deflection on any rib as determined by the thorax displacement transducers, filtered at channel frequency class 180 Hz. The value shall be less than or equal to 42 mm;
- Viscous Criterion (VC) is the maximum value of VC on any rib which is calculated from the instantaneous product of the relative thorax compression related to the half thorax and the velocity of compression derived by differentiation of the compression, filtered at channel frequency class 180 Hz. The value shall be less than or equal to 1.0 m/sec.

2.2.3 The pelvis performance criterion.
Pubic Symphysis Peak Force (PSPF) is the maximum force measured by a load cell at the pubic symphysis of the pelvis, filtered at channel frequency class 600 Hz. The value shall be less than or equal to 6 kN.

2.2.4 The abdomen protection criterion.

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Abdominal Peak Force (APF) is the maximum value of the sum of the three forces measured by transducers mounted 39 mm below the surface of the crash side, CFC 600 Hz. The value shall be less than or equal to 2.5 kN internal force.

2.3 EuroSID

EUROSID is the EURopean Side Impact Dummy and has been developed in four European countries under the auspices of the former EEVC WG 9. EUROSID-1 is the production version of the dummy and the successor to the prototype dummies manufactured during 1987/9. The EUROSID-1 is essentially the same as the production prototype apart from some minor design and bio fidelity enhancements. The European Directive 96/27/EC on side impact that has gone into effect on October 1st, 1998, specifies the EUROSID-1 dummy as the injury assessment device to be used in the test procedure. EuroSID-II or ES II dummies are the successor of ES I dummies. These ES II dummies are used in the side impact tests. ES II dummies have the instrumentations in head, neck, shoulder, thorax, abdomen and leg. ES II dummy is shown in figure 2.

Figure 2. ES II dummy model.

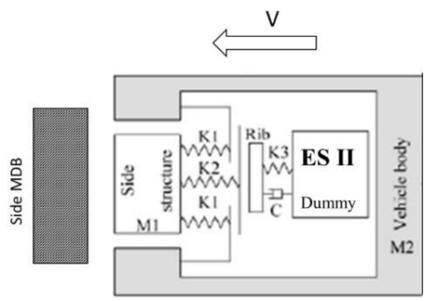

Figure 3. Dynamic model of Side Impact.

3. Dynamic model of Side Impact

The simplified dynamic model for vehicle side impact (MDB) impact is illustrated in figure.3. In this model the struck side of the vehicle is set as one part, M1 and other parts of the vehicle body are set as the rigid part, M2. M1 is connected with the vehicle body by linear elastic springs K1, representing the stiffness of the side structure of the vehicle. The spring K2 is equivalent to the stiffness of the door trim.

Let the impact force be F_{impact} and the side structure intrusion be $X_{intrusion}$. $K_{equivalent}$ is introduced to represent the combined spring constant of K1 and K2. The approximate relationship between F_{impact} and $X_{intrusion}$ can be described according to Hooke’s law:

$$F_{impact} = K_{equivalent} X_{intrusion}.$$

4. Side Structure of Passenger vehicles

In general passenger car side structure consists of A-pillar, B-pillar, sill, doors, and crash beams behind the doors. During the side impact (MDB), sill, B-pillar structure and A-pillar structure will be engaged as shown in the figure 4 & figure 5.The stiffness of a vehicle’s side structure is much lower than that of the front structure and there are not enough components or space to absorb the impact energy. Consequently, there will be a substantial intrusion concentrated in the impact zone.

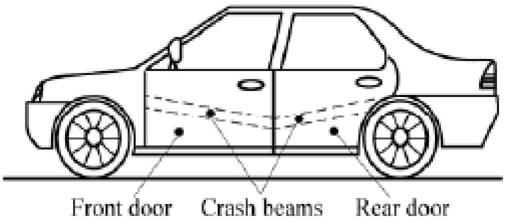

Figure 4. Vehicle side structure.

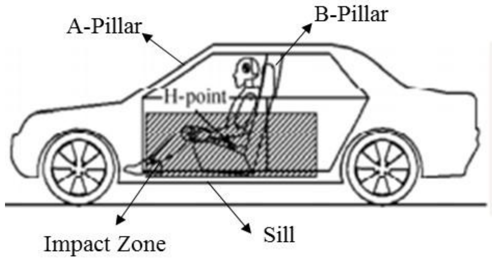

Figure 5. Impactor contact on side structure.

4.1. Side section of B-pillar, Sill, Door.

In this study three different vehicles are considered. The sections of B-pillar, door along with crash beam and sill of each vehicle are taken. These three vehicles have the nomenclature as V1, V2, and V3. This will be used in the entire paper for comparison. The section A-A is the b-pillar section and Section B-B is the door section with sill and crash beam taken in the respective vehicles as shown in figure 6 and figure 7. We could observe from the comparisons that the vehicle V2 has more reinforcements on the b-pillar section and the cross section of the crash beam is larger in vehicle V3. Materials used for these sections are cold rolled steel, high strength steel, dual phase steel and hot formed steel.

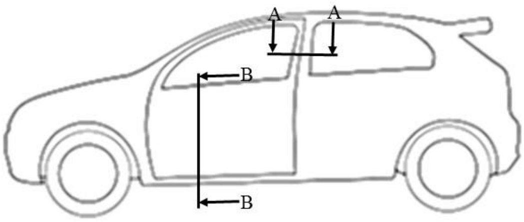

Figure 6. Section A-Aand Section B-B

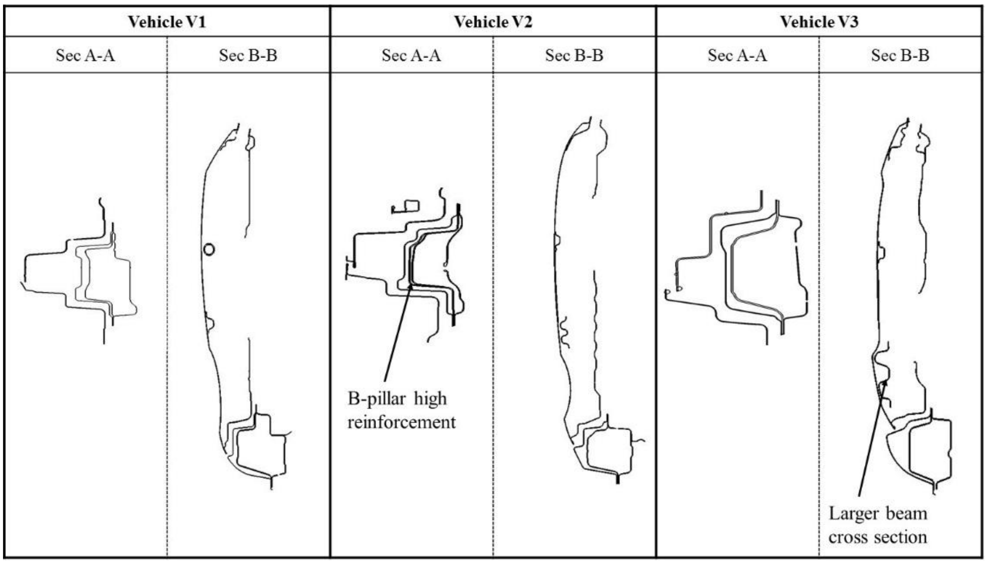

Figure 7. Sections of B-Pillar and Door

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4.2. Space comparison

Space available around the ES II dummy when it is seated at intended position on the driver side is tabulated for all the three vehicles in table 1.These spaces are important for our study as we will be able to know how the vehicle performs with respect to space in the event of side collision. It can be observed from the values that the vehicle V2 has small space when compared to vehicles V1 and V2.

Table 1. Space Comparison of vehicles.

Vehicle Model	Head to window	Shoulder to window/padding	Elbow to door	Pelvis to door	Knee to door/padding	Side Restraints
V1	166	135	69	144	215	Yes
V2	220	80	62	129	112	No
V3	215	134	55	152	150	No

5. Deformation

Post-test the deformation profiles of the side door and the B-pillar of all the considered vehicles are shown in the figure 8 & figure 9. It is seen that the deformation is small in Vehicle V2 and V3 compared to V1. This can be attributed due to fact that the B-pillar of the vehicle V2 has more reinforcements and the presence of larger crush beam in the door in vehicle V3.

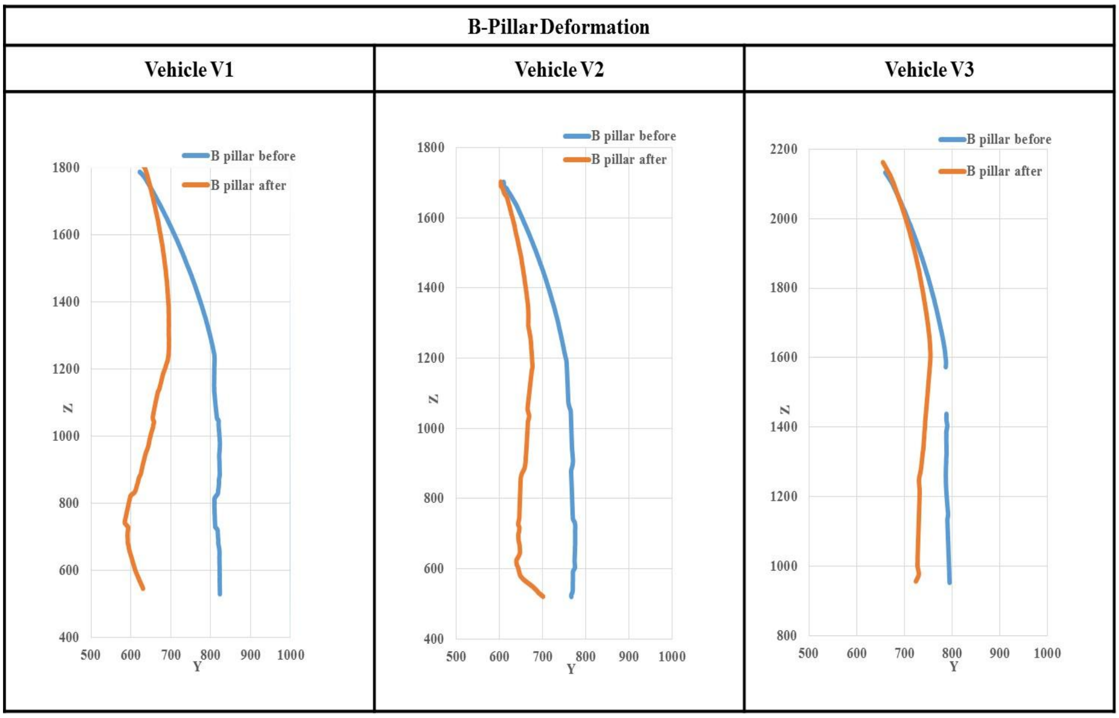

Figure 8. B-Pillar deformation of the vehicles.

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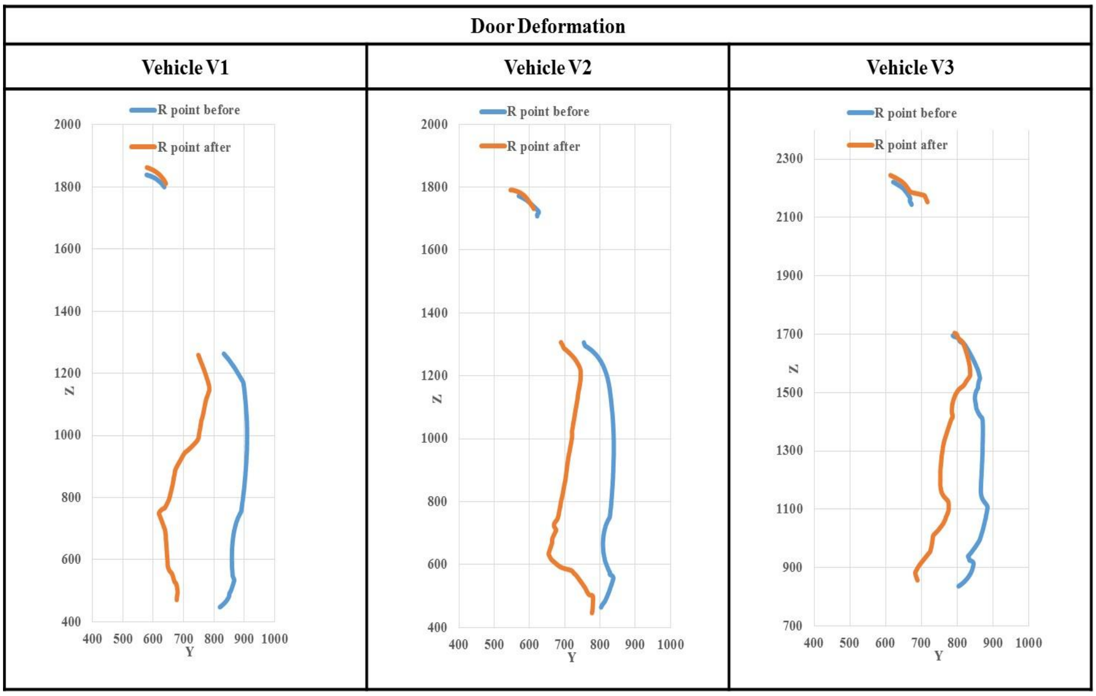

Figure 9. Door deformation of the vehicles.

6. Dummy Performance in Side (MDB) Test.

The dummy performance in each case after side impact test is tabulated in the table 2. The values shown here are normalised percentages with respect to nominal values. We could interpret from the values in table 2 and figure 8 and figure 9 that the vehicle V2 has lower rib compression due to smaller deformation of the door and B-pillar similar to V3. It is due to the presence of crash beam in the door and the reinforcements at B-pillar, the intrusions in V2 and V3 are relatively smaller. On the other hand lower rib compression is more in V1 due to more intrusion. The upper rib value is more in case of V2 and V3 due to higher pelvic force and geometry of the vehicle respectively. The head injury value in V1 is less due to the presence of the side restraint system.

Table 2. Performance Comparison of vehicles.

Vehicle	Head	Chest						Abdomen peak force (KN)	Pelvic peak force (KN)
	HPC	Upper Rib		Middle Rib		Lower Rib			
		Compression (mm)	Viscous criterion (m/s)	Compression (mm)	Viscous criterion (m/s)	Compression (mm)	Viscous criterion (m/s)		
V1	1.14	24.52	4.00	34.60	8.00	47.71	15.00	27.20	17.33
V2	8.23	64.26	20.00	48.21	17.00	29.29	15.00	39.20	36.33
V3	1.83	64.19	20.00	47.24	27.00	25.84	7.00	20.80	11.50

7. Conclusion

This paper investigates the sensitivity vehicle parameters (Interior space, B-pillar and door section deformation) which affect the injury parameters of ES-II dummy in the event of side (MDB) collision. It can be noted that, higher the intrusions higher is the injury parameters. Rib deflections are one of the important parameters to be monitored in the side impact. V1 which has relatively higher intrusion, resulted in higher lower rib deflection whereas V2 and V3 has relatively lesser lower rib deflection due to lesser intrusion.

These intrusions can be managed by having reinforcements on the B-Pillar and crash beam on the door. The reinforcements can be decided based on the space availability around the occupant in the cabin at the concept stage itself, thus reducing the injury value by reducing the intrusion level. In addition to these providing side restraints helps us in getting better performance of the occupant.

8. References

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