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RESEARCH ARTICLE

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EVALUATION AND DEVELOPMENTS OF OFFSET DEFORMABLE BARRIER IMPACT WITH OCCUPANT USING FINITE ELEMENT METHOD

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ABSTRACT
Many fatalities and injuries were caused by slow speed impacts at 15 to 30 mph. The occupants were injured by either falling out of the car or bumping into the vehicle and hitting something in front of occupant when they suddenly stopped after collision with another vehicle. In most cases, M1 class vehicles carried passengers at high speed. There are many active safety systems in this vehicle such as brakes, lights, horns etc. to avoid accidents. In the event of an accident, the improved passive safety system helps reduce injuries and protect the occupants from the injuries. It has been determined that restraining the occupants of the seat will prevent this "second impact“: People who hit the inside of the car after the car hits an obstacle.

During the vehicle collision, the kinetic energy of the vehicle is converted into the internal energy of the vehicle by the shape of the vehicle deformation. The vehicle structure deforms and absorbs energy. Therefore, this transformation is effective and should not spread to the cockpit area. In addition, steering wheel displacements, dash panel and pedal intrusions should be too small to reduce the risk of injury to the occupants.

In this research, Offset Deformable Barrier collision was used as the collision condition. To improve the passive safety of the vehicle, several ODB collision enablers have been introduced. This developments will helps to reduce the occupant’s injury level and increases the safety points during crash testing. Also, this report shows a comparison with base vehicle and after enablers added vehicle results.

KEYWORDS: M1-Vehicle, Crash and Safety, ODB Impact, SUV Vehicle Crash, collision, ECE-R94, FEA Simulation, Vehicle Injury, Occupant Safety, Impact Simulation, LS-Dyna Simulation, Explicit.

INTRODUCTION

The drastic development of automotive vehicle, increases the no of vehicle running on the road, also due to this vehicle collision rate also increasing year by year. The Automotive industry trying to provide the vehicles with safety. This safety level of the vehicle measured by several testing agencies around the world. Based on the crash test

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rating the vehicle safety level announced the 5 star rating scale, The IIHS is the once of the main testing agency in the world. This testing are conducted with proto or physical vehicle. So to reduce this no of proto making, the automotive companies are going with virtual testing, that is achieved with the help of Finite element Method. The complete physics of the vehicle represented in the FEA model, and validation with helps of computers. This will helps to reduce the testing and proto making time, also reducing lots of cost.

A good restrain system will provide more safety to the occupant, do airbag deployment at right time with correct deployment force will reduce the level of injury. By development of inflator with proper pressure has provide good improvement in Air Bag passive safety [6]. Most of the studies conducted to reduce the occupant injury level. Since the evaluation method has various types. Physical construction of Humanoid Dummies and Conduct the experimental testing, Finite element analysis of crash and safety with FE Dummy model, and FE Analysis of total human model for safety. The various occupant injury levels has evaluated for the purpose of future safety development. [7]. New car assessment Program is a testing agencies, which test the all new cars and publishing their safety performance. To evaluate all the vehicles in a same method, it has procedures for test the vehicle [8].

In the frontal impact, vehicle front structure should absorb more energy in order to reduce the propagation of energy into the compartment area. Also this front structure has mounts for engine and suspension systems, so this should have enough stiffness to withstand in long durability. So an optimised structure development for the both cases carried out [9]

Procedure finite element method- model info

FE Model of Vehicle was dissembled and verified with BOM thickness and material information. Full view of vehicle shown in the figure 1 and 2. Full vehicle model has converted from design model to the FEA model by using appropriate elements and joints.

Fig. 1 Vehicle ISO View

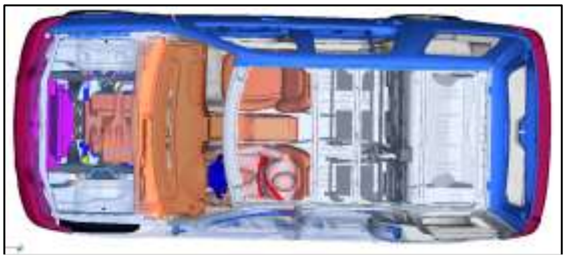
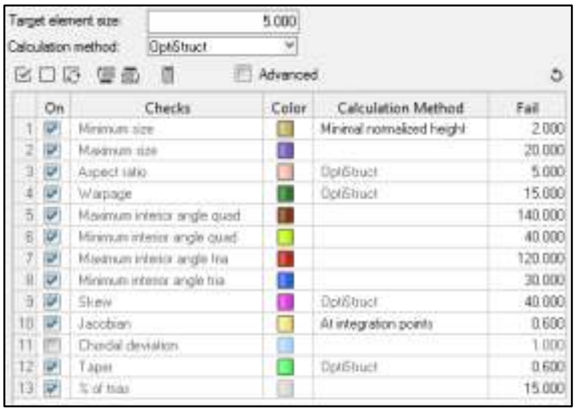


Fig. 2 Vehicle TOP View

Elements parameters

The sheet parts of the vehicle has model with shell elements (Quad and Triangular). The meshing has made in the mid plane of the components and thickness assigned to that elements, these elements will extrude both side equally to represent the thickness. Casting parts, thickness more than 6mm parts, foam has modelled with hexa penta elements. Bolts are model with 1D-beam elements with corresponding diameters. Welds are represented by using DYNA SPOT Weld elements. All joints of vehicle modelled with appropriate joints like Spherical joint, revolute joint, universal joint, Translation Joint, and lock Joints. All element Types with their counts has shown in the Figure 4.

Elements average size is 5mm. and the quality parameters are shown in the fig 3.



Target element size: 5.000
Calculation method: OptiStruct
Advanced

	On	Checks	Color	Calculation Method	Fail
1	☑	Minimum size		Minimal normalized height	2.000
2	☑	Maximum size			20.000
3	☑	Aspect ratio		OptiStruct	5.000
4	☑	Warpage		OptiStruct	15.000
5	☑	Maximum interior angle quad			140.000
6	☑	Minimum interior angle quad			40.000
7	☑	Maximum interior angle tria			120.000
8	☑	Minimum interior angle tria			30.000
9	☑	Skew		OptiStruct	40.000
10	☑	Jacobian		At integration points	0.600
11	☐	Chordal deviation			1.000
12	☑	Taper		OptiStruct	0.600
13	☑	% of trias			15.000

Fig. 3 Element Quality

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ELEMENT	904726
ELEMENT_BEAM_ELFORM_1	185
ELEMENT_BEAM_ELFORM_2	258
ELEMENT_BEAM_ELFORM_3	52
ELEMENT_BEAM_ELFORM_6	45
ELEMENT_DISCRETE	46
ELEMENT_MASS	478
ELEMENT_SEATBELT	283
ELEMENT_SEATBELT_ACCELEROMETER	14
ELEMENT_SEATBELT_SLIPRING	1
ELEMENT_SHELL	752808
ELEMENT_SOLID	149958
ELEMENT_TSHELL	598

Fig. 4 Element Type and Numbers

Constrained Connections

In the vehicle connection, Joints, extra nodes, Nodal Rigid Bodies and spot weld options has used. Joints used to represent the actual joints in the physical vehicle. Additional Extra Node option for connecting rigid parts with deformable parts. With NRB, the bold connection and another connection location were modelled. Spot weld connection to represent the physical spot with the actual diameter. Complete vehicle spot welding highlighted in Figure 6.

CONSTRAINED	9719
CONSTRAINED_JOINT_UNIVERSAL	2
CONSTRAINED_JOINT_CYLINDRICAL	3
CONSTRAINED_EXTRA_NODES_NODE	20
CONSTRAINED_JOINT_SPHERICAL	21
CONSTRAINED_JOINT_STIFFNESS_GENERALIZED	27
CONSTRAINED_JOINT_REVOLUTE	61
CONSTRAINED_RIGID_BODIES	112
CONSTRAINED_EXTRA_NODES_SET	187
CONSTRAINED_NODAL_RIGID_BODY	2444
CONSTRAINED_SPOTWELD	6842

Fig. 5 FE Connections

Fig. 6 FE Spot weld Connections

LS Dyna Material Information's

LS Dyna has comprehensive material library, in the vehicle components are made with lots of different material, which should model in the FEA with appropriate material card, also the rate of loading should be considered for high impact simulations. If some mistake modelling of material will lead to large changes in the behaviour of components. All list of material card used in the model shown in the fig 7. Elastro-plastic materials are modelled with MAT24 card, with strain rate dependent stress strain curves.

MATERIAL	1135
MAT71 MAT_CABLE_DISCRETE_BEAM	1
MAT_B01 MAT_SEATBELT	1
MAT_S02 MAT_DAMPER_VISCOUS	1
MAT26 MAT_HONEYCOMB	2
MAT123 MAT_MODIFIED_PIECEWISE_LINEAR_PLASTICITY	2
MAT_S05 MAT_DAMPER_NONLINEAR_VISCOUS	2
MAT83 MAT_FU_CHANG_FOAM	3
MAT_S01 MAT_SPRING_ELASTIC	4
MAT_S04 MAT_SPRING_NONLINEAR_ELASTIC	4
MAT3 MAT_PLASTIC_KINEMATIC	7
MAT6 MAT_VISCOELASTIC	14
MAT77 MAT_OGDEN_RUBBER	14
MAT66 MAT_LINEAR_ELASTIC_DISCRETE_BEAM	16
MAT7 MAT_BLATZ-KO_RUBBER	17
MAT57 MAT_LOW_DENSITY_FOAM	23
MAT1 MAT_ELASTIC	82
MAT9 MAT_NULL	90
MAT20 MAT_RIGID	301
MAT24 MAT_PIECEWISE_LINEAR_PLASTICITY	551

Fig. 7 FE Materials

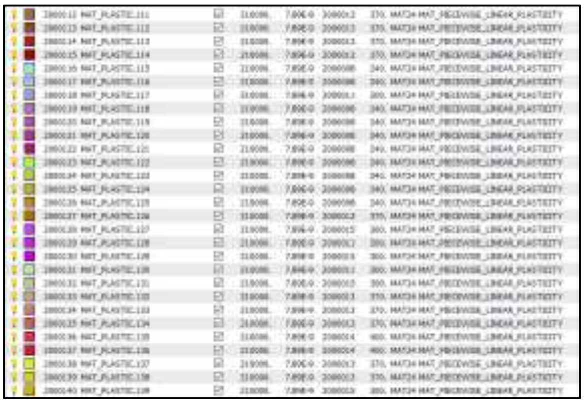

Fig. 8 FE Materials MAT24

Assembly mass and COG information

The Mass of the vehicle has corrected with assembly level mass. Because kinetic energy of the vehicle depends on the vehicle mass also. The mass and centre of gravity details are shown in the table I.

TABLE I: Mass and COG information of Vehicle

S.No	Assembly	Mass (Kg)	COG
1	Chassis	317	X=-2543.16 Y=-8.4368 Z=415.307
2	All-Upper Body	954.2	X=-2522.26 Y=9.6351 Z=868.38
3	Engine & Transmission	363.3	X=-1090 Y=-7.6504 Z=630.188
4	Radiator	30.56	X=-360.53 Y=4.3557 Z=675.66
5	Fuel Tank	49.05	X=-2590.53 Y=279.75 Z=333.221
6	Front Power Train	50.22	X=-965.25 Y=88.53 Z=345.53
7	Rear Power Train	107.4	X= -3597.62 Y= 6.304 Z=378.72
8	Front-Wheel assembly	155.7	X= -828.955 Y= 3.57 Z=388.9117
9	Rear-Wheel assembly	184.5	X= -3700.92 Y=-1.4466 Z=364.149
10	Exhaust System	32.23	X=-2349.22 Y=222.468 Z=357.5
	TOTAL MASS	2244.16	

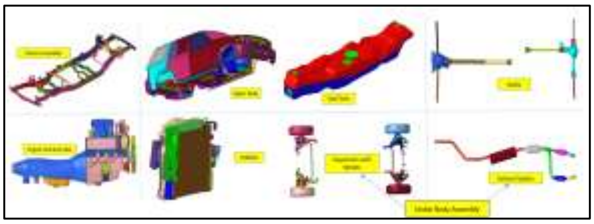

Fig. 9 Vehicle Sub-assemblies

40% OFFSET DEFORMABLE BARRIER IMPACT SETUP

In a complete test, the car travels at 56 km/h and overlaps at 40 percent overlap with deformable barrier that represents the oncoming vehicle. This test represent an accident running between two cars of the same weight, running at 56 km/h. ECE R94 specifies performance requirement for the protection of occupants in the event of frontal collision. This regulation is applied to vehicles of category M1 with total permissible mass not exceeding 2.5 tonne. Vehicle Kerb mass considered with HIII 50 % DUMMY (78kg). Acceleration due to gravity with the value of 9.81m/sec2 applied to full model. A 40% overlapped Deformable Barrier placed in front of the vehicle with close to front portion of the vehicle, and a 56 kmph velocity applied to the vehicle in X direction. Occupant positioned in the driver seat with seat belt locked condition. The ODB impact setup shown in the fig 10 and HIII-50% Dummy with cut view shown in the fig 11.

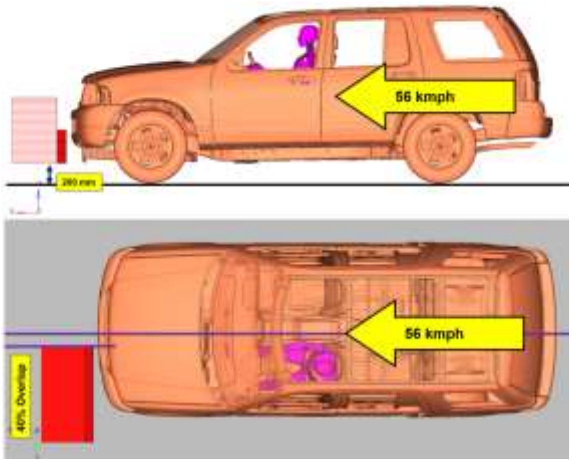

Fig. 10 ODB Impact Load case setup

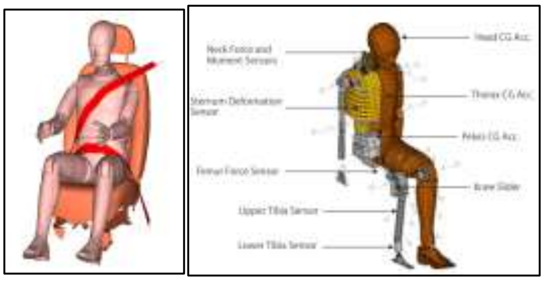

Fig. 11 Hybrid III Humanoid Dummy

IMPROVEMENTS AND ENABLERS

In this crash, the vehicle structure is tested. With limited structural involvement, inmates may be exposed to increased intrusions. Collision forces must be efficiently directed to those parts of the car that can efficiently and safely absorb energy. The front crumpled zone must collapse in a controlled manner so that the passenger compartment does not deform as much as possible. To avoid serious injuries, it is necessary to limit the backward

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movement of the handle and pedal. Based on the base vehicle behaviour, observed some unfriendly deformations. To reduce and control this deformation some of the following ODB impact enablers introduced in the vehicle after one by one separate contribution study.

1. Additional crush can
2. Collapsible steering column
3. Chassis frame stiffness improvement
4. Seat Structure Integrity Improvement
5. Seat belt Anchorage location improvements.

A. Additional Crush can

To reduce the dynamic crush value in the vehicle, the overall deformation should completed in less length of the vehicle. The kinetic energy should be absorbed by the parts which is located before engine mounts. So an additional load path member introduced with crush initiator holes, which is connected with front rail tip to engine bay cross member. Due to this new crush member has absorbed some amount of energy by the way of deformation, along with load transferred to engine by cross members. The fig 12 shows the new additional load path crush can.

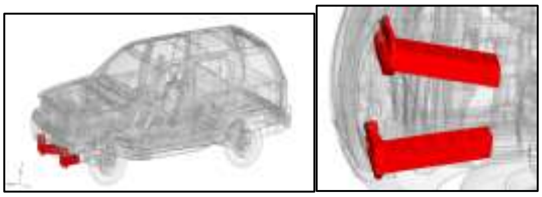

Fig. 12 Lower Crush can

B. Collapsible Steering Column

In the ODB Impact, rack and pinion assembly has moves the steering column towards compartment area.

Due to this push steering wheel displaced more in the X and Z Direction in the compartment area. Due to this push, steering wheel displaced more in X and Z Direction in the compartment area.

This continuous displacement initiated from the rack and pinion. This displacement should be stopped by in between the steering rods. So a telescopic rod like allow to translate in about axis with some limited value and constrained in the rotational. This mechanism is called as collapsible steering column. This fig 13 Shows the collapsible steering column.

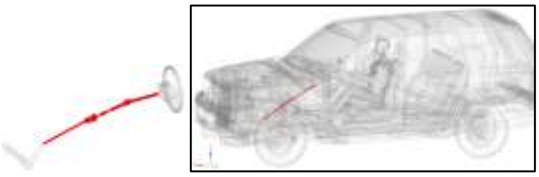

Fig. 13 Collapsible Steering Column

C. Chassis Frame Stiffness Improvement

In the base model, observed high deformation on the frame under the compartment area, this deformation will lead to risk on the seat mounting and fuel tank assembly. So a detailed study carried on the chassis frame to improve the strength and structural rigidity of the frame members. Based on that new frame introduced on the vehicle, the fig 14 shows the new chassis frames.

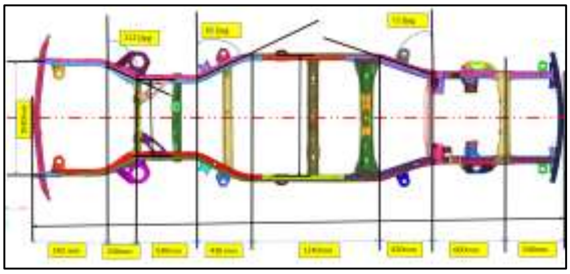

Fig. 14 Chassis Frame

D. Seat Structure Improvement

The restrain system plays a vital role in the occupant second hit at inside of the vehicle. A good seat restrain seat remain maintain the occupant on the seat, which lead to avoid some additional hit by the occupant. To develop the seat structure development, the driver seat carried out separate study to achieve good improvement, those load cases are like SBA, Frontal Impact, Rear Impact of seat structure level and Static stiffness of seat back structure. After structure meets the target values included in the full vehicle model. The driver seat structure model shown in the fig 15.

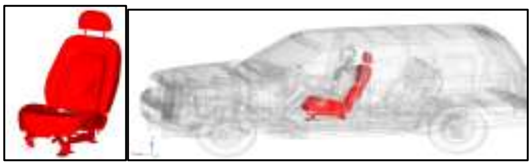

Fig. 15 Developed Driver Seat

E. Seat belt Anchorage location Improvement

From the observation of the base vehicle model, there is too much slag and movements on the seat belt. Due to this seat belt allows to move the occupant from the seat. It should be control, because the movement of occupant will lead to increase in the injury level. So the seat mounting location identified and it connected with strong BIW parts, which has overall very less deformation. So the movement of seat mounting location control during frontal Impact.

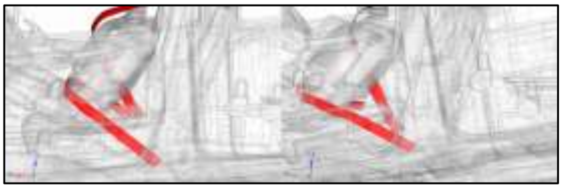

Fig. 16 Seat Belt Slag Reduction

RESULT COMPARISONS

A. *Overall Deformation*

The ODB impact end picture of Developed vehicle vs Base vehicle shown in the fig 17. By the introduction of ODB impact enablers, overall structural integrity improved.

Fig. 17 over view of vehicle behaviour

B. *BIW Plastic Deformation*

Body in White (BIW) is the important structure in the compartment area, which deformation has significantly reduced. This helps to improve the compartment area structural rigidity. The picture shows the comparison between the improved vehicles to base vehicle. Chassis frame separating from the BIW, which has avoided in the improved vehicle, so the seat mounting location and seat belt fixation locations has improved.

The fig 18 and 19 shows the plastic deformation of Chassis Frame, in the base vehicles frame has deformation under the compartment area, particularly at Fuel tank location this will lead to fuel leakage risk. After improved the vehicle, frame deformation moved to front kick down location, this helps to reduce the deformation on the compartment area.

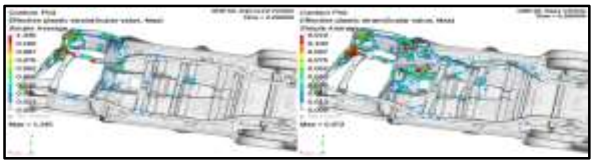

Fig. 18 BIW Plastic deformation underbody view

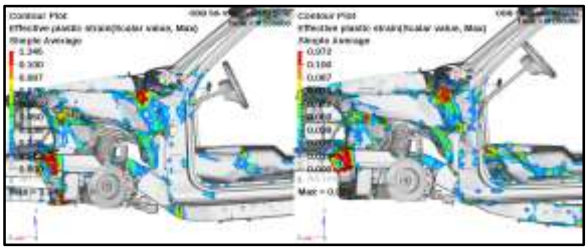

Fig. 19 BIW Plastic deformation of LH view

The overall occupant behaviour shown in the fig 20. The occupant hits on the steering wheel around 95ms in the base vehicle, this second hits avoided in the improved vehicle. Also the movement of occupant hip from the seat structure has significantly reduced. And same time seat structure deformation considerably reduced. Along with this steering wheel intrusion reduced.

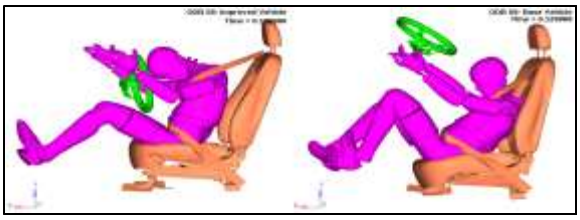

Fig. 20 Occupant behaviour

The maximum pulse of LH Sill and RH sill shown in the fig 21. The peak pulse has decreased compare with base vehicle, also this peak pulse within the target limit of 80g. The decrease in the pulse observed because of the overall vehicle crashworthiness performance has increased, so the

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intrusions reduced and correspondingly the acceleration pulse has decreased.

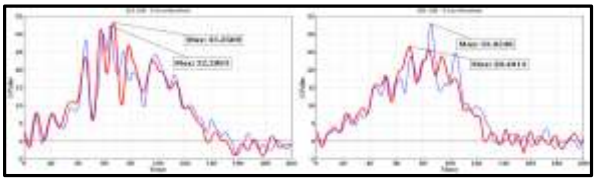

Fig. 21 Deceleration pulse

The steering wheel displacement of X intrusion and Z Intrusions has shown in the fig 22 and fig 23.

This overlayed picture shows the Comparison between base vehicles to developed vehicle. Blue cure is Base vehicle values and Red curve is Improved Vehicles Curve. So from the Steering wheel displacement curve the displacement of the steering wheel has significantly reduced.

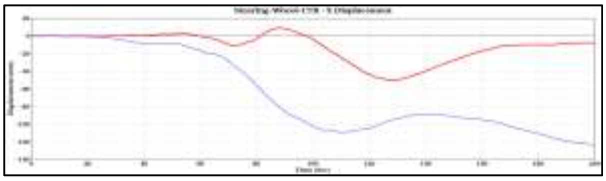

Fig. 22 Steering wheel X Displacement

Fig. 23 Steering wheel Z Displacement

The Average sill pulse, Average Sill velocity, Dynamic Intrusions in inches and Acceleration with Dynamic crush curves for Base vehicle (blue) compared with improved vehicle (Red) has shown in the fig 24.

The average pulse has increased due to the overall structural rigidity improvement. The Time to Zero velocity has reduced, so the overall vehicle starts to rebound 110ms, the vehicle crush has reduced so the intrusions of the vehicle has significantly increased. The area under the curve acceleration vs Dynamic crush shows the overall energy absorbed during the impact. This abortion has increased with short time period.

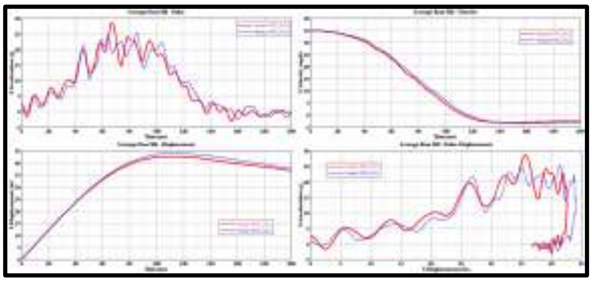

Fig. 24 Crash worthiness Performance

CONCLUSION FUTURE SCOPE OF WORK

This study has shown the possibilities to improve the vehicle structural rigidity to reduce the injury of the occupant during ODB impact collision. The base vehicle performance evaluated in the Finite element method and after observing the overall behaviour, the special enablers introduced to improve the vehicle ODB impact performance.

TABLE III: ODB56 Impact SUMMARY

S.No	Measurements	Target	Base Vehicle Results	Improved Vehicle Results
1	Average Pulse	80g	25	28
2	Left Sill Pulse	80g	32	33
3	Right Sill pulse	80g	33	26
4	Steering wheel X Displacement	100mm	123	50
5	Steering wheel Lateral Displacement	mm	+25/-36	+14/-40
6	Steering wheel vertical Displacement	80mm	155	46
7	Time to Zero velocity	Time (ms)	120	115
8	Overall Sill Displacement (Dynamic Crush)	inch	44	42
9	Center of IP Pulse	G	46	55
10	Center of IP Displacement	inch	47	45
11	Engine Top Pulse	G	52	48
12	Engine Top Displacement	inch	37	37
13	Engine Bottom Pulse	G	43	39
14	Engine Bottom Displacement	inch	41	40
15	Left In board Knee Bolster	inch	43	42

	Intrusion			
16	Left Out board Knee Bolster Intrusion	inch	42	40

From the summary table II, in the base vehicle mainly steering wheel displacements are not with in the target value, also large deformation observed in the compartment area, and the second hitting of occupant happed due to poor restrain system, these are avoided due to the introduction of ODB Impact enablers.

These enablers improving the overall structural rigidity and reducing the deformations with less intrusion, due to this sill acceleration has increased, but still this acceleration value with in the target limit. Mainly the second hitting happed because of large movement of steering wheel in to the compartment, this avoided by enablers, also not much changes observed in the IP panel displacement.

So from this study the overall Occupant injury level has reduced and structural performance has increased.

References

[1]. Nitin S. Gokhale. (2008). "Practical Finite Element Analysis". Finite to Infinite. ISBN: 8190619500.

[2]. Federal Motor Vehicle Safety Standards FMVSS no.208.

[3]. Economic Commission for Europe safety regulations, ECE r94.

[4]. American Iron and Steel Institute Southfield (2004). "VEHICLE CRASHWORTHINESS AND OCCUPANT PROTECTION"

[5]. LS-DYNA User,s Mannual version971,2016.

[6]. Maruthi.B.H 1, Punith Gowda.K 2, Chetan.H.M (2016) 'Behaviour Study On Restraining System For Frontal Impact Euro NCAP. Elsevier: IJSETR, Volume 5, Issue 2.

[7]. Kakit Fung, (2016) "Center for Accessibility and Safety for an Aging Population", Florida State University

[8]. U.S. DEPARTMENT OF TRANSPORTATION NATIONAL HIGHWAY TRAFFIC SAFETY ADMINISTRATION "Laboratory Test Procedure for New Car Assessment Program Frontal Impact Testing".

[9]. Hao Chen (2015) "Vehicle Front Structure Energy Absorbing Optimization in Frontal Impact" The Open Mechanical Engineering Journal, 2015, 9, 168-172.

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