

Computational Validation and Improvement of M1 Category Vehicles during Flat Frontal Impact with Occupant Safety Development by 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 flat frontal collision. 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, flat frontal collision was used as the collision condition. To improve the passive safety of the vehicle, several frontal 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, Flat Frontal Impact, SUV Vehicle Crash, collision, Euro-NCAP, FEA Simulation, Vehicle Injury, Occupant Safety, Impact Simulation, LS-Dyna Simulation, Explicit.

I. 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 rating the vehicle safety level announced the 5 star rating scale, The New Car Assessment programme 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.

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A good restraint 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 a optimised structure development for the both cases carried out [9].

II. FINITE ELEMENT METHOD - MODEL INFORMATION

FE Model of Vehicle was dissembled and verified with BOM thickness and material information. Full view of vehicle shown in the figure 2.1 and 2.2. Full vehicle model has converted from design model to the FEA model by using appropriate elements and joints.



Figure 2.1 Full Vehicle ISO View

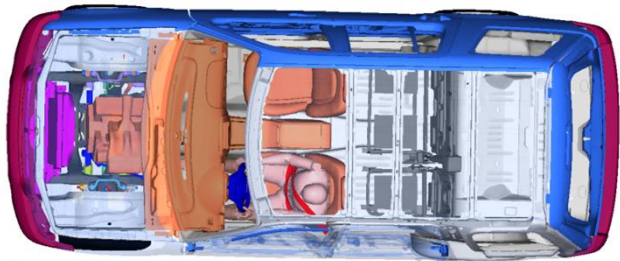


Figure 2.1 Full Vehicle TOP View

2.1 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.

III. FLAT FRONTAL IMPACT SETUP

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 Full rigid wall placed in front of the vehicle with close to front portion of the vehicle, and a 60 kmph velocity applied to the vehicle in X direction. Occupant positioned in the driver seat with seat belt locked condition. The Flat Frontal impact setup shown in the fig 3.1.

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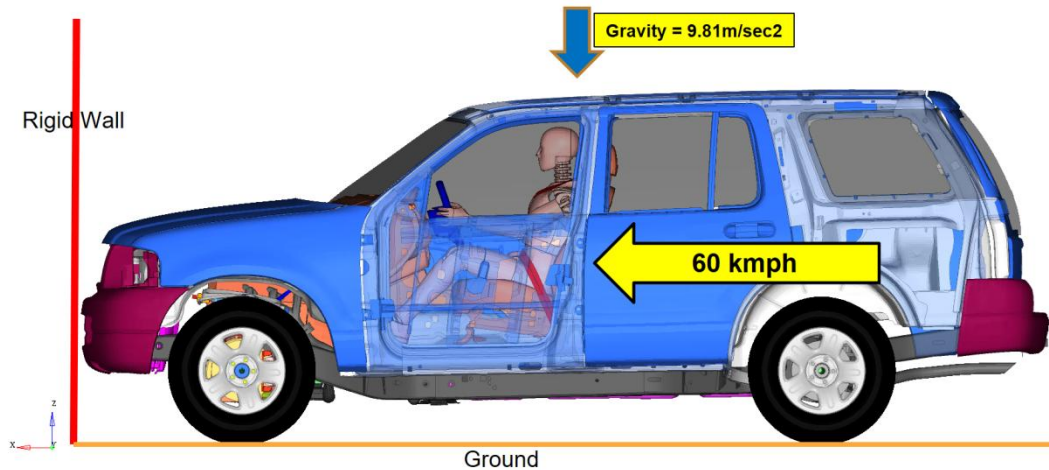


Figure 3.1 Chassis Dimension

IV. IMPROVEMENTS AND ENABLERS

Based on the base vehicle behaviour, observed some unfriendly deformations. To reduce and control this deformation some of the following flat frontal 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.

I 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 4.1 shows the new additional load path crush can.

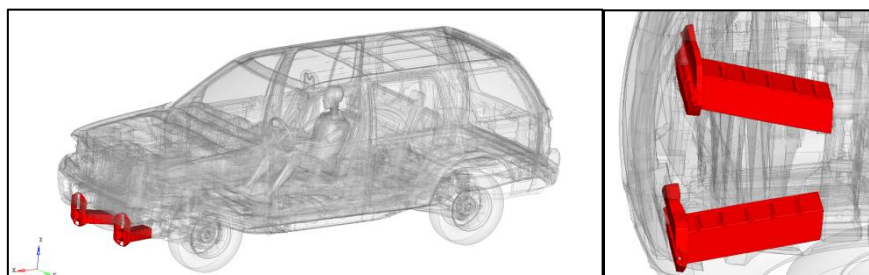


Figure 4.1 Lower Crush Can

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II Collapsible Steering Column:-

In the flat frontal 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 4.2 Shows the collapsible steering column.

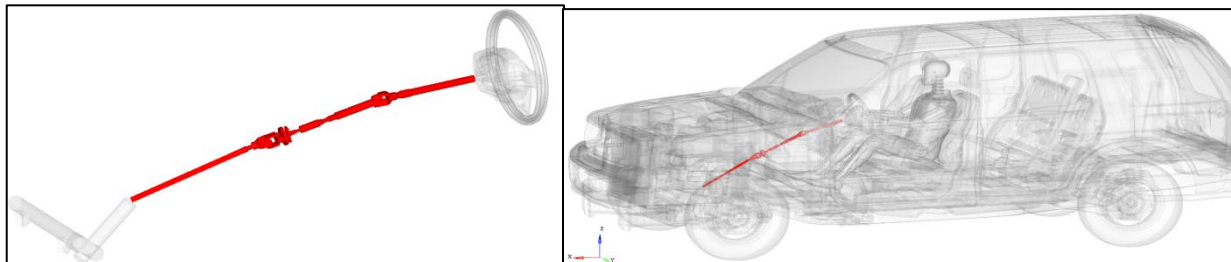


Figure 4.2 Collapsible Steering column

III 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 4.3 shows the new chassis frames.

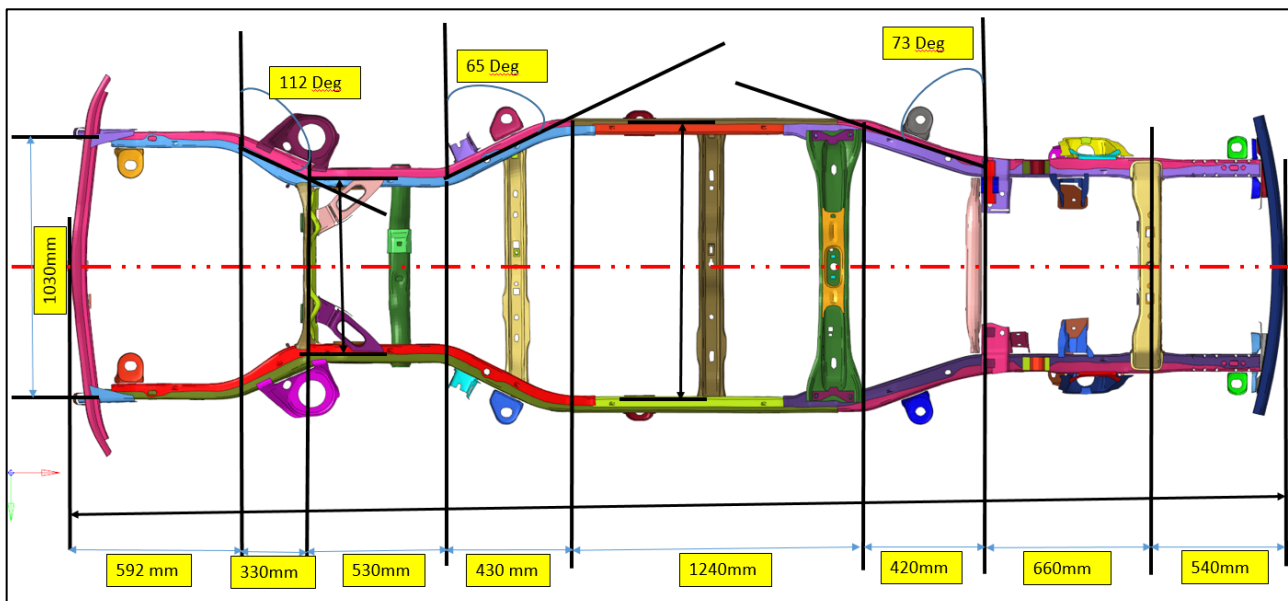


Figure 4.3 Chassis Frame

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IV Seat Structure Improvement:-

The restraint system plays a vital role in the occupant second hit at inside of the vehicle. A good seat restraint 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 4.4.

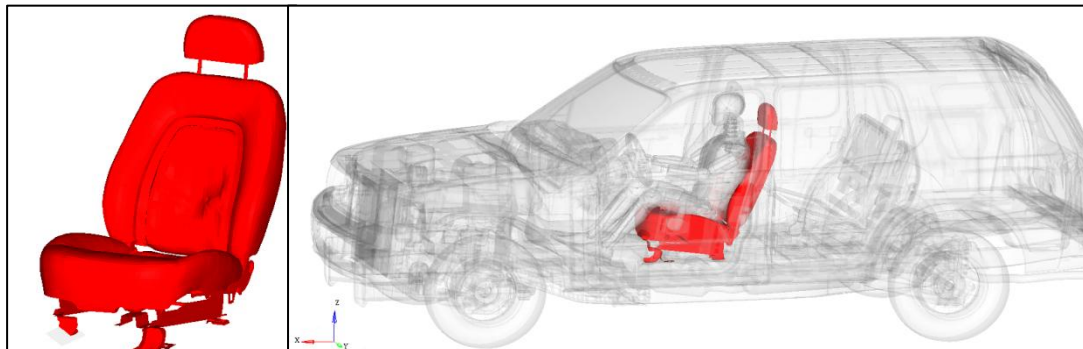


Figure 4.4 1st Row seat

V 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 allowsto 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.

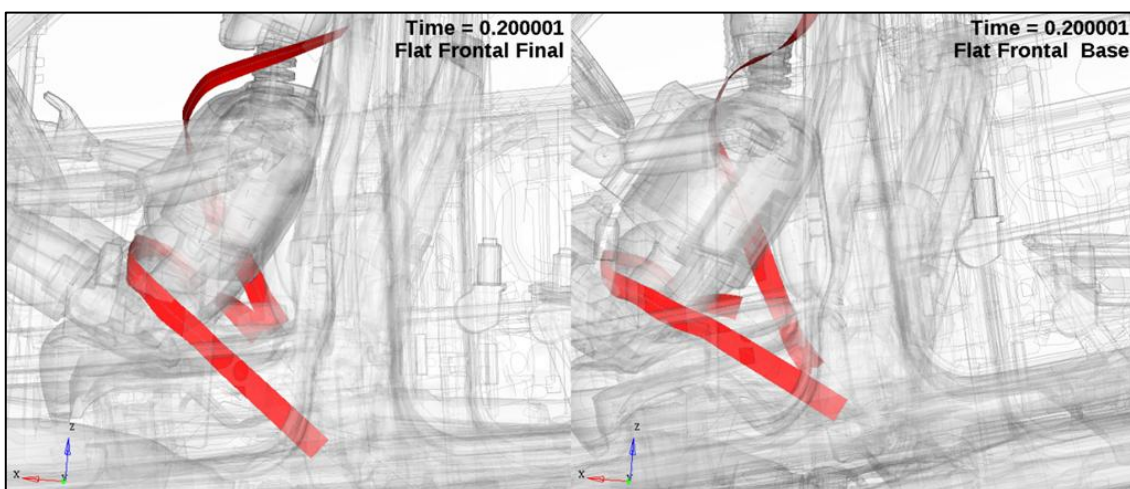


Figure 4.5 Seat belt slag

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V. RESULT COMPARISONS

5.1 Overall Deformation

The frontal impact end picture of Developed vehicle vs Base vehicle shown in the fig 5.1 by the introduction of frontal impact enablers, overall structural integrity improved.

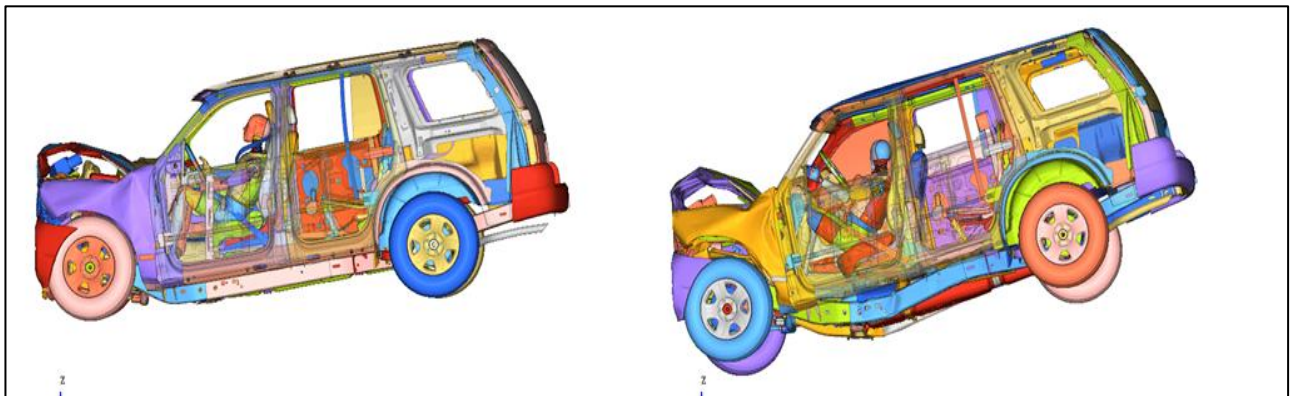


Figure 5.1 Vehicle Deformation mode

5.2 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.

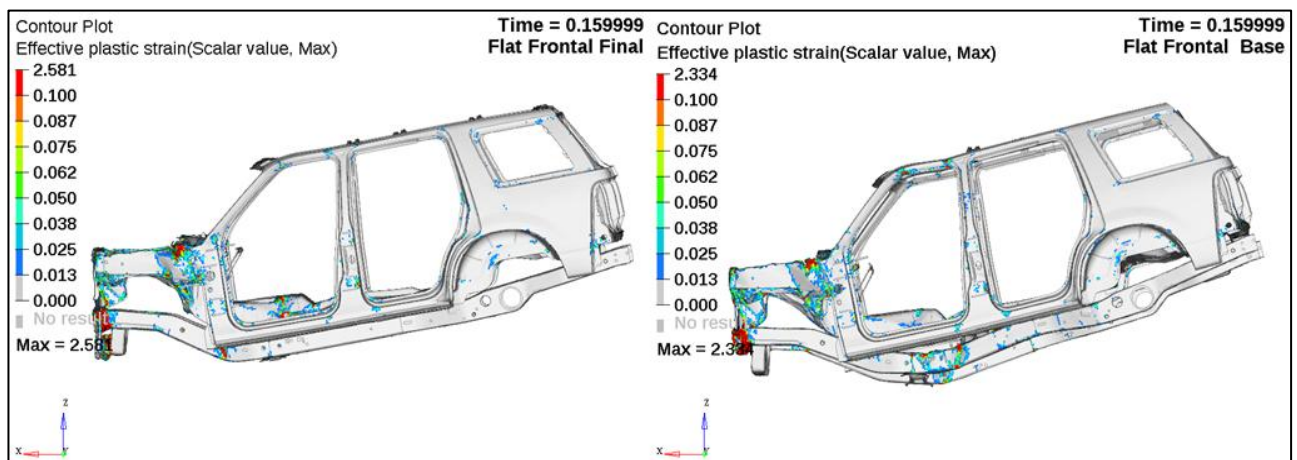


Figure 5.2 BIW Plastic Strain contours

The overall occupant behaviour shown in the fig 5.3. The occupant hits on the steering wheel around 80ms in the base vehicle, this second hits avoided in the improved vehicle. Also the movement of occupant hip from the seat

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structure has significantly reduced. And same time seat structure deformation considerably reduced. Along with this steering wheel intrusion reduced.

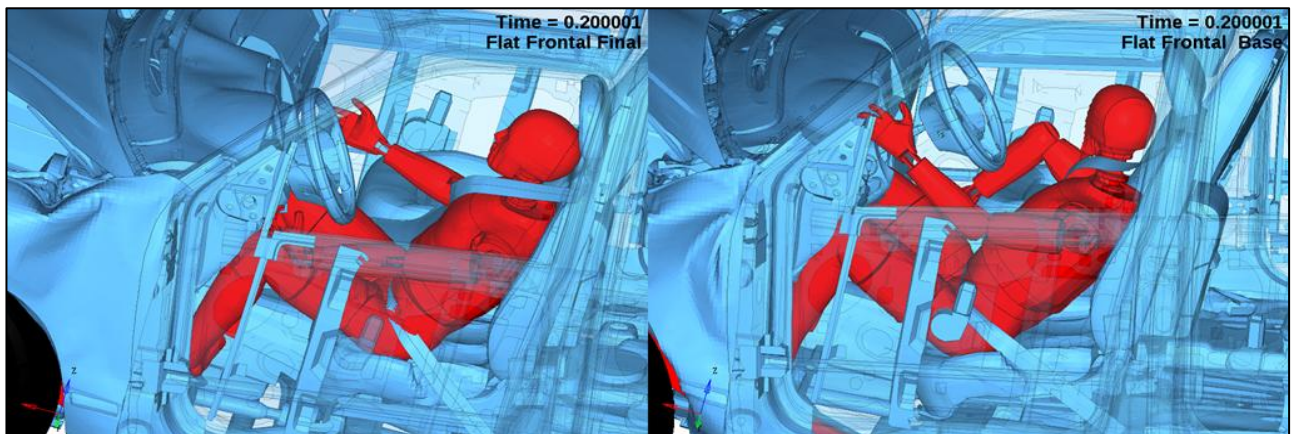


Figure 5.3 Occupant Behaviour

The fig 5.4 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.

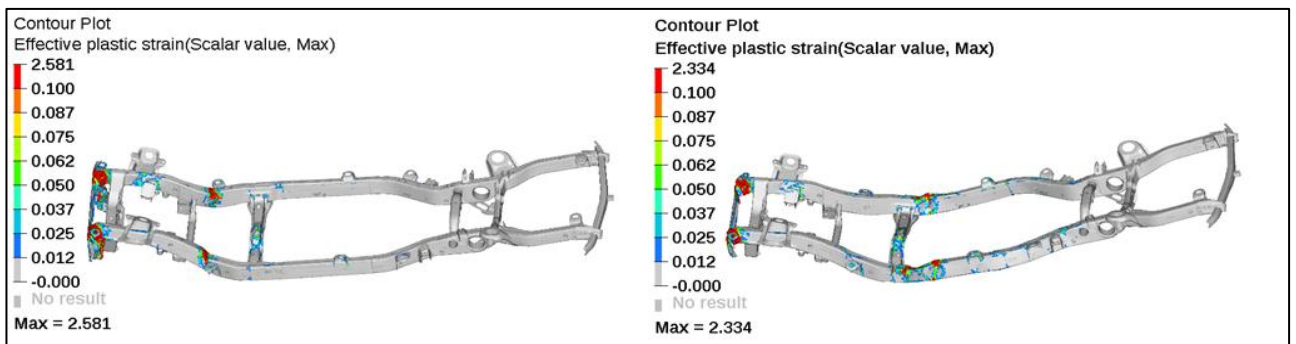


Figure 5.5 Frame Deformation

The maximum pulse of LH Sill and RH sill shown in the fig.5.6. The peak pulse has increased compare with base vehicle, but still this peak pulse within the target limit of 80g. The increase in the pulse observed because of the overall vehicle structural rigidity has increased, so the intrusions reduced and correspondingly the acceleration pulse has increased.

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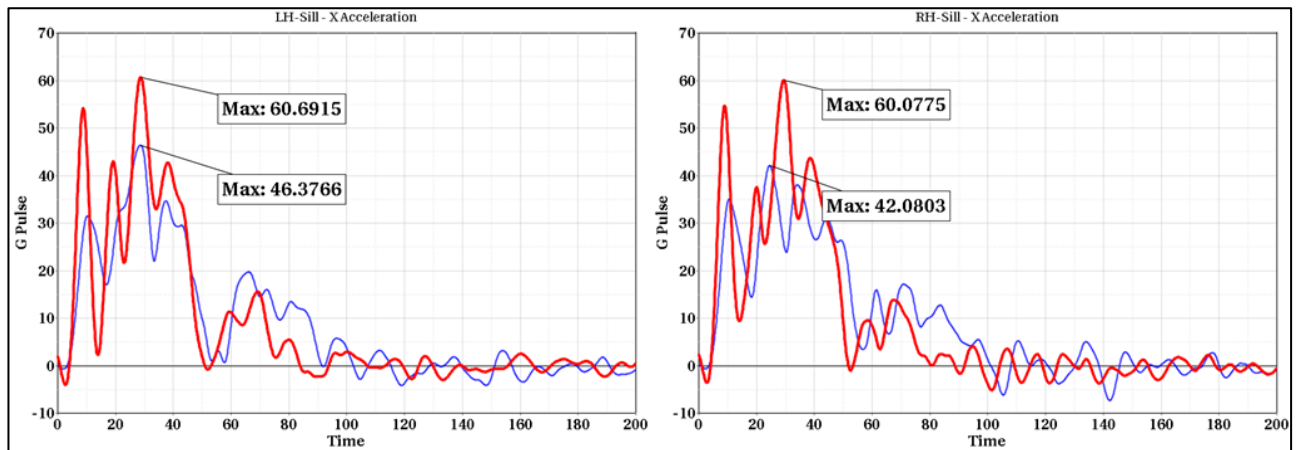


Figure 5.6 Acceleration pulse for both LH and RH.

The steering wheel displacement of X intrusion and Z Intrusions has shown in the fig 5.7 and fig 5.8.

This overlaid picture shows the Comparison between base vehicles to developed vehicle. Blue curve 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.

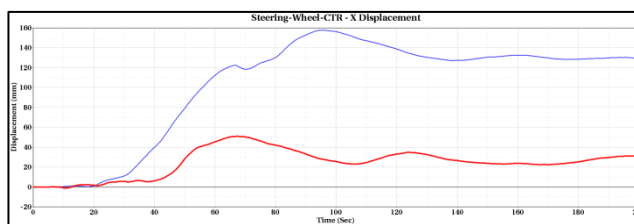


Figure 5.7 Steering wheel X Displacement

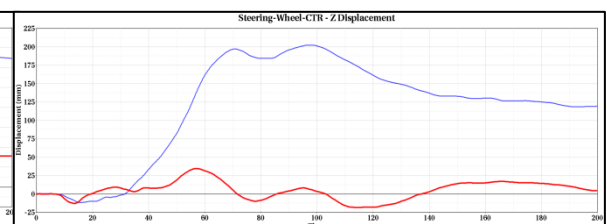


Figure 5.8 Steering wheel Z Displacement

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 5.9. 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 68ms, 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.

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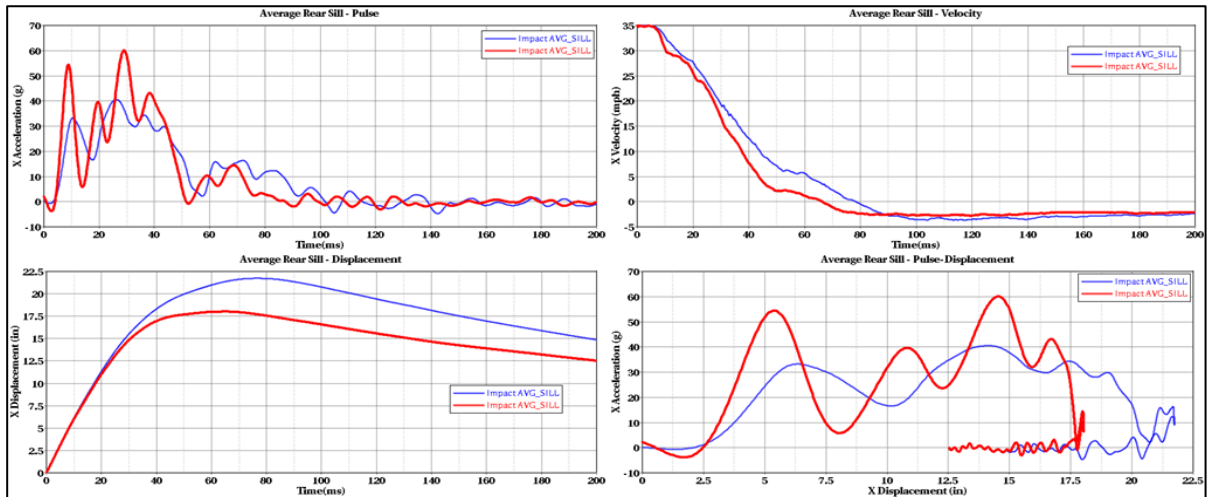


Figure 5.9 Flat Frontal impact performance curves.

VI. 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 flat frontal 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 frontal impact performance.

Table 1 Summary of Flat Frontal Impact

S.No	Measurements	Target	Base Results	Vehicle	Improved Vehicle Results
1	Average Pulse	80g	40	60	60
2	Left Sill Pulse	80g	46	60	60
3	Right Sill pulse	80g	42	60	60
4	Steering wheel X Displacement	100mm	158	51	51
5	Steering wheel Lateral Displacement	mm	44	33	33
6	Steering wheel vertical Displacement	80mm	202	34	34
7	Time to Zero velocity	Time (ms)	78	68	68
8	Overall Sill Displacement (Dynamic Crush)	inch	22	18	18
9	Center of IP Pulse	G	66	85	85
10	Center of IP Displacement	inch	23	24	24
11	Engine Top Pulse	G	97	97	97
12	Engine Top Displacement	inch	15	15	15
13	Engine Bottom Pulse	G	75	89	89
14	Engine Bottom Displacement	inch	16.2	16.4	16.4
15	Left In board Knee Bolster Intrusion	inch	23	18.8	18.8
16	Left Out board Knee Bolster Intrusion	inch	20.5	17.2	17.2

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From the summary table 1, 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 flat frontal 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 CRASH WORTHINESS AND OCCUPANT PROTECTION"
- [5] LS-DYNA User's Manual version 971, 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.