
Pravin E. Fulpagar, Dr. S.P. Shekhawat
Department of Mechanical Engineering, SSBTS COET Jalgaon.

Abstract—This paper addresses the design and development of a conceptual crash preparation feature, called an Impact energy absorber to reduced damage to an occupant during a high risk of frontal impact. The goal is to define an occupant protection system that in crash testing up to an impact velocity of 56km/h with an occupant would result in injury measures below the FMVSS 208 injury criteria levels. A crashworthy vehicle must meet the impact energy management criteria that require the passenger compartment structure to sustain crash loads without excessive deformation while absorbing and dissipating the kinetic energy of impact. An extendable and retractable impact energy absorber is assembled in a vehicle bumper which forms an extendable and retractable bumper that could provide the desired crush space only when a need appears. The additional crush space would allow the extended bumper structure to absorb additional crash energy to reduce the severity of crash. A detailed FE simulation is carried out on the extendable and retractable bumper & the results obtained are compared with the standards. At the end of this project we have to analyze the theoretical and technical potential to develop an efficient crash safety system for passenger vehicle occupants in a frontal crash at high impact velocity.

Index Terms—frontal crash, occupant protection system, Impact energy absorber, an extendable and retractable bumper, FMVSS 208, crashworthy vehicle, FE simulation.

I. INTRODUCTION

The major focus behind this project is to study the energy absorption capabilities of the energy absorber when fitted in the vehicle in case of full frontal impact of a car. [1]. ‘Crashworthiness of a vehicle structure is the ability of the structure to plastically deform and yet maintain a sufficient survival space for its occupants in crashes.’ The crash test gives us a measure of how well a passenger vehicle would protect its occupants in the event of a serious real world frontal crash. A conceptual crash preparation feature, called the Impact energy absorber is presented to reduced damage to occupant in situations in which there is a high risk of frontal impact to prepare the vehicle for crash. The assessment of scope for energy absorption showed that the extendable and retractable energy absorbers help in reducing the amount of structural intrusion to the passenger compartment. The presence of Extendable and Retractable impact energy absorbers helps in absorbing and dissipating the kinetic energy of impact. The vehicle is to be decelerated in a relatively short time and distance to reduce high impact load occurring in axial collapse of a crush. The major focus behind this project is to study the energy absorption capabilities of the energy absorber when fitted in the vehicle in case of full frontal impact against a rigid barrier. Depending upon these aspects the problem is stated and this report gives a brief idea to the reader about the work carried out in this project.
II. PROBLEM STATEMENT
Reconfiguration of a vehicle’s structure by designing of the occupant protection system to efficiently protect the occupant up to an impact velocity of 56 km/h and further evaluation of the improvements in crashworthiness of vehicle.

III. LITERATURE REVIEW
Various technical aspects are reviewed from several technical papers and applied to execute this project. Wang, J. T., 1999, addresses an extendable and retractable bumper. The extendable and retractable bumper is intended to automatically extend in situations in which there is a high risk of frontal impact to prepare the vehicle for crash and retract when the risk subsides. In this paper the description about the method of assembling the extendable and retractable energy absorbers are also mentioned. The paper is very important in co-relating the simulation and the actual test.
Darin Evans and Terry Morgan 1999, focuses on the energy absorption capabilities of the bumper system. Most widely used energy absorption construction is made from expanded polypropylene foam (EPP). This paper addresses toward the use of thermoplastics as bumper energy absorber. High strength to weight ratio and specific energy of engineering. This paper gives an idea of various factors – like Cost, Performance, Design, Process and Material.
H.F .Mahmood et.al.1989, addresses the structural analysis for crashworthiness which consist of three parts, those are:
- Thin wall element model
- Thin wall element stiffness formulation
- Thin wall element numerical solution
This paper has helped in understanding the behavior of thin walled element under the following conditions:
- Pure axial loading and bending
- Combined axial compression and bending
D Al Galib et al, 2006, focuses on the crack appearance and development in metallic tube energy absorbers when subjected to axial crush.
IV. EXPERIMENTAL METHODOLOGY FEA AND SIMULATION

4.1 Methodology:

Figure 2 - Flow chart of Experimental Methodology
4.1.1 Modeling of Impact Energy Absorbers:
The impact energy absorber used in this project is known as self-locking telescopic mechanism. The Geometric model of extendable and retractable mechanism is carried out in CAD Softwares like Catia V5. The various dimensions of this self-locking telescopic mechanism are shown in the table below:

<table>
<thead>
<tr>
<th>Components</th>
<th>Dimensions (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner Tube diameter</td>
<td>50</td>
</tr>
<tr>
<td>Inner Tube Length</td>
<td>220</td>
</tr>
<tr>
<td>Outer Tube diameter</td>
<td>65</td>
</tr>
<tr>
<td>Outer tube length</td>
<td>150</td>
</tr>
</tbody>
</table>

Table 1. Dimensions of energy absorbers

4.1.2 Finite Element Modeling:
The finite element model of extendable and retractable mechanism is created in Hypermesh 11.0. The finite element model of the telescopic structure is created by using shell element with an element size of 5. The finite element of the balls used in this mechanism is modeled and meshed in Hypermesh only for the ease of meshing and maintaining the connectivity between the elements. The ball being solid meshed with hex element.

4.1.3 Assembling Extendable and Retractable energy absorbers to automobile: In this project the vehicle FE model used for the simulation is the 2002 Dodge caravan (MUV) developed by NCAP for the National Highway Traffic Safety Administration (NHTSA).
The impact energy absorbers are fitted between the front rail and inner bumper. Outer tube is connected to the front rail by means of rigid links where as inner tube is connected to the bumper mounting bracket by means of rigid links and this bumper mounting brackets are connected to the inner bumper by means of spot welds.

4.1.4 Assigning Materials: From the material library in Radioss High Strength Low Alloy Steel is used for the extendable and retractable bumper mechanism. High-strength low-alloy (HSLA) steels, or micro alloyed steels, are designed to provide better mechanical properties and/or greater resistance to atmospheric corrosion.

4.1.5 Rigid Wall: In this simulation the barrier is constructed ‘rigid’ with all degrees of freedom constrained at each node. The rigid wall is created using shell element. The material assigned for the rigid wall is MAT_RIGID (Mat type 20). Rigid bodies do not undergo any deformation.

4.1.6 Boundary Conditions: Boundary conditions includes defining contacts, constraints etc. In this case contact between rigid wall and the vehicle is defined. Contact type used in RADIOSS for crash worthiness application is CONTACT_AUTOMATIC_SINGLE_SURFACE. In RADIOSS, a contact is defined by identifying a master surface and the other as slave.
Similar contact is given between the tyre and the road surface. A rigid wall is considered as the road for carrying out this project. In this case roads surface acts as master surface whereas the nodes of tire acts as slave nodes. A contact force is generated as the slave nodes penetrate the master surface. The friction between tyre and road and vehicle and wall is neglected as the analysis is carried out for a very small time.

**4.1.7 Safety Standard FMVSS 208:**

The National Highway Traffic Safety Administration (NHTSA) strives to establish test produces in regulatory that lead to improvements in real world safety. According to Law, the entire vehicle must meet pass certain safety tests before they are sold. The guidelines and regulation that are adopted for the thesis work are NHTSA FMVSS 208.

A crash test for **FMVSS 208** is to determine how well a passenger vehicle would protect its occupants in the event of a serious real world frontal crash. The Full Frontal Fixed Barrier Crash test (or Rigid Barrier test) represents a vehicle - to - vehicle full frontal engagement crash with each vehicle moving at the same impact velocity.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact Speed</td>
<td>56km/hr or 35 mph</td>
</tr>
<tr>
<td>Impact object</td>
<td>Fixed rigid barrier</td>
</tr>
<tr>
<td>Vehicle and barrier orientation</td>
<td>Full Frontal</td>
</tr>
<tr>
<td>Injury criteria</td>
<td>Head and chest deceleration</td>
</tr>
</tbody>
</table>

**Table 2 Frontal Impact Test Specifications**

For FMVSS No. 208, the impact velocity is 0 to 56 kmph and the barrier rebound velocity is small compared to the impact speed. It is a full systems test, which evaluates the protection provided by both the energy-absorbing vehicle structure and the occupant restraint system.

**4.2 Simulation of full frontal impact:** The validation is carried out as per the EURO NCAP standards in which the finite element model of Dodge Caravan is crashed against a rigid barrier at a velocity of 15 m/s. The simulation of this crash event can be viewed using HYPERVIEW. It is carried out for time duration of 150 milliseconds.
The above picture shows the accuracy of the simulation to real test. From the picture it can be seen that front of the car is completely crushed after the test. This is good, as the car has to get crushed and collapse in order to absorb the kinetic energy and stop the car. The actual test is conducted on Dodge Caravan by the Transportation Research Center Inc., (USA) for NHTSA, (USA). From the above pictures the model is validated for the visual correlation.

V. ANALYSIS AND RESULT

5.1 Analysis:

5.1.1 Assembly of Extendable and Retractable Energy Absorber in Hypermesh:

5.1.2 Elemental stresses in Extendable and Retractable Energy Absorber in RADIOSS:
5.1.3 Numerical Correlation:

Numerical correlation is even more important as compared to visual correlation. For numerical correlation the vehicle frontal crash is simulated for 150 millisecond at a velocity of 56 km/hr. For the numerical simulation following graph were taken from the accelerometers mounted on the engine top. Following graphs are obtained from the simulation.

5.2 Result discussion:

From various graphs the FE model is validated for the full frontal crash fitted with Extendable and Retractable impact energy absorbers.

5.2.1 Displacement Vs Time: According to FMVSS 208, the maximum displacement for this particular vehicle i.e. for Dodge Caravan should not be more than 653mm. The simulation shows that the maximum displacement of the vehicle is 648.4 mm which meets FMVSS standards.

5.2.2 Velocity Vs Time: As per the simulation results The velocity of vehicle is dropping significantly and at 77.8 milisecond the velocity is equal to zero and after that the vehicle is bouncing back as it strikes the rigid wall so there is a negative velocity. The simulation conducted is matching the simulation carried out at NHTSA.

5.2.3 Acceleration Vs Time: From the comparison of graphs of simulated vehicle and the test conducted on actual vehicle it can be seen that the pattern of both graphs are similar apart from their values.

5.2.4 Energy Balance Graph: From the energy balance graph it can be seen that the impact energy absorbers provide additional time or it prevents the sudden drop in kinetic energy and hence reduces the injury risk to the passenger. It can be seen that the energy balance of simulated
Vehicle is matching almost exactly to that of the simulation conducted in NCAP. These energy absorbers help in reducing the acceleration forces affecting the structure and eventually prevent the acceleration force being transferred to the occupant. From the graph it could be concluded that the E/R energy absorber is effectively absorbing the maximum amount of energy as compared to the various bumper component.

**Comparison of Intrusion:**
The pictures in figure shows the deformation of vehicle front structure is very large in case of the vehicle without E/R impact energy absorbers where as the deformation has drastically reduced in case of vehicle with E/R impact energy absorbers and further provides better safety to the occupant as the amount of intrusion of front structure of vehicle is very less as compared to that of a vehicle without E/R energy absorbers.
VI. CONCLUSION

The study in project illustrates that the E/R bumper may provide additional crush space in an at-risk situation of frontal impact to prepare the vehicle for a subsequent crash and retract when that risk subsides. The Extendable and Retractable impact energy will provide additional safety to the occupant without affecting the styling of the vehicle structure. However, no attempt was made in this study to assess manufacturability, mass implications and the reliability of the pre-crash sensing technology. Further developments to address all safety requirements, including real-world crash events, are necessary before implementing this feature in a production vehicle.

REFERENCES

[1]. Wang, J. T., 2005 “An Extendable and Retractable bumper”, General Motors Corporation, United States Paper no. 05-0144


[7]. crash.ncac.gwu.edu/pradeep/NCAP/caravan_ncap.pdf

[8]. www.euroncap.com/content/test_procedures/downloads.php?area