Abstract— Side Impact crashes can be generally dangerous because there is no room for large deformation to protect an occupant from the crash forces. The side impact collision is the second largest cause of death in United States after frontal crash. it is very essential to take necessary precautions to avoid fatalities during the event of side impact crash. The main object of this thesis work is to change the current car door impact beam with the modified design and using a high strength steel of yield stress 1.2 GPa instead of low strength steel of yield stress 0.366 Gpa in order to reduce the intrusion of side closure structure to reduce the injury of the occupant. The usage of the high strength impact beam on the car door has been implemented and its effectuality in reduction of intrusion of the door structure has been evaluated using cae.

Keywords— Impact Beam, Crash, Material Displacement, High Strength Steel.

I. INTRODUCTION

The automotive industry in India is one of the largest automotive markets in the world. By the end of the year 2015, India is expected to be the fourth largest automotive market by volume in the world. Over the next 20 years, India will be a part of the big global automotive triumvirate. Statistics says that the domestic market share in the year 2013-14 of passenger vehicle is 13.59%. According to a survey the total estimated vehicles in India will be 40-45 crore in next 20 years. Now currently there are around 6 to 7 crore of vehicles in India.

As per the recent report provided by the World Health Organization (WHO), India has highest number of road accidental deaths in the world. Therefore, to reduce the accidental fatalities, safety regulations of passenger car are having major role in automotive industry. The industries have to meet the needs of particular crashworthiness standards by manufacturing the nearer dimension design change in the vehicle structure and by implementing necessary structural parts that suits the overall design requirements.

To reduce the accidental risk of occupants in the event of side impact crash, the car doors are manufactured with impact beams. The major objective of the side door intrusion beam is to reduce injuries to the occupants by providing high strength to car door structure. Car door impact beam is mounted to the car side door inner structural part in three locations which is shown in the above figure. The door frame and three beams are designed in such a way that it minimizes the door intrusion in the event of side crash.

The resistance to the force per unit deformation of the material plays a major role in the optimization of car door structure design. The effect of the intrusion by the car door structure should be as little as possible. And the force developed on the car door structure during the side impact crash must be equally divided in such a way that the occupants in the car are affected minimal. In regard to these safety precautions FMVSS 214 of American standards is one of the regulations which should be taken into consideration at the time of designing the side closures.

Tom Gibson, MONASH University[1] has explained recent developments on side impact protection. And he has discussed in detail regarding severity of accidents in side impact crashes and the extent and patterns of injuries to occupant. He has taken real time accidents data from the year 1989 to 1997 in the whole state of Victoria. For real time crashed vehicle analysis he has taken data from National accident analysis sample (NAAS). And he has provided all injury details of side impact crashes.

E. Ėrniauskas, A. Keršys, V. Lukoševičius and J. Sapragonas[2] Presented a paper on anti impact beams in 2010 by considering FMVSS 214 old regulation. They have analyzed impact beams by considering different cross sections and different grade steel material. They have explained the importance of analyzing individual parts rather than complete vehicle.

Divakara H Basavaraju[3], Wichita state university, 2005. Presented a paper on impact beam in 2005 to Wichita State University. He has discussed and compared the energy absorption and displacement of a side impact beam by considering carbon fiber composite material and steel. Finally the conclusion was

- Weight has been reduced considerably.
- Deformational energy absorption capability
- Composite material impact beam is more.
- Composite materials can be use where high stiffness and strength are needed.
• But the cost to manufacture the composite material beam is very high. Hence, it cannot match the lower end priced cars.

II. METHODOLOGY

This project starts with the design modification of the car door side impact beam, then comparing current steel beam with the newly designed steel beam with a current for capability of total energy absorption. The material property of the newly designed beam is replaced from low strength steel to high strength steel. Then the results are discussed in detail. Effectuality of the current side door impact beam and newly designed high strength steel beam is identified by finding the intrusion, acceleration & displacement at the node at center location of the beam by incorporating them into the FE model of a car door and tested as per the new regulation FMVSS 214.

III. TEST PROCEDURES FOR OCCUPANT PROTECTION

Occupant safety regulations are introduced by different organizations, including the International Organization for Standardization (ISO), working committees of the European Enhanced Vehicle Safety Committee (EEVC), and the International Human Rights Association (IHRA). However, the test methods for all the regulations are very similar. These different regulation test methods are designed in such a way that it replicate vehicle to pole or vehicle to vehicle crashes at different speeds like 55kmph and 35kmph. An impact speed of 55kmph and 35kmph are used, because it is observed to be these speeds are a sensible upper speed and lower speed of the car in city limits. (Mizuno 2005). Federal Motor Vehicle Safety Standard (FMVSS) 214 regulation is amended in the year 1990 to ensure the occupant protection of a car in side impact crashes that causes a serious injuries to the occupants. The percentage of accidents and fatalities reduced tremendously after implementing this regulation. It is one of the best promising safety test method amended by National Highway Traffic Safety Administration (NHTSA).

IV. FE MODEL BUILDING AND SIMULATION

Finite Element model building of left hand side car door is performed by using pre processing software ANSAA. The physical model is described in European Commission. The simulations were performed using LS-DYNA version 971 R4.2.1. The details of the FE model are discussed. The calibration requirements car door, specified by the regulation FMVSS 214 are compared with results obtained from the FE model. The FE model demonstrates good agreement with the calibration specifications. All components are modeled with shell elements. Constrained nodal rigid body elements, spherical joint and revolute joint are used to connect between the parts. The full door is constrained in five location by using single point constraint element assuming door is fixed to car’s A and B pillar.

Table 4.a Door Fe Model

<table>
<thead>
<tr>
<th>Element size</th>
<th>5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of nodes</td>
<td>116376</td>
</tr>
<tr>
<td>Number of elements</td>
<td>116002</td>
</tr>
</tbody>
</table>

4.1 Description Of The Pole Used In The Simulation

The pole is considered as an analytically rigid body with mechanical properties of the steel. The dia of the pole is 254mm and the height is 945mm. The rigid pole is a course FE modeled with the element size of 10mm, since it is a rigid body the number of nodes does not depends on the solution time. The total mass of the pole is 20 kg.

Table 4.b Element Details Of Pole

<table>
<thead>
<tr>
<th>Element size</th>
<th>10 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of elements</td>
<td>7200</td>
</tr>
</tbody>
</table>

4.2 Material Models And Properties

Table 4.c Material properties for structural parts

| Material card | MAT 24 |
| Mass density | 7.85e-06 |
| Young’s modulus | 210 Gpa |
| Poissons ratio | 0.3 |
| Yield stress | 0.19 |
**Study and Advanced Concept For Side Impact Protection Beams to Reduce the Injury of the Occupant Using CAE**

### Table 4.d Material properties for Impact beam

<table>
<thead>
<tr>
<th>Material card</th>
<th>MAT 24</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass density</td>
<td>7.85e-06</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>207 Gpa</td>
</tr>
<tr>
<td>Poissons ratio</td>
<td>0.29</td>
</tr>
<tr>
<td>Yield stress</td>
<td>0.46</td>
</tr>
</tbody>
</table>

### Table 4.e Material properties for Glass

<table>
<thead>
<tr>
<th>Material card</th>
<th>MAT 32</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass density</td>
<td>2.50e-06</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>73 Gpa</td>
</tr>
<tr>
<td>Poissons ratio</td>
<td>0.20</td>
</tr>
<tr>
<td>Yield stress</td>
<td>0.0412</td>
</tr>
</tbody>
</table>

### Table 4.f Material properties for Pole

<table>
<thead>
<tr>
<th>Material card</th>
<th>MAT 20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass density</td>
<td>7.85e-06</td>
</tr>
<tr>
<td>Young’s modulus</td>
<td>210 Gpa</td>
</tr>
<tr>
<td>Poissons ratio</td>
<td>0.3</td>
</tr>
</tbody>
</table>

### 4.3 Contact Interfaces

Totally there are two different contact interfaces are used in the model.

**CONTACT_AUTOMATIC_GENERAL**

This contact interface is used for all the door structure parts. In this contact method all parts are considered as slaves and contact will define between each individual parts.

**CONTACT_AUTOMATIC_SURFACE_TO_SURFACE**

This contact interface is used in between the pole and the door outer. In this contact method the pole is considered as master and the door outer is considered as slave. And the contact will define between the parts at the time of displacement of pole.

### 4.4 Control cards

Control cards govern the entire simulation, by using control cards we can activate the solution options and they will strongly affect our results or outputs. (Viz. implicit solution, adaptive remeshing, mass scaling, control termination etc)

The different types of control cards in which we have used in this model are

*CONTROL_ACCURACY
*CONTROL_CONTACT
*CONTROL_ENERGY
*CONTROL_HOURGLASS
*CONTROL_SHELL
*CONTROL_SOLID
*CONTROL_TERMINATION
*CONTROL_TIMESTEP

### 4.5 Output requests

We can request results or graph according our requirement, by using the option

**DATABASE_BINARY** option.

We have used below mentioned options to measure displacement, stress, strain and different types of energies.

ELOUT, GLSTAT, MATSUM, NODEOUT, etc.

### V. RESULTS AND DISCUSSION

**Description of current beam**

Fig 5.a: current beam

- The current impact beam has C type c/s section
- Current impact beam is having uniform width along the length.
- Current beam has having sharp edges in its major deformation area
- The length of the current impact beam is 992 mm long and 33 mm width with an equal thickness 1.6 mm.
- The mass of current side impact beam is 0.64 kg

**Result of current beam**

Below fig shows the energy curves for the FE model. The kinetic energy developed due to velocity of the pole is 28*E3 KJ. The kinetic energy minimized by internal energy developed due to material strength. Finally according to law of conservation of energy the total energy remains constant

**Graph 5.a: Energy curves**

**Graph 5.b: Displacement curve**
it shows displacement of impact beam at its center location. The max displacement noticed is 180 mm. the acceptable value for FMVSS 214 regulation is 154 mm. Hence, it is very essential to increase the strength of the beam to reduce the intrusion of the car door.

5.2 Design modification of impact beam.
The energy absorbing ability of the material depends on the term section modulus. 

\[ Z = \frac{I}{Y} \]

where, 
\[ I = \text{Moment of Inertia} \]
\[ Y_{\text{max}} = \text{distance from Neutral axis} \]

C sections, circular tubes, and rectangular tubes are the different cross sections used for impact beams. In all above sections resistance to deformation can be enhanced by increasing its thickness.

The mounting location of the newly design modified beam has not been changed. The new beam contains curve type side wings which provide additional resistance to deformation, which causes considerable reduction in displacement. Some portion of the impact beam is under compression and some portion of the impact beam is under tension, so we can expect increase in spring back effect on the entire cross sections. When material get deformed in plastic state the largest portion of the energy absorbed by side wings. Under the application of load it is expected the curved side wings will fold inward. Smooth flow in the fillet region ensures that high stress concentration factor is avoided.

The total length of the impact beam is 991 mm. The highest displacement expected in mid location of the beam. And it is identified 570 mm long (Mid span) and was chosen according to the applied load position. The impact beam c/s section is like the shape of English letter M. It is 41 mm wide in widest section. The thickness of the beam is 1.6 mm. The total mass of the beam is 0.80 Kg

5.3 Comparison of Current Beam with New Beam
Current impact beam is having C type c/s section and the new design modified beam is having M type c/s section
- Current impact beam is having uniform width on its full length, but the new impact beam has more width to strengthen it in mid location.
- Current impact beam has cornered edges along its length; so it affects on its force distribution. The newly designed beam is having round edges, so force will distribute smoothly

5.4 Material Description
Steel material behaves very effectively in the absorbing of large amount of energy as in case of rear end and front of the car. And it will withstand high range marked loads. According to the basic knowledge of how static strength can be with stand by high strength steel, crash resistance, and energy absorbing capability steel is proffered in automotive industry for increase in weight reduction and safety. The material which we have selected is \textit{DOCOL 1200} which is a high strength steel.

<table>
<thead>
<tr>
<th>Material Details</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass density</td>
<td>7.85E-06 Kg/mm³</td>
</tr>
<tr>
<td>Young's modulus</td>
<td>210 Gpa</td>
</tr>
<tr>
<td>Poisons ratio</td>
<td>0.3</td>
</tr>
<tr>
<td>Yield strength</td>
<td>1.2 Gpa</td>
</tr>
</tbody>
</table>
5.5 Beam FE modeling
The geometry creation of side impact beam is done by using NX and all the necessary preprocessing functions are performed by using HYPERMESH. To get close result we have modeled 5 mm global size. The new designed beam replaced by current beam to the car door.

![Beam FE modeling](image)

Fig 5.5.a: current beam

FE modeled newly designed beam.

VI. RESULTS AND COMPARISONS

Case 1: The maximum displacement identified 188 mm in current beam.

Case 2: The maximum displacement identified 171 mm in newly designed beam without updating the material.

Case 3: The maximum displacement identified 140 mm in newly designed beam with high strength steel.

According to FMVSS 214 new regulation the max displacement should not be more than 154 mm. In case 2, (newly designed beam) we have noticed a displacement of 171 mm. By performing number of iterations we have optimized the design and finally updated the material. The maximum displacement in case 3 is 140 mm which is less than upper limit value of FMVSS 214 new regulation. From the fig we can observe the intrusion of the impact beam is less throughout the duration. If we compared the current beam and new high strength steel beam nearly 20% of displacement has been reduced.

![Results and Comparisons](image)

Graph 6.a result comparison

CONCLUSIONS AND RECOMMENDATIONS

Total energy absorbing capability of the current side impact beam, new side impact beam with current material and new beam high strength steel comparison has done. Effectuality of all the above impact beams is compared by testing the beams according to the regulation FMVSS 214. By replacing the newly designed side impact beam there is a considerable reduction in the intrusion of the side door structure, which leads to decrease the injuries of side impact crashes.

By comparing the computational results of current impact beam and new high strength steel beam it is concluded that,

- There is significant reduction in the deformation of impact beam nearly 25%
- By using new high strength beam, it is identified there is 40% increase in total energy absorption
- High strength steel is more effective for FMVSS 214 new regulation
- Manufacturer can manipulate the mechanical properties of the high strength steel material by using number of heat treatment process
- High strength steel material is preferred when high stiffness and high strength are needed.

7.1 Future Recommendation

- Experimental tests need to conduct before practical implementation of the high strength steel door impact beam in car door.
- By finding the occupant injury parameters we can verify the effectiveness of the new side impact beam with high strength steel using test dummies in LS dyna.
- The energy absorbing capability of the impact beam can be enhanced by using different c/s sections.

ACKNOWLEDGMENTS

The support extended by Mr Jaganadh is highly appreciated for providing technical support to this
research work. The support given by Hindustan University is acknowledged with due respect.

REFERENCES

[4] Andrew S McIntosh a, Dimitrios Kallieris, Bertrand Frechete , Neck injury tolerance under inertial loads in side impacts2006 Elsevier Ltd Door velocity and occupant distance affect lateral thoracic injury mitigation with side airbag by Jason J. Halinana,b,c,∗, Narayan Yoganandana,b,c, Frank A. Pintara,b ScienceDirect