EVALUATION OF OCCUPANT HEAD INJURY DURING AUTOMOTIVE INTERIOR HEAD IMPACT AS PER FMVSS 201U REGULATIONS USING FEA APPROACH

[1]AMRUTH C H, [2]SUDHEER KUMAR B N, [3]HARSHA G O

[1]Assistant Professor, [2]Head of the Department, [3]Assistant Professor
[1]Mechanical Engineering Department
[1]Shrinivasa Institute Technology, Mangalore, India

***Abstract*: A significant fraction of fatalities involving passengers in Automobile accidents is due to severe Head Injury. These injuries occur when an occupants head is struck against the interior of vehicle during crashes. Head impact safety which in turn is the occupant safety is a significant consideration particularly in the design of Passenger Vehicles. Sports Utility Vehicles (SUVs) have a greater tendency to rollover when compared to other Passenger Vehicles as they have higher center of gravity. During the rollover of SUV the head comes in contact with the parts such as the B-Pillar so in order to evaluate the occupant safety during rollover National Highway Traffic Safety Administration has set Federal Motor Vehicle Safety Standard 201Upper (FMVSS201U). The regulation FMVSS201U emphasizes on the design and testing methodology of the occupant injury levels during interior impact scenario.**

As per the requirements the Finite element model of the SUV is generated. The Free motion Head Form is positioned at the pre-identified target locations on the B-Pillar as per the standard requirements. The pre-identified target points on the B-Pillar are BP1, BP2 and BP3. The Free Motion Head Form is made to hit the target location at 15 mph initial velocity and the Head Injury Criteria HIC (d) which is a non-parametric number indicating the head injury levels is identified. HIC (d) number higher than 1000 is critical for the survival of the occupant and calls for the re-design of the B-Pillar. The FEA tool Hypermesh is used for the pre-processing ie; model preparation and load case setup. LS-DYNA 3D, a non-linear dynamic solver is used for solving. Hyper view is used as post-processor to derive the HIC (d) values from the analysis.

The evaluation of HIC (d) for various grades of steel such as SAE 340S, SAE 280A, SAE 250A and SAE 180A for B-Pillar has been carried out. SAE 180A grade of steel is preferred for B-Pillar as it provides HIC (d) value lower than other grades of steel and also HIC (d) value is less than 700 which is the requirement of Original Equipment Manufacturers (OEM's).

Index Terms - FMVSS201U, SUV, pattern, LS-DYNA, B-Pillar, Hypermesh

I. INTRODUCTION

Head injury is the most frequent type of injury experienced by all seriously injured road users, especially car occupants.Vehicle crashworthiness and occupant safety are the two most important aspects that are considered in the automotive industry today.

AUTOMOTIVE SAFETY STAGES

There are 3 stages in development history of Automotive Safety.

1. **First Period (1889-1935)**

This period focused on basic improvements such as reduction of tire blowouts to avoid loss of vehicle control, introduction of the self-starter, incorporation of headlamps, and adopting an all-steel body structure for better occupant protection.

2. **Second Period (1936-1965)**

- Auto manufacturers introduced many crash avoidance devices (i.e. turn signals dual windshield wipers high penetration-resistant windshield glass.
- First car-to-barrier frontal crash test by General Motors.
- Most significant safety device of that era was the introduction of seat belts as an option in 1956.

3. **Third Period**

- The third period starts from 1966.
- Creation of the National Highway Traffic Safety Administration (NHTSA).
- Federal Motor Vehicle Safety Standards (FMVSS) were introduced for regulating several aspects of vehicle crashworthiness and crash avoidance performance.

2. PROBLEM DEFINITION

- The objective of the project is to evaluate the head injury levels during an occupant interior head impact as per FMVSS201U guidelines on B-Pillar of a passenger Vehicle.
- Design modifications for safety

OCCUPANT SAFETY

- Occupant Safety is a key criterion in the road crash scenario. There has been a major development in the field of safety engineering of the vehicle.
- Occupant safety in an automobile is a measurable parameter in terms of the star rating as determined by the New Car Assessment Program (NCAP) conducted by National Highway Transportation Safety Administration (NHTSA).
- A vehicle's rollover resistance rating is an estimate of its risk of rolling over in a single-vehicle crash, not a prediction of the likelihood of a crash. As the chart above indicates, the lowest-rated vehicles (1 star) are at least four times more likely to roll over than the highest-rated vehicles (5 stars) when involved in a single-vehicle crash

ROLL OVER

- Roll over's are crashes involving vehicle rotation of at least one quarter turn ($\geq 90^0$) about a lateral or longitudinal axis.
- SUVs have a greater tendency to roll over because of its larger size, higher center of gravity, fault or flaw in the design, and fragile roofs.

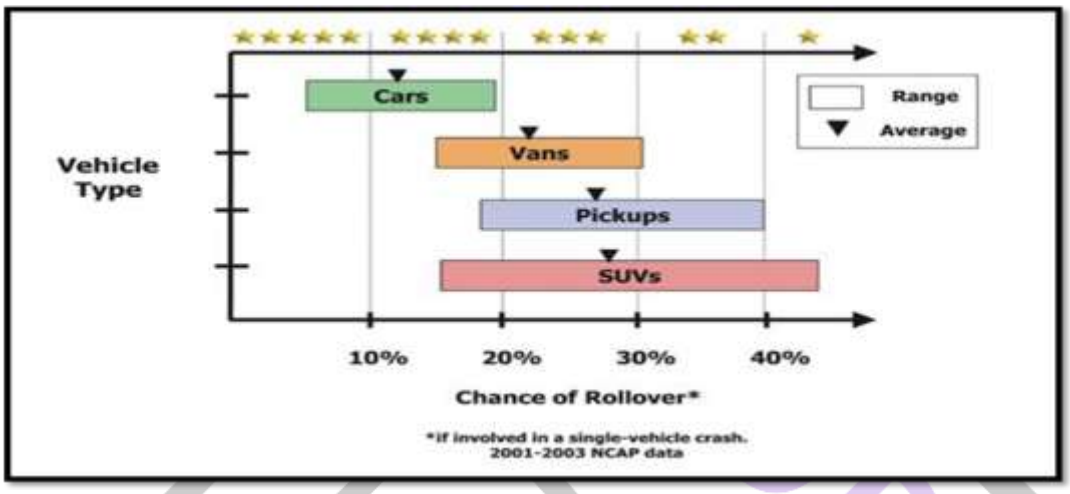


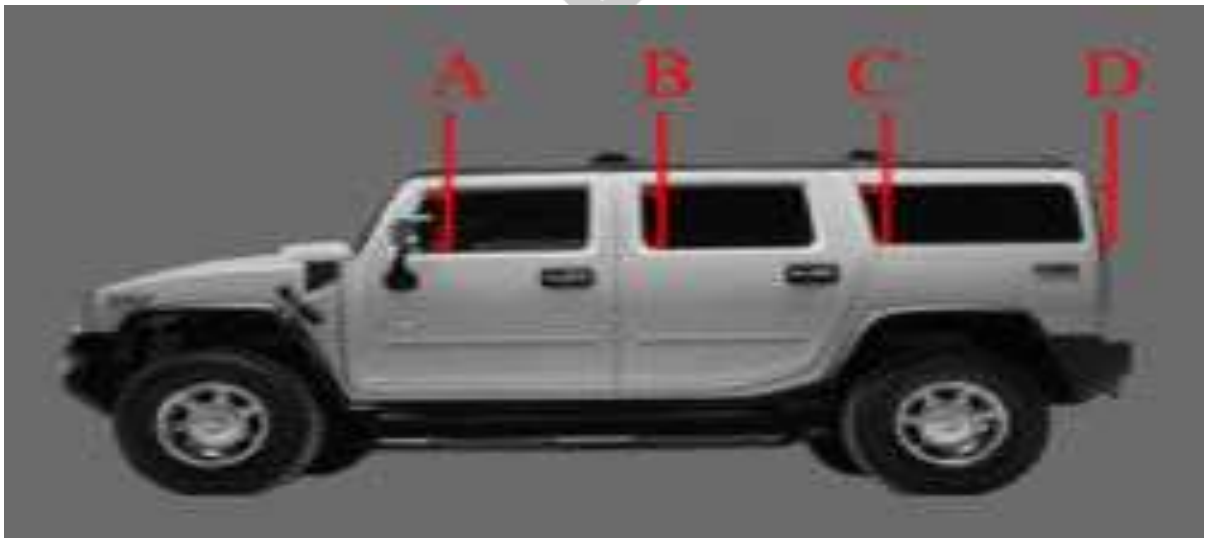
Fig. 1 Vehicle Class Comparison Based on Roll Over

FMVSS 201U REGULATION

- The Federal Motor Vehicle Safety Standards (FMVSS) has set the guidelines on which the safety of the occupant in the passenger vehicle needs be evaluated.
- As per FMVSS the HIC greater than 1000 will cause fatalities and the vehicle is considered as un-safe.
- This study will be performed as per the FMVSS201U guidelines.

PILLAR

Pillar means any structure, excluding glazing and the vertical portion of door window frames, but including accompanying molding, attached components such as safety belt anchorages and coat hooks

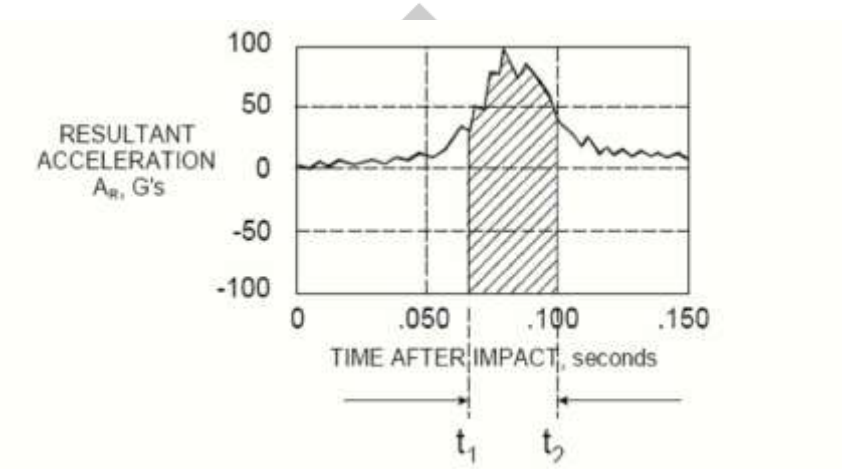


HEAD INJURY CRITERIA (H.I.C)

- The Head Injury Criterion (HIC) is a measure of the likelihood of head injury arising from an impact.
- The Head Injury Criterion (HIC) should be used for all impacts to the head, independent of impact type or location as it is the best predictor of brain concussion
- Normally the variable is derived from the acceleration/time history of an accelerometer mounted at the centre of gravity of a dummy's head, when the dummy is exposed to crash forces.

Head Injury Criterion Equation with Abbreviations

$$HIC = \left\{ (t_2 - t_1)\left[\frac{1}{t_2 - t_1}\int_{t_1}^{t_2} a(t)dt\right]^{2.5} \right\} max$$



Where t_1 and t_2 are the initial and final times (in seconds) of the interval during which HIC attains a maximum value and acceleration is measured in g's. Note also the maximum time duration of HIC, $t_2 - t_1$, is limited to a specific value, usually 15 ms. HIC (d) =0.75446(Free Motion Headform HIC) + 166.4

FREE MOTION HEAD FORM (F.M.H)

- Free Motion Headform (FMH) is the Hybrid 111 dummy model of the 50 percentile human head.
- This is a universal dummy head used for physical testing of Occupant Interior Impact injury evaluation.
- The corresponding calibrated FE FMH model is available and needs to be used in finite element simulations.

FEM

Definition of FEM is hidden in its words itself. Basic theme is to make calculations at only limited number of points and then interpolate the results for entire domain (surface or volume).

- Finite –FEM reduces degrees of freedom from infinite to finite with the help of discretization i.e. meshing (nodes and elements).
- Element – All the calculations are made at limited number of points known as nodes. Entity joining nodes and forming a specific shape such as a quadrilateral or triangular etc. is known as Element .

Method – There are 3 methods to solve any engineering problem. FEM belongs to numerical method category.

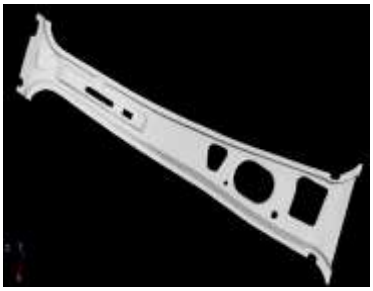
- For using any commercial Software there are three steps –

1) Preprocessing.
2) Processing.
3) Post processing.

HYPERMESH

- Altair Hyper Mesh is a high-performance finite element pre- and post-processor for major finite element solvers.
- Hyper Mesh allows engineers to analyze design conditions in a highly interactive and visual environment.
- HyperMesh's user-interface is easy to learn and supports the direct use of CAD geometry and existing finite element models, providing robust interoperability and efficiency.

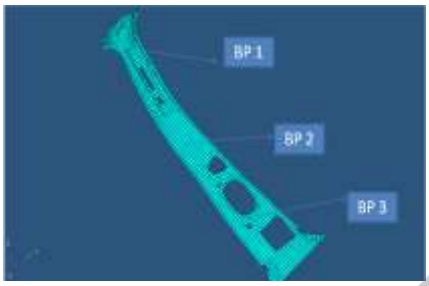
B-PILLAR

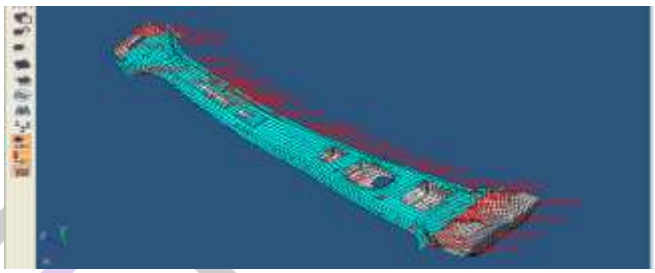


MESHED BPILLAR

QUALITY PARAMETERS

Target Points of B-Pillar





Overall length of B-Pillar is 1208mm.
Distance between top node and BP1 is 109mm.
Distance between BP1 and BP2 is 467mm.
Distance between BP2 and BP3 is 362mm

In this step the B-Pillar inner layer is connected to the outer B-Pillar with rigid body connections as shown in the fig below.

HEAD FORM POSITIONING

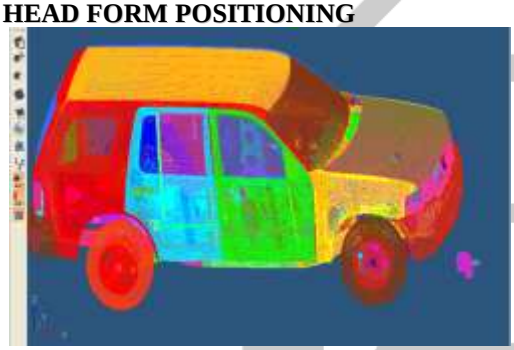
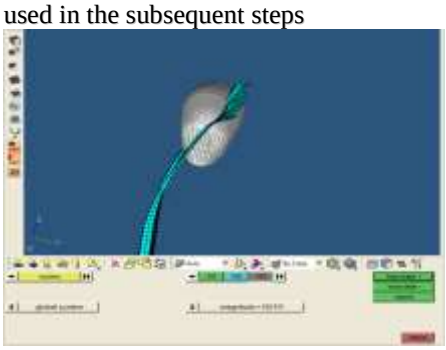
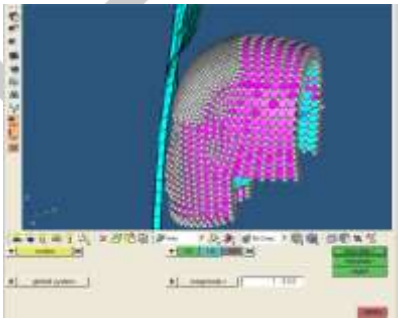


Fig. : SUV and FMH

Sl. No.	Element Type	Component	Total number of Nodes	Total number of Elements
1	1D, 2D & 3D	SUV Vehicle	632595	627798
2	Shell first order	FMH	4329	4374

In order to position the FMH at the target locations of the B-Pillar, commands such as translate and rotate can be used and are used in the subsequent steps





- After positioning of the FMH at the target points of the B-Pillar it is important to define the contact between them. The boundary conditions resemble an ON / OFF switch which will be detected by the software. If there is no contact defined then FMH will simply penetrate into B-Pillar and this is unphysical.
- FMH is the Master body and B-Pillar is the slave body.

APPLYING VELOCITY

After the contact is established between FMH and B Pillar the velocity with which the FMH should impact the B Pillar needs to be defined. During the rollover of SUV the velocity is specified as 15 mph (6705 mm/s) as per the FMVSS 201U regulation so this velocity needs to be applied

Fig. : Velocity Applied

CONTROL CARDS

- Control cards are those which are used for controlling the simulation process of FMH hitting the B-Pillar during rollover of SUV. The various control cards used are control _Termination, Database_binary_D3plot and Database Option_ nodout.

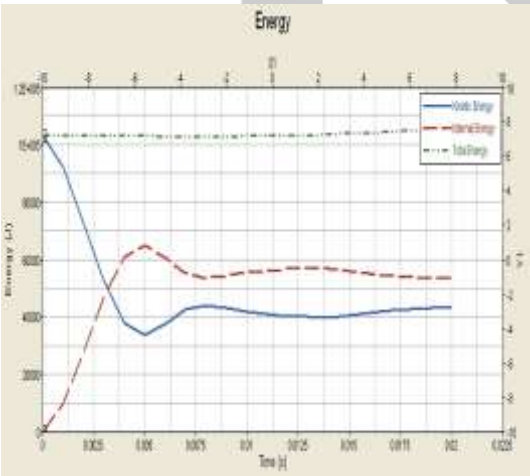
LS-DYNA

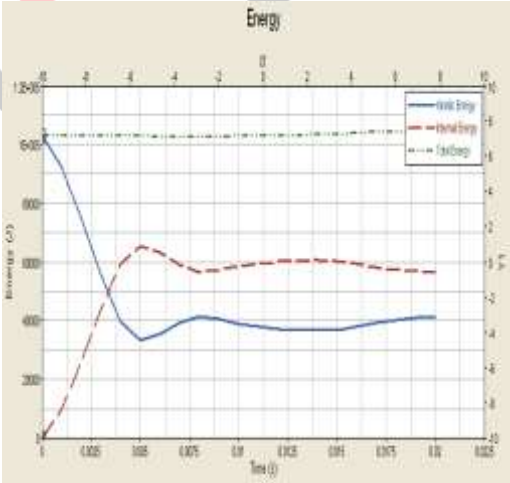
- LS-DYNA is an advanced general-purpose multiphysics simulation software package that is actively developed by the Livermore Software Technology Corporation (LSTC).
- LS-DYNA is being used by the automobile, aerospace,construction,military, manufacturing, and bioengineering industries.

Table :General units used in LS- DYNA

	(a)	(b)	(c)
Length unit	**meter**	**millimeter**	**millimeter**
Time unit	**second**	**second**	**millisecond**
Mass unit	**kilogram**	**tone**	**kilogram**
Force unit	**Newton**	**Newton**	**kilo Newton**
Young's Modulus of Steel	**210E+09**	**210E+03**	**210.0**
Density of Steel	**7.85E+03**	**7.85E-09**	**7.85E-06**
Yield Stress of Mild steel	**200E+06**	**200.0**	**0.200**
Acceleration due to gravity	**9.81**	**9.81E+03**	**9.81E-03**
Velocity equivalent to 30mph	**13.4**	**13.4E+03**	**13.4**

ENERGY GRAPHS AT BP1

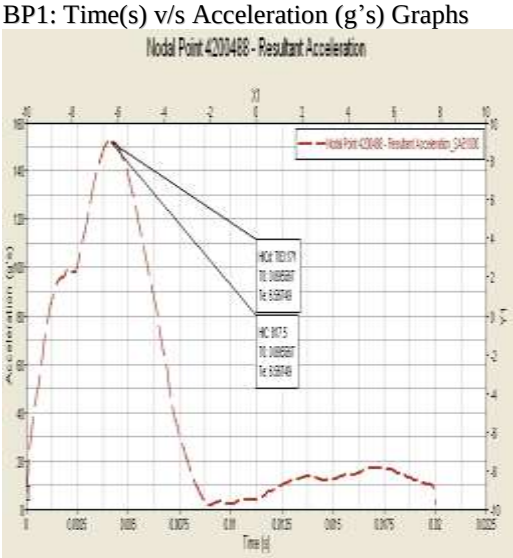




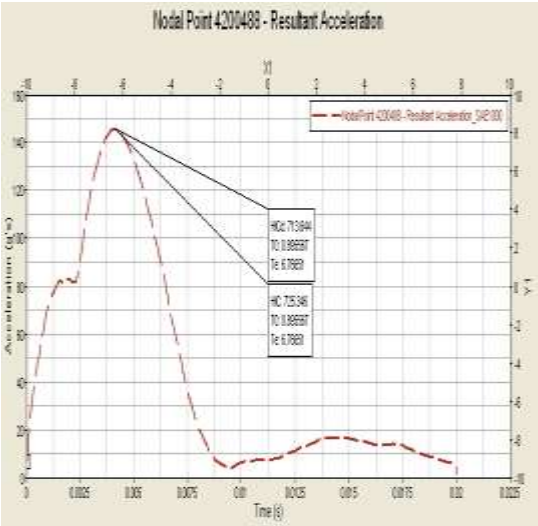
Energy Graph for Steel Grade SAE 340S

Energy Graph for Steel Grade SAE 280A

BP1: Time(s) v/s Acceleration (g's) Graphs



Time(s) v/s Acceleration (g's) for SAE 340S



Time(s) v/s Acceleration (g's) for SAE 280A

CONCLUSION

[1] Evaluation of HIC(d) is important from the occupant safety point of view during the rollover of SUV as they have the greater tendency to rollover.
[2] Evaluation of HIC(d) for various grades of steel such as SAE340S,SAE280A
[3] SAE280A grade of steel is preferred for B-pillar as it provides HIC(d) value less than 735 which is the requirement of OEM .

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