Evaluation of Occupant Head Injury during Automotive Interior Head Impact Using FEM Approach

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Abstract: ***A significant fraction of fatalities involving passengers in automobile accidents is due to severe Head Injury. Head impact safety which in turn is the occupant safety is a significant consideration particularly in the design of Passenger Vehicles. 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 (NHTSA) has set Federal Motor Vehicle Safety Standard 201 Upper (FMVSS201U). The regulation FMVSS201U emphasizes on the design and testing methodology of the occupant injury levels during interior impact scenario. The FEA tool, Hypermesh is used for the pre-processing i.e 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.***

Keywords: B-Pillar, FEA, Hypermesh, LS-DYNA, Head Injury Criteria (HIC)

1. 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. The demands on safe vehicle design have increased enormously in order to satisfy safety regulations and this has led the safety engineers to perform various tests to evaluate the crashworthiness and occupant safety at the early stage of vehicle development.

With the different dynamic properties of the brain and skull, plus different injury types and mechanisms, it is very difficult to produce single injury criteria for the head.

- The skull is a rigid spherical shell, comprised of several interlocked thin curved bone plates covered by a thin compliant skin; therefore a force criterion would be used to predict fracture
- The brain is a visco-elastic material, in which internal shear and tensile forces cause brain damage; therefore an acceleration based criterion would be used
- The facial area is a complex of thin highly shaped bones covered by varying thickness of skin and muscles; so a force / intrusion criterion would be used to predict facial bone fracture and injury.

2. Literature Survey

A brief review of contemporary research supporting this paper is presented below.
Anindya Deb et al., worked on “A lumped parameter-based approach for simulation of automotive head form impact with countermeasures”. A new non linear lumped mass model has been presented for simulating head form impact with rotation on a stiff target with countermeasure for HIC reduction. This paper deals with a new nonlinear lumped parameter model that can serve as a preliminary design tool.

Knotz Christoph, et al., worked on “Virtual aided development process according to FMVSS201u”. A reliable, fast and robust methodology is shown to deal with impactor testing on the virtual testing side. They have showed a complete virtual development process for the FMH regulation (FMVSS 201U), where a combination of self developed and standard software has been used. Warren N Hardy et al., have conducted research on “Literature Review of Head Injury Biomechanics”. This Literature survey provides an assessment of hypothesized brain injury mechanisms, brain injury criteria, and mathematical models of head injury and available techniques for measuring head kinematics and brain tissue deformation associated with exposure to dynamic loads. In this paper the extensive work carried out on HIC, Theories of brain injury mechanisms, Brain deformations, Mathematical models of head injury and Methods of measuring head motion are discussed. The above mentioned strategy was applied to reduce the head injury impact with the available techniques and main objective of the project is to evaluate the occupant head injury by LS-DYNA solver.

3. Objectives

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 SUV.
- Simulation of contact establishment and velocity applied.

4. Meshing and Analysis

In this present work model of SUV is imported from Catia V5 software in IGES format into Hypermesh 9.0. The imported model of SUV is further discretized into finite elements and all the elements have passed the quality check. The meshed model is then solved using LS-DYNA Software. The Results are analyzed using Hyperview software.

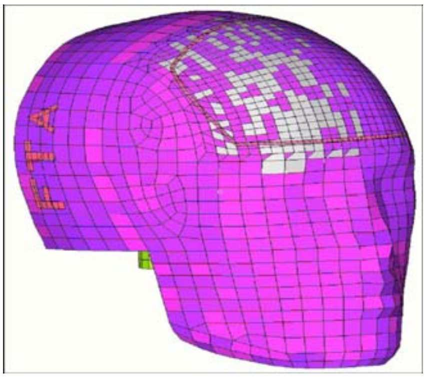

Figure 1: FE Model of Free Head Form

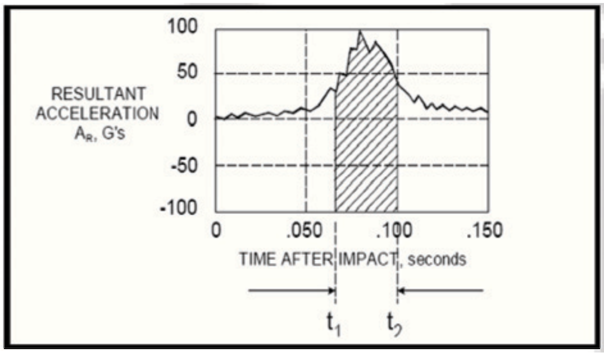

Figure 2: Resultant Acceleration Curve for HIC Determination

The FE model of the FMH generated also has similar parts as in the physical model.FMH finite element models are available as calibrated models which have been correlated with the physical test results. Currently used FMH is Hybrid III family 50%

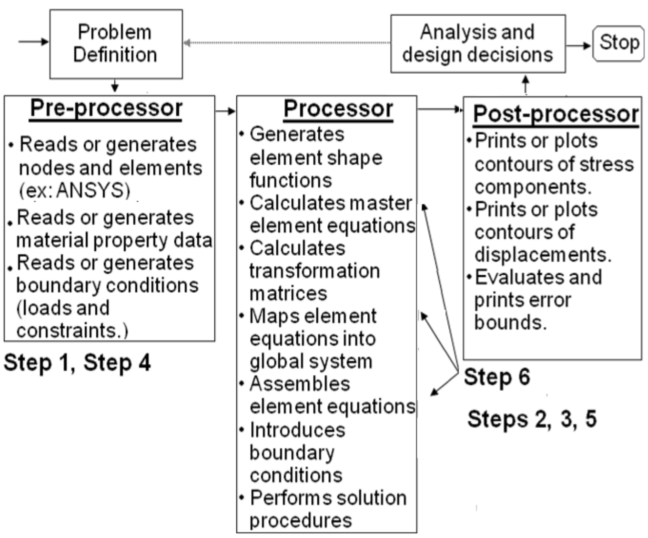

Figure 3: Process Flow in Typical FEM Analysis

4.1 LS-DYNA

LS-DYNA is an advanced general-purpose multiphysics simulation software package that is actively developed by the Livermore Software Technology Corporation (LSTC). While the package continues to contain more and more possibilities for the calculation of many complex, real world problems, its origins and core-competency lie in highly nonlinear transient dynamic finite element analysis (FEA) using explicit time integration. LS-DYNA is being used by the automobile, aerospace, construction, military, manufacturing, and bioengineering industries.

Table 1: 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
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	9.81	9.81E+03	9.81E-03
Velocity equivalent to	13.4	13.4E+03	13.4

From the Table 1 it can be observed that for SUV meshing the types of elements used are solid and shell. The number of elements in SUV is 627798 and nodes are 632595. The element type used for the FMH is shell of first order and the number of elements present is 4374 and nodes are 4329.

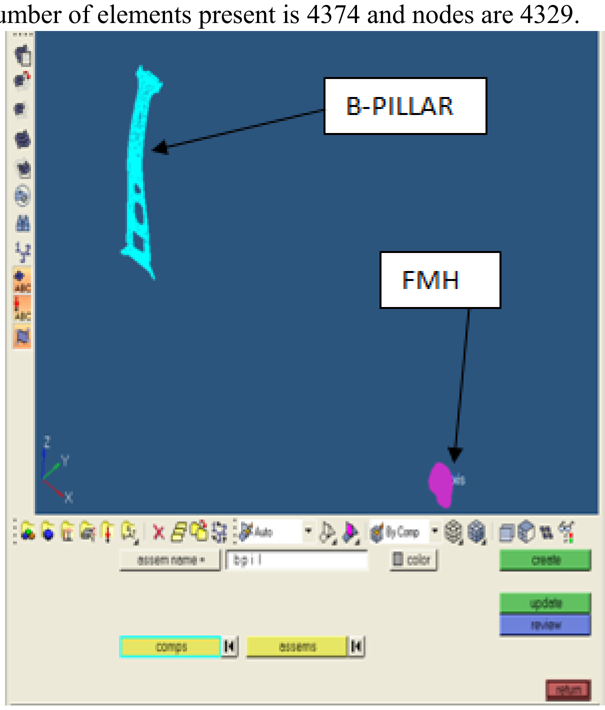

Figure 5: B-Pillar Assembly Collector

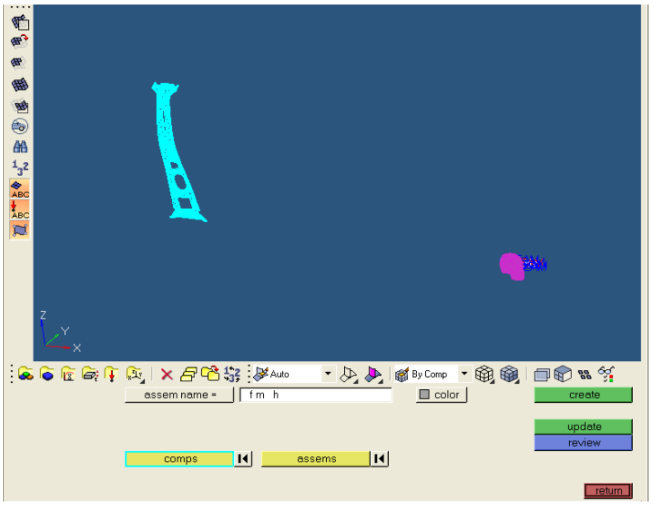

Figure 5: FMH Assembly Collector

After positioning of the FMH at the target points of the B-Pillar it is important to define the contact between them and contact between FMH and B-Pillar occurs when they try to come towards each other during the roll over. In this step the surface to surface contact is established between free motion head form and target point BP1where FMH is the Master body and B-Pillar is the Slave. The elements of the FMH are selected as the master elements and the B-Pillar elements are selected as slave elements.

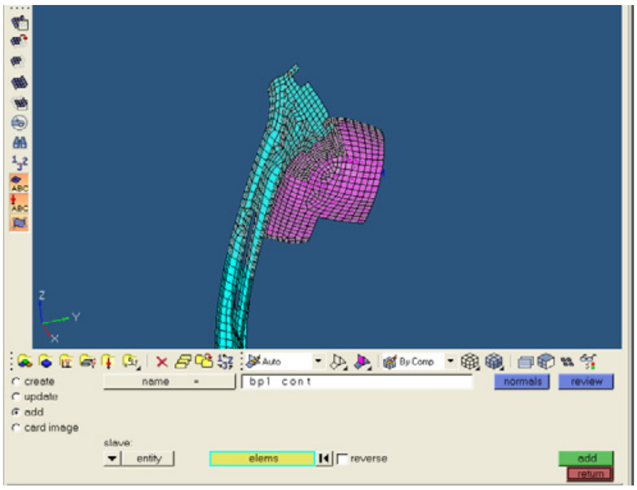

Figure 6: Contact Established between FMH and B Pillar

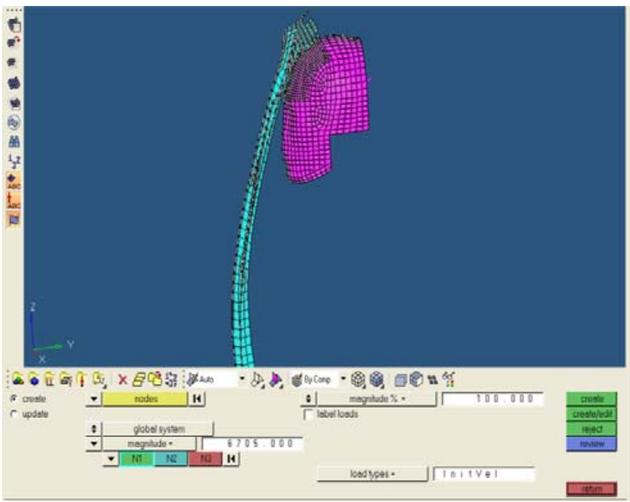

Figure 7: Velocity Applied

5. Results and Discussions

For the current analysis the important parameters considered are the Energy Balance (Energy Law) and the second important parameter is the HIC parameter as per the FMVSS 201U regulation. During the rollover of SUV one of the part which comes in contact with the FMH is the B-Pillar. The FMH will hit the target locations of the B-Pillar with a particular velocity during which the kinetic energy of the FMH which itself is the total energy will be converted into internal energy.

$$\text{Kinetic Energy(K.E)} = \frac{1}{2} * m * v^2 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where, m = mass of the FMH in kg, v = velocity of the FMH in $mm/s^{2.}$, K.E= Kinetic Energy in joules.
At the start of the rollover, Total Energy = Kinetic Energy of FMH = 1/2 $*m*v^2$ = 1/2 * (4.578e-3)*$(6705)^2$ = 1,02,906 J During the process of impact between FMH and B Pillar the velocity is decreasing and hence kinetic energy is decreasing and at the same time internal energy is increasing as the strain energy is increasing in the model.

6. Conclusion

Evaluation of HIC is important from the occupant safety point of view during the rollover of SUV as they have the greater tendency to roll over. During the roll over the head comes in contact with B-pillar of SUV so the evaluation of HIC for various grades of steel such as SAE340S,SAE280A, SAE250A and SAE180A can be carried out. SAE180A grade of steel is preferred for B-pillar as it provides HIC value less than 700 which is the requirement of OEM and SAE 180A is found to be good for sheet metal pressing work for the Automotive BIW manufacturing.

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