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Impact Behavior of Automotive Bumper Beam under Crashes

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Abstract

Objectives: This work is an attempt to present commercially used designs and analyze it to compare the impact behavior of each design of bumper beams during head-on collisions **Methods/Statistical Analysis:** In order to avoid series of destructive test for a new vehicle to be performed the necessity of economical design using finite element is performed in this study. Parameters like materials, shape and thickness are considered for carrying out analysis with the help of Hypermesh 9.0 and LS-DYNA software **Findings:** The main criterion to be discussed is energy absorbing Behavior of bumper beams during head-on collisions. Analysis is carried out upto 20 millisecond. Results for different Designs and for varying thickness are obtained and compared to study the impact Behavior of beams under study. Impact behavior of Bumper beam is analyzed based on energy absorption of the beam and the displacement condition. Maximum nodal displacement is obtained for different thickness and materials and plotted over the period of time **Application/Improvements:** Experimental setup has to be developed for the testing of the model under crashes and to be analysed at operating condition.

Keywords: Bumper Beam, Bumper Rebound, Crashes, Energy Absorption, Investigate, Impact

1. Introduction

The Bumper is one of the most important parts of a car, found at the rear-most and front-most parts. It helps the vehicle sustain tremendous impact while preventing the safety systems from being damaged. However, it can reduce the injury of passengers especially during high-speed impacts. It can somehow lessen the injury that pedestrians can suffer after being hit by a car. The use of bumpers in a car is a legal requirement in most jurisdictions. It is important to abide by this rule so as not to cause bad outcomes in case accidents happen. An international RCAR working group has developed test procedures to assess how well a vehicle's bumper system protects the vehicle from damage in low speed impacts. Damage in these tests closely replicates the damage patterns observed in real world low speed crashes[1] and addresses three components of bumper performance:

Geometry – vehicle bumpers need to be positioned at common heights from the ground and extend laterally to the corners in order to properly engage other vehicles in low speed crashes.

Stability – vehicle bumpers need to be tall and wide enough to remain engaged with the bumpers of other vehicles despite vehicle motion due to loading, braking, etc.

Energy-absorption – vehicle bumpers should absorb low speed crash energy without damage to other parts of the vehicle.

2. Mechanics and Modelling

It is important to distinguish between the two different types of impacts that occur, elastic and plastic impacts.

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In an elastic impact a negligible amount of energy is lost between the two impacting bodies, for example, the collision of two billiard balls. A plastic impact involves a significant amount of energy dissipated in the collision. An impact between two vehicles or between one vehicle and a rigid body, where the vehicles crumple on impact, is an example of an Elastic-plastic impact. The impacting phenomenon between an impactor and the front bumper under collisions could be very complicated, since transient and nonlinear analyses are involved. But, in designing the front bumper, automobile manufacturers insist that the bumper system should not have any material crash or failure. Therefore, up to that point, the total energy is conserved throughout the impact duration. Some simpler conceptual designs are made according to Bumper standards and Dimensions referred from RCAR bumper test, National Highway Traffic Safety Administration laboratory Test procedures. Thickness is considered as variable parameter and other dimensions are designed under allowable sizes Sheet metal Design is involved for designing Bumper Beams. Using CATIA V5 R11 the models are designed. Bumper is designed as per the Standards followed. Simpler Designs Profiles of Bumper beams are taken into study and Modelled Using CATIA v5 R11. Variable Parameters like Shape, thickness can be modified from this basic Design in future for analysis and Improvement. Options like Bends, Punch, and Rib are used to create the model. These models are analysed for the Energy absorption behaviour[2] and categorise the results to compare among the other designs.

3. Modelling

There was a general approach for all the aforementioned models, i.e. with different material[3,4] shape and thickness created in LS_DYNA. The CAD data of the bumper structure was imported and the surfaces were created and meshed. Since the average thickness of bumper was much smaller than the other dimensions[5] of the part, the best element for meshing was the shell element. Hypermesh is used to mesh the model and to give all the inputs and load conditions that can be directly exported to LS-DYNA. Explicit Dynamic Analysis Finite Element Program is used to solve highly non-linear Transient Dynamic Problems. LS-DYNA solver has Benefits of fastest explicit features than any other explicit code in Market place. The procedure for an explicit dynamic analysis is similar to any other analysis that is available in the ANSYS program.

The three main steps are:

- Build the model
- Apply loads and obtain the solution
- Review the results

When solving Dynamic problems with Fem, it must be remembered that we use FEM only for spatial Discretization and the temporal time Discretization is always using the FEM. We divide the total response time into much smaller intervals called time steps or increments. The equilibrium equation and the value of unknowns are determined at (t+At) based on value of time t. Explicit methods are those in which the information at time step n+1 can be obtained in terms of previous time steps and there is no dependence on the current time step.

Altair HyperMesh 9.0 includes many new features that can improve and automate your CAE processes. It is Universal Finite element pre-post processor software. This capability allows for consistent modeling practices for 1D, 2D, and 3D elements. The basic modeling process in HyperMesh, given a mesh, involves the creation materials and properties followed by the assignment of properties to elements or components.

4. Processing

The impactor, as a steel structure, was modelled with rigid solid impact elements according to precise dimensional drawings from the E.C.E. Standard. Material type 20 (mat-rigid) is assigned using Hypermesh 9.0 used for further analysis in LS-DYNA. Bumper beam is assigned as deformable structure is so called "MAT type 24"A, Piecewise Linear Isotropic model. As shown, the impactor collide to the bumper beam in straight direction and perpendicularly. Usually in all finite element study constraints plays a major role. Bumper beam is constrained at both the ends as shown in Figure 1. The impactor collides to the bumper perpendicularly with 18.6 mm/msec velocity (based on LS-DYNA standard units) Parameters[6] like thickness, shape is varied for carrying out the analysis with constant velocity. Characteristics of Impactor remain constant for all the cases[7]. Thickness varies from 2mm to 4mm in the increasing order of 0.25 mm.

Hypermesh software is used to assign all loads and constraints that will be used in LS-DYNA for analysis. Keyword file is exported from Hypermesh that is used in LS-DYNA solution manager to solve and LS-DYNA Pre/Post processor to produce results.

Case (i): Simple hat Profile is tested for impact behaviour for varying thickness 2mm to 4mm in the increasing order of 0.25 mm with three different materials viz., Steel, Aluminium, PEP (Poly Ethylene Propylene)

Case (ii): Double hat Profile is tested for impact behaviour for varying thickness 2mm to 4mm in the increasing order of 0.25 mm with three different materials viz., Steel, Aluminium, PEP (Poly Ethylene Propylene).

Case (iii): Oblique hat Profile is tested for impact behaviour for varying thickness 2mm to 4mm in the increasing order of 0.25 mm with three different materials viz., Steel, Aluminium, PEP(Poly Ethylene Propylene).

Case (iv): Closed hat Profile is tested for impact behaviour for varying thickness 2mm to 4mm in the increasing order of 0.25 mm with three different materials viz., Steel, Aluminium, PEP (Poly Ethylene Propylene).

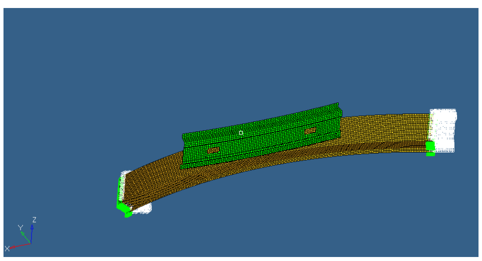

Figure 1. Fixed Constraints.

5. Result and Discussion

The main criterion to be discussed is energy absorbing Behavior of bumper beams during head-on collisions. Analysis is carried out upto 20 millisecond. Results for different Designs and for varying thickness are obtained and compared to study the impact Behavior of beams under study. Results for case (i) with thickness 2mm and steel material is shown below. Similarly Results are obtained for different thickness and materials. Max. Displacement is measured at the condition of Bumper Rebound i.e. the time at which the impactor gets Rebound after hitting the bumper.

Impact behavior of Bumper beam is analyzed based on energy absorption of the beam and the displacement condition. Figure 2 shows the Nodal Displacement at the bumper rebound condition. Figure 3 shows Max. Nodal displacement plot over the period of time. A good bumper should prevent the impact energy getting transferred to the passengers also with a minimal thickness. Figure 4 shows the Energy plot for the Bumper system including Bumper and impactor. Figure 5,6 shows the kinetic energy plot for Impactor and bumper individually. Similarly by increasing thickness and by varying Materials results are plotted for comparison.

Analysis is to be carried out for other cases to find the appropriate condition for the different designs based on energy absorption behavior and nodal displacement.

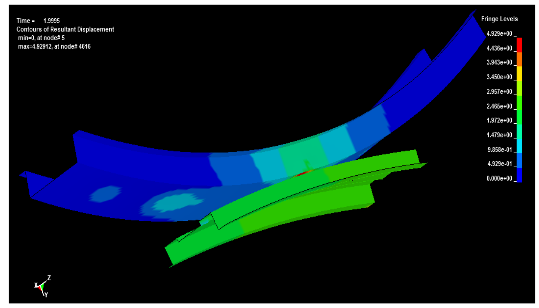

Figure 2. Nodal Displacement at Bumper rebound condition.

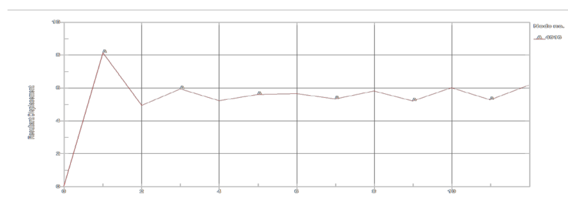

Figure 3. Max. Nodal Displacement Plot over time.

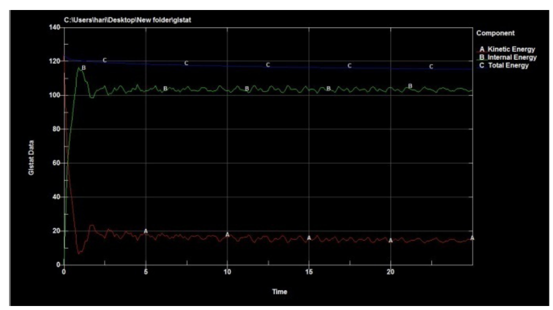

Figure 4. Energy plot for Bumper system (Simple hat profile Steel material 2mm).

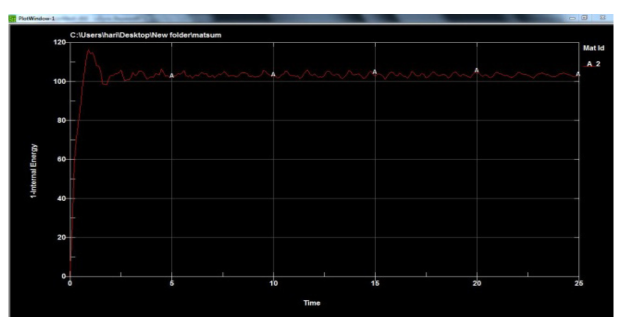

Figure 5. Kinetic Energy plot (Impactor).

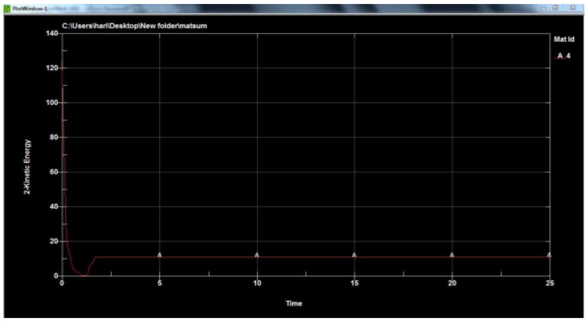

Figure 6. Kinetic energy plot (bumper).

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