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Design and Crash Analysis of Automotive Crush Box

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Abstract: The crush box analysis is carried based on basic principle of FMVSS by using Finite Element Method. The HYPERMESH software is used for meshing and LS DYNA software is used as a solver. Evaluate the results by changing thickness and design of crush box. Von misses stress and energy graphs are plotted, by comparing the results can suggest 1.8mm thickness and corrugated design absorb optimum stress and more energy than other. For further can improve and change the design and material properties.

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I. INTRODUCTION

The safety is more important in automotive vehicle the designer should concentrate improve safety parameters to reduce injuries by accidents. Drivers and passengers need more safety protection. Car driving is safer and luxurious than other vehicles. The design engineers must follow the standard regulations and satisfy the requirements as per FMVSS and NHTSA. The crash is depending on kinetic energy. When the vehicle is moving, it has some amount of kinetic energy. The vehicle will come to a complete stop after the crash, kinetic energy will be zero. To minimize the injuries, reduce the kinetic energy evenly as possible. Crash protection depends on the velocity of the vehicle. The front end of the car is designed to act as a crumple zone, it absorbs and manage the crash energy, impact energy affects only to the car not a driver or passenger. For absorbing the kinetic energy crush boxes are used in car.

Crush box is mounted on the rear side of the front and rear bumper. Crush box is one of the components in automotive which absorb the crash energy. At the time of impact the crash box will fold like a squeeze box to absorb impact loads and minimize the kinetic energy. In frontal collision the crash box will play a major role to absorb energy by collapsing than the other body parts. It minimizes the damage of bumper, main frame and saved the passengers by major injuries.

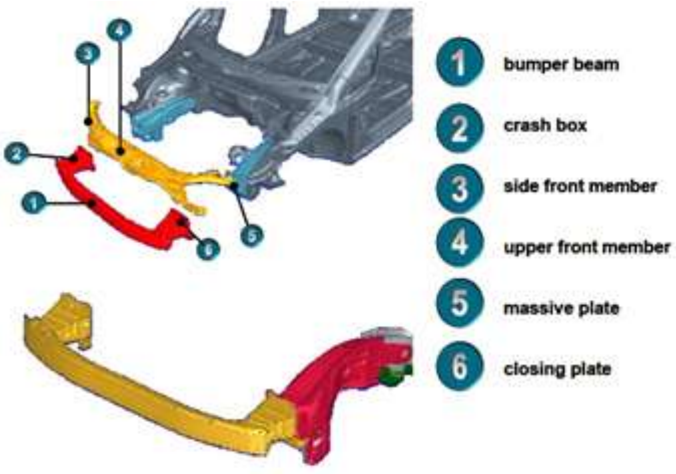


Fig 1: Car frontal assembly

1.1 Different shapes of crush box are as follows

1. Square shape.
2. Rectangle shape.
3. A circle shape.
4. Hexagonal shape.
5. Octagonal shape.

II. LITERATURE SURVEY

Analyze the three frontal car parts with a rigid obstacle at rest and these are analyzed in ANSYS software. The models have different crash boxes and finite element mesh size for each part of the model varies depending on its role. Geometry modeling was performed by using ANSYS. Structural steel NL1 and Structural steel NL2 (HSLAS S300MC and S250MC) materials are used for crash box and bumper respectively. Total plastic deformation increase

during the impact, reaches a maximum value and remain quasi constant around this value for all three models. From this moment, it is considered that the impact energy is not consumed any more by the crash boxes, but the energy is sent to the front frame rail [1].
The simulation of the crash itself was done by LS-DYNA code. The design of the crush box will be designed which should absorb more energy during RCAR Crash performance. Design the crush box with different shapes and apply the different materials for simulation. Finally square and rectangular shapes are absorbing lower energy compared to other shapes [2].

Crush boxes are modeled in two different shape one is hexagonal and other is rectangular-shape.H360 steel and aluminium 6008T7, optimized steel caisson, optimized aluminum caisson with polyurethane foam materials are used. The best behavior in case of low speed impact is obtained by the optimized shape of the caisson made from Aluminum, filled with PU foam [3].

In this work a Rectangular cross-section Crash box is used and it was modeled in CATIA V5R14, meshing is carried out in HYPERMESH-9 and LS DYNA is used as a solver. For different material models they determine displacement and energy absorption. For a particular model, find out results at different thickness and various velocities. The results are plotted for 3 cases which are different material model, various thickness and velocities. Square and rectangular cross sections absorb lower energy than the other cross sections [6].

III. FEDERAL MOTOR VEHICLE SAFETY STANDARDS

These federal safety standards are guidelines written in phrases of minimum protection overall performance requirements for motor cars. These requirements are laid out in any such manner that the public is included towards unreasonable danger of crashes taking place as a result of the design, manufacturing or performance of motor motors and also protect against unreasonable threat of dying or injured within the event crashes do occur.

Federal Motor Vehicle Safety Standard was classified as 3 categories:

I. Crash avoidance
II. Crashworthiness
III. Post crash survivability

FMVSS 208: OCCUPANT CRASH PROTECTION

In the year 1982 the crash protection for front seat occupants in automobiles has started. Automatic crash protection will be effective from 1983 for intermediate and compact passenger vehicles. Occupant crash protection Standard is one of the NHTSA most significant regulations. In the year 1980suggest for evaluating automatic restraint systems and Standard 208 proposed by NHTSA.

Different types of frontal crash test procedures are as follows

1. Oblique frontal fixed barrier test.
2. Full frontal fixed barrier test.
3. Frontal fixed offset deformable barrier test.
4. Oblique moving deformable barrier (MDB) test.
5. Perpendicular MDB test.
6. Generic sled test.
7. Full frontal fixed deformable barrier (FFFDB) test.

IV. Crash Analysis

The effect of crash and impacts on structure is one problem and the second one which is of prime importance is the safety of occupants. Find that occupant safety simulation accurate results which can save lots of testing time and cycle time. The CAE development for this application was delayed due to unavailability high end computing power it can be said that such simulation are 20 years old. There is an increase in the application of software to solving problems related to automotive, aerospace, and drop test components. Determine the displacement, velocity and acceleration given initial condition on displacement and velocity with respect to time. Other quantities are derived from these and some important are the element stress, contact force, plastic strains and energies such as potential energy, kinetic energy, etc.

V. LS–DYNA

LS-DYNA is a command shell, and enters the file, and enough loose disk area to extend the calculation. All enter documents are in easy ASCII format. Input files can also be coordinated with the preprocessor.Licensees of LS- DYNA mechanically have got entree to all the application's abilities, from the simple linear static mechanical analysis as much as advanced thermal and get with the flow solving strategies.

LS-DYNA is used by the automobile industry to research automobile designs. LS-DYNA correctly predicts a vehicle's behavior in a collision and the effects of the collision upon the automobile occupants. Through the usage of LS-DYNA car designers can take a look at vehicle designs, experimentally test a prototype. It saves the cost and time.

VI. MODEL

The design is carried out in solid Edge software, which has length 231mm, width 97mm and thickness 1.8mm. Two different shapes are created one is corrugate shape and other one is plane shape. Prepare the experimental model which includes rigid wall, bumper, main pillars, side pillars etc.

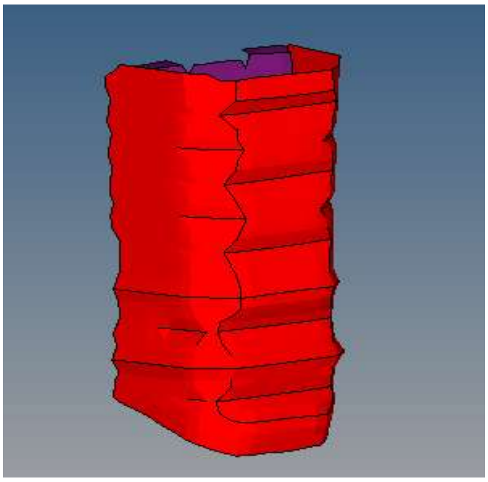


Fig corrugated design

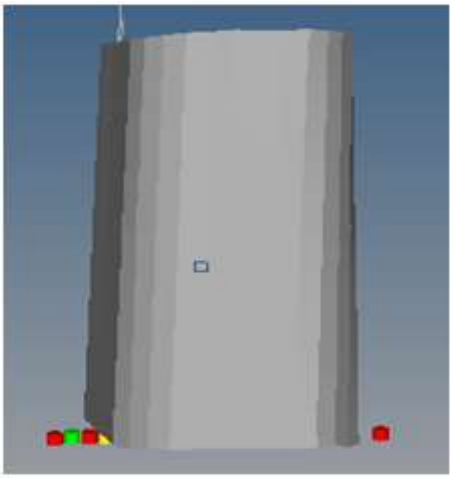


Fig plane design

The experimental model was imported from solid edge and shell meshing is carried out in HYPERMESH, shell meshing is used when surface area larger than the thickness. The main objectives in meshing is capture geometry and minimize tria elements, avoid opposite trias, touched trias, maintain element size and projection of elements should be on geometry line with neat flow, and clear all quality parameters such as jacobian, warpage, skew, minimum and maximum angles of tria and quad as per requirements.

Fig meshed model

VII. MATERIAL

MAT24 (Piece wise linear plasticity) material is used. It is an elastic - plastic material with arbitrary strain rate and arbitrary stress versus strain curve.

VIII. PROCEDURE

The meshed model is imported to LS DYNA solver for analysis, the analysis carried out in two parameter first one is changing 3 different thicknesses those are 1mm, 1.8mm, 2.5mm and the second one is crash box design i.e. Corrugated and plane design with the initial velocity is 50km/hr. Control termination is 100miliseconds and control time step is -4.

The vehicle is moving and impact to the rigid wall which has a cross section 1500x850mm with initial velocity 50km/hr, at that time crush box will be squeezed and absorb the kinetic energy with given material behavior. Plot the results of kinetic energy, internal energy, total energy and von misses stress, displacement. From these results validate which parameter is absorbing more energy and resist the stress with the same velocity, mass and time.

IX. RESULT AND DISCUSSION

The stress results are plotted in hyper works and graphs are plotted in hyper graph. Kinetic energy and internal energy graphs are plotted with respect to time.

- When the thickness is increased simultaneously stress is increased and stiffness also increases.
- When the surface area increases the stress is decreased.

The stress results and energy graphs are plotted for corrugated and plane design with respect to 3 thicknesses.

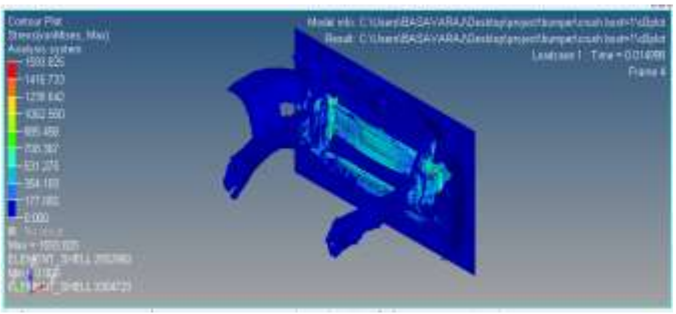
COMPARISON OF RESULTS

1. Stress results of corrugated design and Plane design.
2. Stress results in between Thicknesses.
3. Corrugated design Energy graphs with their Thickness.
4. Plane design Energy graphs with their Thickness.

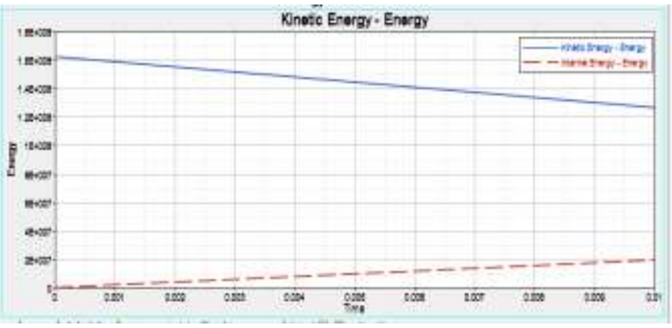
Validate the above results and conclude which design and thickness absorb optimum stress and which thickness absorb more energy.

9.1CORRUGATED DESIGN

Thickness 1mm

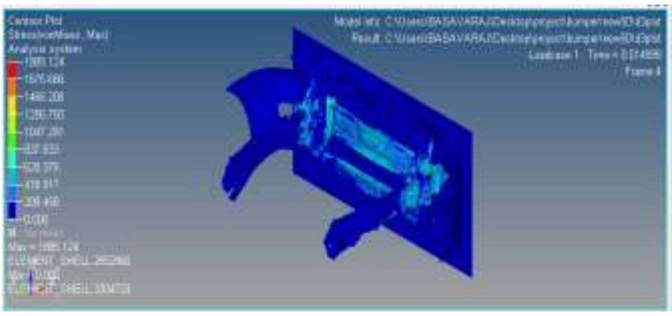


Von misses stress for 1mm

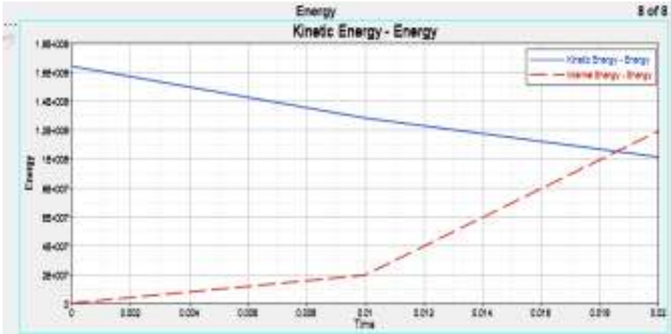


Energy vs. Time for 1mm

Thickness 1.8mm

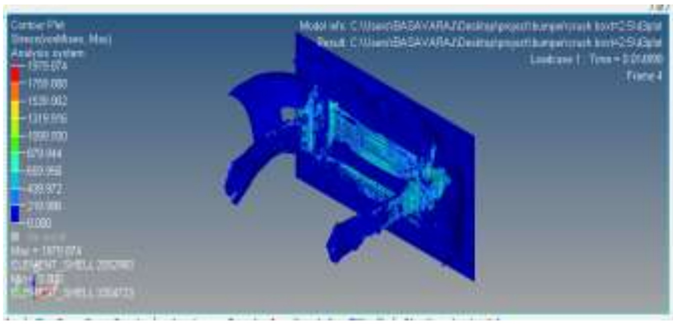


Von misses stress for 1.8 mm

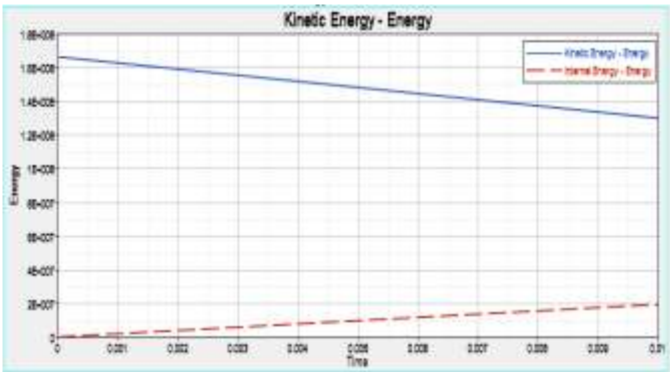


Energy vs. Time for 1.8 mm

Thickness 2.5mm



Von misses stress for 2.5 mm



Energy vs. Time for 2.5 mm

	Thickness in mm	Stress in Mpa
Corrugated design	1	1.5 x10^3 Mpa
	1.8	1.8 x10^3 Mpa
	2.5	1.9 x10^3 Mpa

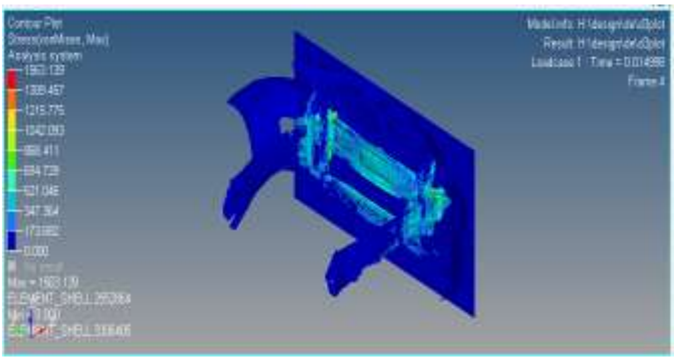
Corrugated design stress

Thickness 1mm				
	Starting time		**Ending time**	
	Time in Sec	Energy in J	Time in Sec	Energy in J
Kinetic energy	0	$1.6x10^8$	0.01	$1.28x10^8$
Internal energy	0	0	0.01	$2x10^7$
Thickness 1.8mm				
Kinetic energy	0	$1.6x10^8$	0.01	$1.28x10^8$
Internal energy	0	0	0.01	$2x10^7$
Thickness 2.5mm				
Kinetic energy	0	$1.69x10^8$	0.01	$1.3x10^8$
Internal energy	0	0	0.01	$2x10^7$

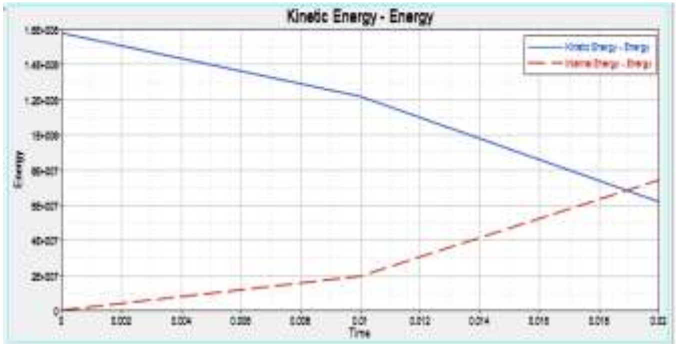
Kinetic and internal energy values of corrugated design

9.2 PLANE DESIGN

Thickness 1mm

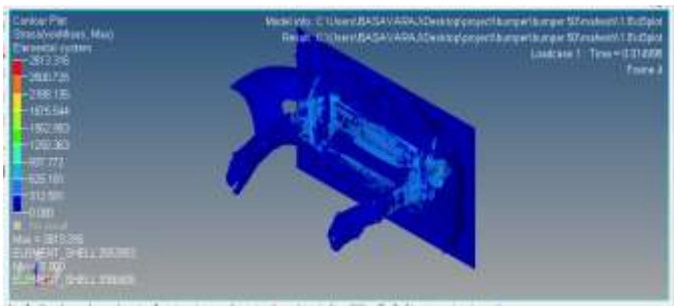


Von misses stress for 1mm

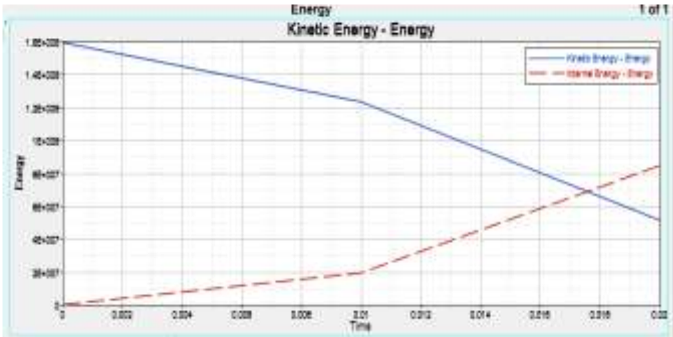


Energy vs. Time for 1mm

Thickness 1.8

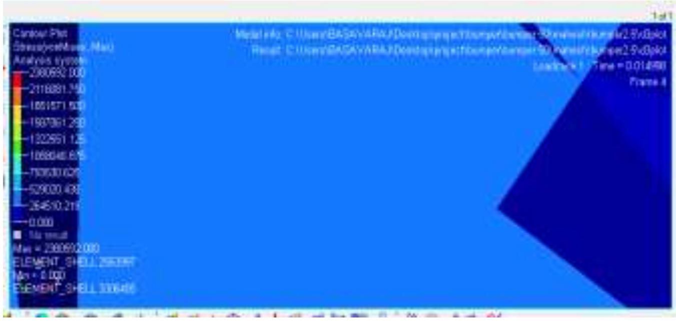


Von misses stress for 1.8mm

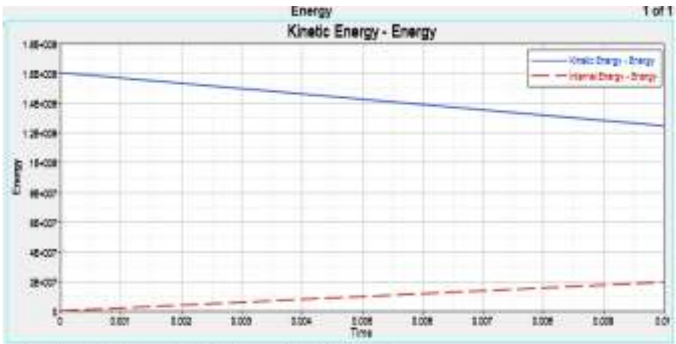


Energy vs. Time for 1.8mm

Thickness 2.5



Von misses stress for 2.5mm



Energy vs. Time for 2.5 mm

	Thickness in mm	Stress in Mpa
Plane design	1	1.5 $x10^3$Mpa
	1.8	$2.8x10^3$ Mpa
	2.5	$2.3x10^6$ Mpa

Plane design stress values

Thickness 1mm				
	Starting time		**Ending time**	
	Time in Sec	Energy in J	Time in Sec	Energy in J
Kinetic energy	0	$1.6x10^8$	0.01	$1.2x10^8$
Internal energy	0	0	0.01	$2x10^7$
Thickness 1.8mm				
Kinetic energy	0	$1.6x10^8$	0.01	$1.22x10^8$
Internal energy	0	0	0.01	$2x10^7$
Thickness 2.5mm				
Kinetic energy	0	$1.69x10^8$	0.01	$1.25x10^8$
Internal energy	0	0	0.01	$2x10^7$

Kinetic and internal energy values of plane design

The stress values vary with their thickness and design, plane design stress values are more than the corrugated design due to minimum surface area compareswith corrugated design. When the surface area increases the stress will be decreased. The stress values are increased when the thickness of the component will be increased and stiffness also increases. The 1.8 mm thickness crash box will absorb optimum stress compare to 1mm and 2.5mm. If stiffness is increase the more shocks will be produced, due to shocks occupant will be injured so that the crash box should absorb optimum stress.

X. CONCLUSION

Thework carried out on the design and crash analysis of the crush box by using HYPERMESH and LS DYNA software. By comparing above results corrugated design is better than plane design because it absorbs low stress when compared to it. While considering thickness factor, 1.8 mm thickness absorbs optimum stress to other two thicknesses (i.e., 1mm and 2.5mm). By the various stress values of thickness and from energy factor as observed from the graph 6.2.4 & 6.3.4 it suggests that 1.8mm thickness yield satisfactory results.

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