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A STUDY ON DESIGN AND CRASH ANALYSIS OF AUTOMOTIVE ENERGY ABSORPTION TUBES

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ABSTRACT

In engineering and technology safety of human life has always been a top priority. With the increasing usage of vehicles in everyday life, probability of deaths and injuries has also increased, but safety is important too. The main aim of this study is for designing an energy absorption tubes (Crush Can) of different shapes, thickness, at 10 km/hr speed and checking its performance by numerical simulation on the basis of FMVSS by using Finite Element Analysis and evaluate the result by changing design of Crush Can in the form of stress, energy graphs are plotted, by comparison of results, we can suggest that 1mm thickness and circular design absorb optimum stress and more energy than other. The HYPERMESH software is used in meshing and LS-DYNA software is used as a solver.

Keywords: *FEA, Frontal Crash Analysis and Pedestrian Safety*

1. Introduction

This paper is for the safety of the Pedestrian, in the road. Millions of people worldwide are killed at road accident, with the increase in production of vehicles, the no of collision & fatalities has also increased, due to this high requirement of safety has be advocated. This has led to continuous research in designing efficient energy absorber to absorb energy during an accident and protecting the pedestrian on the road.

When the vehicle is moving, it has some amount of kinetic energy if the vehicle will come to a complete stop after the crash kinetic energy will be zero, to minimize energy, reduce the kinetic energy evenly as possible. Crash protection depend on the velocity of the vehicle, the front end of the car is designed to absorb and manage the crash energy / impact energy effects the car and pedestrian.

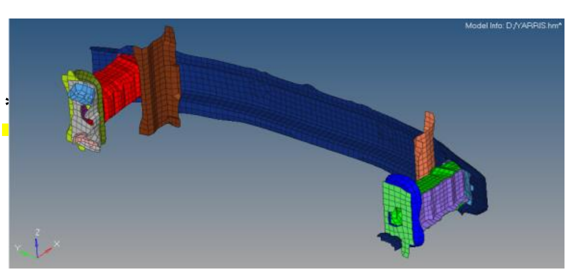

Fig. 1 Crush Can Assembly

Generally, Crush Can is mounted on the rear side of front and rear bumper, it is one of the components in automotive, which absorb the kinetic energy. At the time of impact, the crush can will fold like a squeeze box to absorb impact load as shown in the above Figure 1 Crush Box Assembly. As we can see in the Figure 2 and Figure 3 the car actual crush box assembly of the Maruti Nexa S-Cross vehicle.

Fig. 2 Car Frontal Crush Can Assembly

Fig. 3 Crush Can of Vehicle

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Detailed analysis of collisions between vehicles and pedestrians shows that over 70% of the point of first contact lie in the car frontal area shown in Figure 4 below.

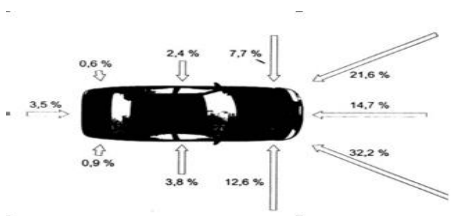

Fig. 4 First Contact Zone In Pedestrian-Vehicle Collisions[6].

1.1. Different shapes of crush can are as follows

1. Square shape. 2. Circular shape.
3. Hexagonal shape. 4. Octagonal shape.

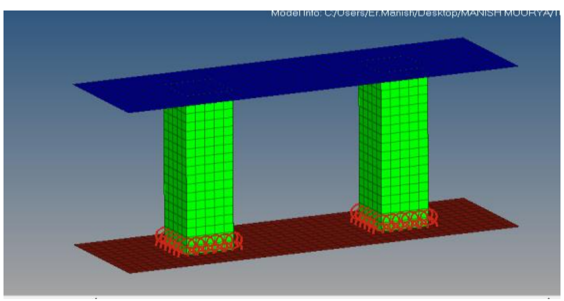

Fig. 5 Square Shape Crush Can

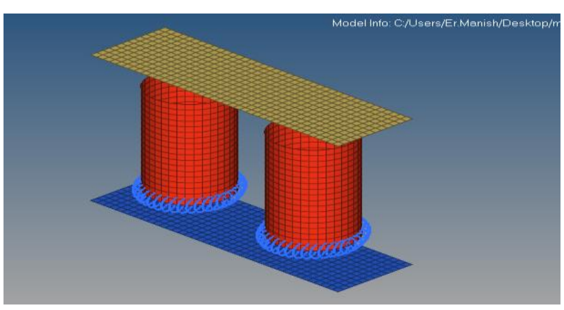

Fig. 6 Circular Shape Crush Can

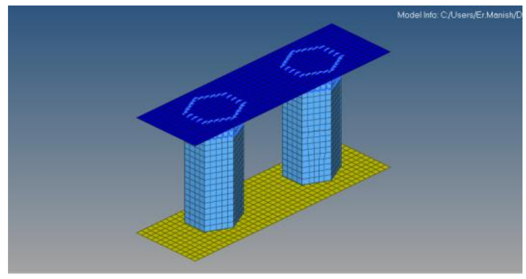

Fig. 7 Hexagonal Shape Crush Can

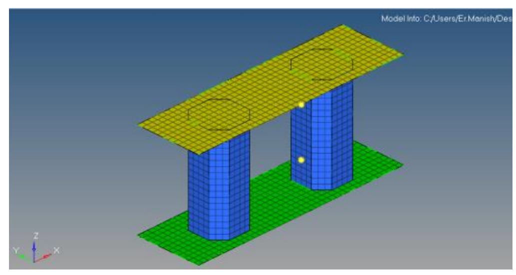

Fig. 8 Octagonal Shape Crush Can

Thus, we can see the geometries of crush can in the figures, the dimensions, meshing criteria, and materials used in crush can are seen in the table's below.

Table 1. Dimensions of Crush Can Assembly

GEOMETRY		
VEHICLE	CRUSH	60X200X1mm
_CAN		24X24X90X0.8mm
WALL		60X200X1mm

Table 2. Meshing Criteria of Crush Can Assembly

MESHING CRITERIA		
VEHICLE	CRUSH	SHELL MESHING
_CAN		SHELL MESHING
WALL		SHELL MESHING

Table 3. Materials Used in Crush Can Assembly

MATERIALS	
VEHICLE	MAT 20
CRUSH_CAN WALL	MAT 24
	MAT 20

2. Literature Review

M. Pohlak et.al. [1] developed an extra frontal protection system of a car satisfying requirements of the European parliament and the council. The car frontal protection system is treated as additional car frontal protection system is treated as additional energy absorbing element. An analysis of a car- pedestrian crash situation is performed by use of explicit Finite Element Analysis solver. In general, tubular extra accessories mounted to the front of vehicle constitute a risk to the safety of pedestrian in the event of a collision in order to protect the pedestrian.

The research work by Schuster et.al. [2] is to understand the state of the art in bumper design for pedestrian impact and two general approaches to reducing the severity of pedestrian lower limb impact were identified. (a) the deployable approach is to implement advanced impact sensors in to the bumper and deploy airbags or structure over the surface just prior to impact. (b) the static approach aim is to provides appropriate cushioning and support of the lower limb using the bumper energy absorber.

Shin et.al. [3] proposed a design method for a new bumper system and the crash box is proposed to satisfy the regulations related to the front structure of the vehicle, a detailed shape of the crash box is determining the result suggest that strain energy of the crash box is maximized because to absorb the impact energy, and it concluded that frontal structure of the vehicle is improved through the proposed design process.

The study carried out by Vinod Kumar et.al. [4] is based on Federal Motor Vehicle safety standard by using Finite Element Method, to analysis by changing the shape and thickness of the crush box. Finally concluded by comparing the result that corrugated design is better than plane design, because it absorb low stress when compare to it and if stiffness is increase the more shocks will be produced, due to shocks occupant will be injured so that the crush box should absorb optimum stress.

Wood et.al. [5] concluded that the car mass, length and frontal crush properties are important parameters in determining the relative injury risk of any particular car. The aggregate specific energy absorption properties for the car population are independent of car size: this means that the depth of crush can be considered to be proportional to car length. However, this study shows that the specific energy absorption capacity of the individual car has a profound effect on the relative injury risk of that car and that safety is improved by having a low specific energy capacity.

Wordenweber et.al. [6] analyzed the requirements for pedestrian protection and spells out the consequences for head lamp design. The objective of this research and development work carried out was to analysis the requirement now arising for pedestrian protection. The study by Ramesh Koora et.al. [7] is aimed at to improve the overall safety, security, quality and reduce the cost of repair of motor vehicle during accidents by proper design of the crush beam of SUV chassis. These crush beams are energy absorbing bumpers and should be able to crush during impacts without dissipating the energy to the structure of the vehicle. The better design when compared to other proposals and study shows that drivers of vehicles that earn good rating in frontal offset crash tests have significantly lower risk of fatal injuries in real world frontal crashes compared with drivers of vehicles with poor ratings.

Arun Basil Jacob et.al. [8] developed a new bumper model which has more crashworthiness than the existing bumper. The crash test was executed in a software environment and all the simulations were executed using Ls-dyna. The proposed model of honeycomb and also foam model have shown better impact absorption capacity than the already existing model. Caihua Zhou et.al. [9] focused on the performance of origami crash boxes under low velocity impact tests with different geometries, loading rates and mass. The researches indicate that different collapse modes influence the performance of those conventional tubes, thin walled structures have been proved to be effective to enhance the energy absorption capacity.

Kohar et.al. [10] presented a framework for optimizing the sizing of a multi cellular aluminium extrusion for automotive crashworthiness application. New aluminium extrusion profile were designed using finite element, fabricated and dynamically crushed using a slid- track apparatus. The energy absorption characteristics response was compared to experimental result, it was shown that the specific energy absorption lineally relates to the crush efficiency and that the optimization of the specific energy absorption function will tend to simultaneously increase the crush efficiency. Gabriel Jiga et.al. [11] proposed a methodology to improve the impact performance and reduce the damage of vehicle body at impact speed. Repair cost at collision accident can be cut down by use of this box, several numerical simulations have been performed on different crash-boxes models in order to obtain an optimized shape necessary to reduce the absorbed energy by the side-member, the best behavior in case of low speed impact is obtained by the optimized shape of the caisson made from aluminium, filled with foam.

Zarei et.al. [12] conducted the impact crush test on the empty and foam filled square tubes in order to find some more details about crush behavior, the process with explicit finite element code Ls-Dyna. Xiong Zhang et.al. [13] investigated the axial crushing of square tubes fabricated by folding of aluminium metal sheet. Experimental study is carried out first and numerical validation is then performed by parametric study is conducted to investigate the influence of several important factors on deformation and force responses of the folded tubes.

Pawel Kaczynski et.al. [14] presented the results of quasi-static and dynamic crushing tests of tapered energy-absorbing element made of magnesium alloy sheets, during the crushing of empty crash boxes, there was no influence of the strain rate on the level of energy absorbed, interaction effect between the crash box and its filling have been observed. The energy absorbed by filled crash boxes was 50-70% higher than the sum of energies absorbed by aluminium foam and crash box separately, this occurred both during the static and dynamic tests.

Desai et.al. [15] performed experimental and numerical simulation by using ANSYS explicit dynamic analysis on plane crash box. Good agreement found out in between analytical, experimental and numerical analysis result, in the crash box there is increase in mean crushing load, lowest crushing load and absorbed energy, the crash box profile is improved and can fulfill the required objectives. Also, they come to the conclusion that absorbed energy increases with increases in thickness. Garud et.al. [16] carried out analytical, experimental and numerical work on various parameters like width, thickness, filler material which affects the crash box performance are studied by using design of experiments at the time of accident it deform axially and absorbs accidental energy, crash box structure provides comfort to the passenger at the time of impact, it works as a safe guard for the costly components behind the bumper like engine hood and cooling system. Atul Gaikward et.al. [17] proposed a study to determine suitable material and develop a suitable crush box used in passenger car. Ghasemnejad et.al. [18] investigated the crashworthiness capabilities of thin walled corrugated crash boxes in axial crushing relative to flat sidewall boxes from the same material. The effect of corrugating the sidewall of aluminium crash box with various pitch distance on dynamic impact loading is investigated.

3. 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

4. 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 pedestrian. Find that 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.

4.1 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 with pedestrian. 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.

4.2 Model

The design is carried out in Hypermesh software, which vehicle and wall length is 200mm, width 60mm and thickness 1mm, Crush Can length is 90mm, width 24mm and thickness 0.8mm at the speed of 10 km/hr, Four different shapes are created square shape, circular shape, hexagonal shape, and octagonal shape. Prepare the experimental model which includes rigid wall, bumper (Vehicle), Crush Box (Tube).

In this experimental model 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.

4.3 Material

MAT20 (steel) used in Crush Can and MAT24 (Elasto-plastic material) material is used in Wall and Vehicle. It is an elastic - plastic material with arbitrary strain rate and arbitrary stress versus strain curve.

4.4 Procedure

The meshed model is imported to LS DYNA solver for analysis, the analysis carried out in thickness which are 1mm and the second one is crash box design i.e. square, circular, hexagonal, and octagonal design with the initial velocity is 10km/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 200x60mm with initial veloci10km/hr, at that time crush box will be squeezed and absorb the kinetic energy with given material behavior as we can see in the figure below. Finally plot the results of kinetic energy, internal energy, total energy, sliding energy and von misses stress. From these results validate which parameter is absorbing more energy and resist the stress with the same velocity, mass and time.

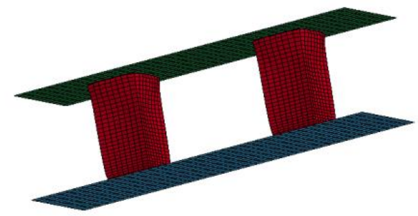

Fig. 9 Square Shape Meshed Model

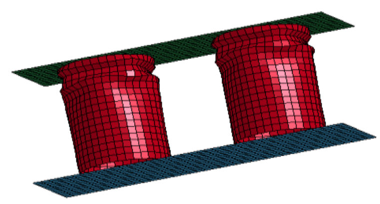

Fig. 10 Circular Shape Meshed Model

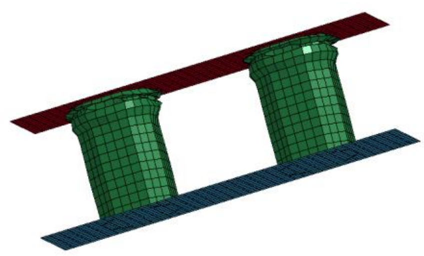

Fig. 11 Hexagonal Shape Meshed Model

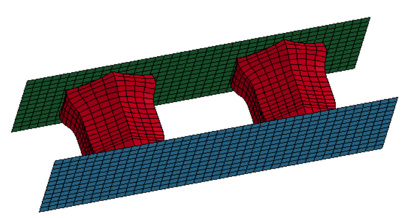

Fig. 12 Octagonal Shape Meshed Model

5. Results and Discussion

The stress results are plotted in Ls-Prepost and graphs are plotted in hyper graph. Kinetic energy, Total energy and internal energy graphs are plotted with respect to time.

i. When the thickness is increased simultaneously stress is increased and stiffness also increases.

ii. When the surface area increases the stress is decreased.

The stress results and energy graphs are plotted for Square, circular, hexagonal and octagonal design with respect to thicknesses. To validate the above results and conclude which design and thickness absorb optimum stress and which thickness absorb more energy.

5.1 Crash Analysis and Graphical Representation of Crush Can

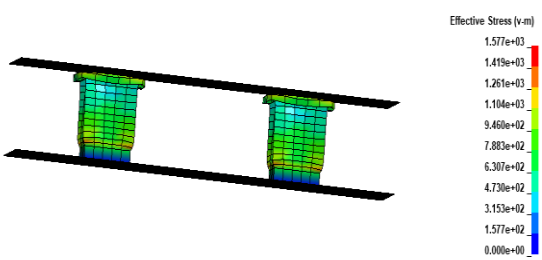

Fig.13 Crash Analysis of Square Shape Crush Can

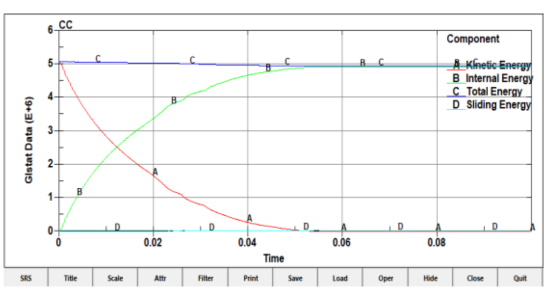

Fig.14 Graphical Representation of Square Shape Crush Can

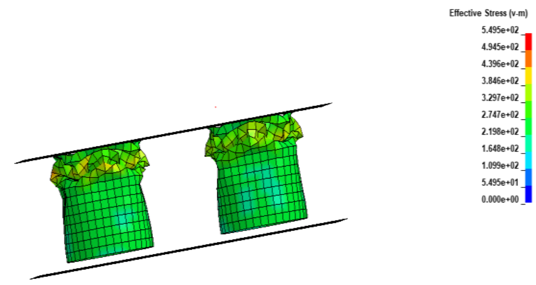

Fig.15 Crash Analysis of Circular Shape Crush Can

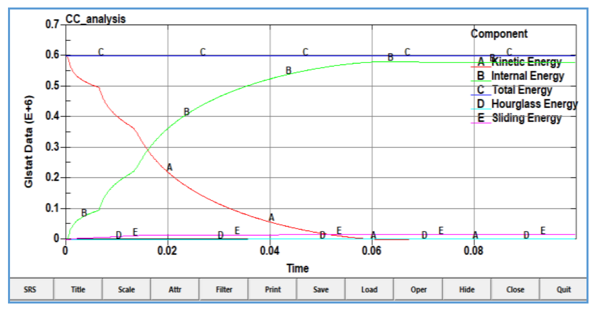

Fig. 16 Graphical Representation of Circular Shape Crush Can.

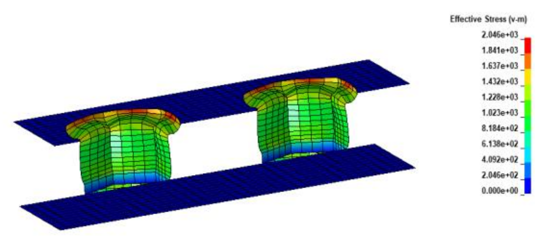

Fig.17 Crash Analysis of Hexagonal Shape Crush Can

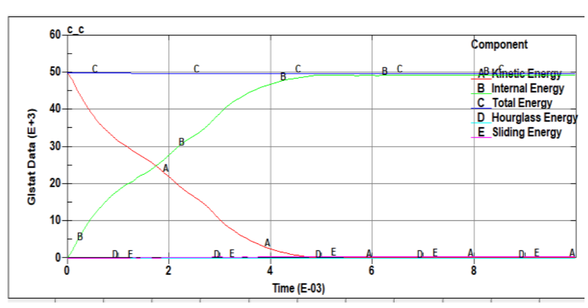

Fig. 8 Graphical Representation of Hexagonal Shape Crush Can

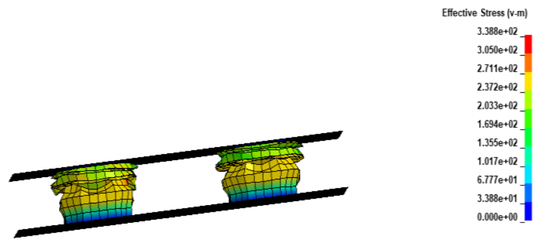

Fig.19 Crash Analysis of Octagonal Shape Crush Can

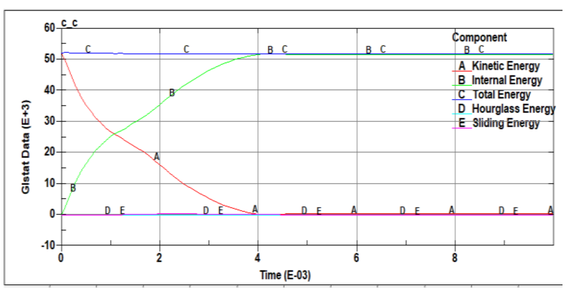

Fig.20 Graphical Representation of Octagonal Shape Crush Can

Table 4. Total Energy of Different Crush Cans

Crush Cans	Total Energy (N-mm)
Square Shape	5.09 N-mm
Circular shape	6.01 N-mm
Hexagonal Shape	5.03 N-mm
Octagonal shape	5.25 N-mm

Table 5. Plastic Strain of Different Crush Cans

Crush Cans	Plastic Strain
Square Shape	1.44
Circular shape	0.4
Hexagonal Shape	1.52
Octagonal shape	2.6

Table 6. Von Misses Stress of Different Crush Cans

Crush Cans	Von Misses Stress (N/mm^2)
Square Shape	1577 N/mm^2
Circular shape	549.5 N/mm^2
Hexagonal Shape	2046 N/mm^2
Octagonal shape	3388 m^2

7. Conclusion

The present work was carried out on the design and crash analysis of the crush box by using HYPERMESH and LS DYNA software. By comparing above results, circular design is found to be better than square, hexagonal, octagonal design because it absorbs low stress, low plastic strain and high total energy.

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Nomenclature

Symbol	Meaning	Unit
V	Speed	km/h
t	Time	m-s
P	Load	N
τ	Stress	N/mm^2
K.E	Kinetic Energy	N-mm

