ISSN(Online): 2319 - 8753
ISSN (Print) :2347 - 6710

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 5, May 2015

Effect of Oblique Loading on Energy Absorption in Bumper System

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ABSTRACT: The automobile energy-absorbing component equipped at the front end of car, is one of the most important automotive parts for crash energy absorption .The C- Chanel with two main longitudinal members will absorb most of the crash energy with a progressive folding deformation of a steel column. The longitudinal fail under progressive folding pattern which absorb shock energy. A rectangular tube with C- Chanel (Bumper System) of mild steel is analysed for its energy absorption capability using the finite element based software LS-DYNA. For pre-processing & post processing, software HYPERWORKS is used. Meshing is done using Belytschko Tsay shell element with 5 mm element size. Quasistatic Analysis are carried out in this work for axial loading. Mean crushing load is taken as a parameter for validation of the results. The analytical equations of square tubes are used for comparison of mean force. Energy absorption, Peak crushing force and deformation of the Bumper System are observed during the analysis.

KEYWORDS: Energy Absorption, LS-DYNA, Mean Load, CFE.

I. INTRODUCTION

The accidents are considered as one of the most threatening dangers in daily life. It is an unexpected event that can change people's life radically. Frontal accidents on country roads against other cars have a high fatality rate, frontal collisions not always axially. Maharashtra has reported 62,770 accidental deaths out of 4, 00,517 such deaths in the country during the year and remained at the top with nearly one-sixth (15.7%) of total accidental deaths reported in the country.

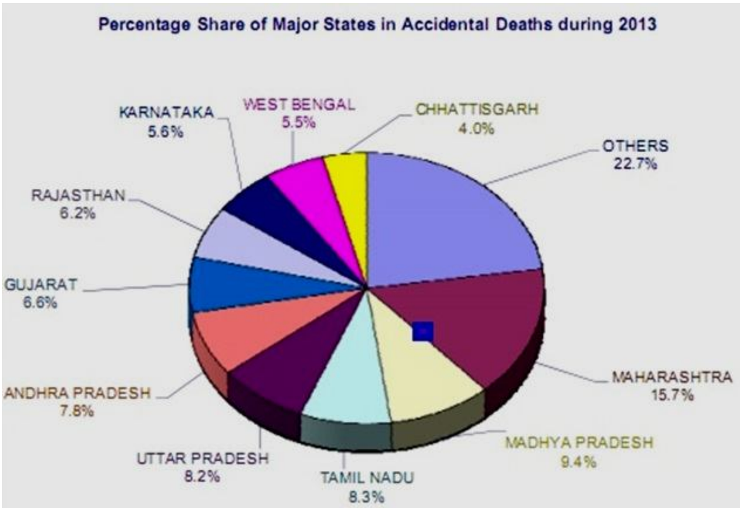

Fig.1 Percentage Share of Major State in Accidental Deaths during 2013

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ISSN (Print) :2347 - 6710

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For improved frontal car safety it is necessary to design a structure that absorbs enough energy in each realistic crash situation. Bumper systems are design to prevent or reduce physical damage to the front or rear ends of Passenger motor vehicles in collision condition.

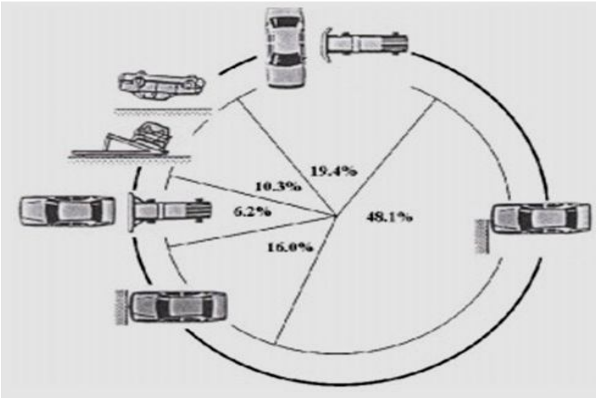

Fig 2.Distribution of real-world severe passenger car accidents by type of collision [4]

The two main longitudinal members will absorb most of the crash energy with a progressive folding deformation of a steel column. The longitudinal fail under progressive folding pattern which absorb shock energy. Thus, the modern bumper beam systems should play a key part in the safety concept of an automobile, ensuring that minimal accelerations are transferred to the passenger.

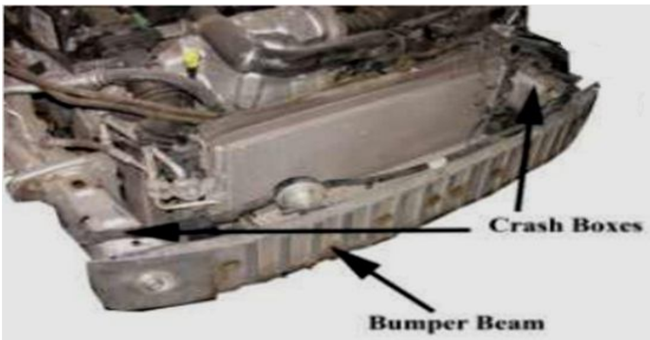

Fig.3 Positions of Bumper and cashbox.

It is therefore important to understand what happens to the Bumper & crash box (Bumper System) when subjected to oblique impact; Studies in this area are limited. [4]

Crush Force Efficiency (CFE):

The crush force efficiency (CFE) can be defined as the main crushing force (P mean) divided by the peak crushing load (P peak) as below. The CFE is one of the main factors to estimate the performance of energy absorbing structures .

$$CFE = \frac{P_{mean}}{P_{peak}}$$

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Literature Survey:

Javad Marzbanrad[1],The amount of energy absorption per weight of steel tube is 4.5 times greater than for the aluminium tube for all 3 sections. However, the square section and then the circular section of steel tube absorbed energy per weight more than the elliptic section of the aluminium tube, respectively. Reyes,[2]. The crushing behaviour of square aluminium columns subjected to oblique loads has been studied, experimentally and numerically. The deformation mode seems to depend on both load angle and thickness. The quasi-static simulations were able to predict the local mechanisms that occurred in the experiments. The energy absorption drops drastically by introducing a load angle of 5 degree and drops additionally with increasing load angle.

Satyanarayana Kokkula,[4]. In a frontal or rear crash, the bumper beam is the primary component which undergoes damage and transfers the forces to the rest of the structure. Thus, the modern bumper beam systems should play a key part in the safety concept of an automobile, ensuring that minimal accelerations are transferred to the passenger. In general most research is based on only an axial load, while more realistic load cases are with an angle of incidence.
W.J. Witteman,[5]. The improved frontal crashworthiness of cars necessitates totally new design Concepts, which take into account that the majority of collisions occur with partial frontal overlap and under off-axis load directions. Realistic crash tests with partial overlap have shown that conventional longitudinal structures are not capable of absorbing all the energy in the car front without deforming the passenger compartment. For improved frontal car safety it is necessary to design a structure that absorbs enough energy in each realistic crash situation. To protect the occupants, the passenger compartment should not be deformed and intrusion must be avoided too.

Gregory Nagel,[6]. In automobiles there is front longitudinal column which provide dual purpose i.e. energy absorption during frontal impacts and mounting vehicle auxiliary equipment such as the bumper beam. Bumper beams are one of the main structures of passenger cars that protect them from front and rear collisions. The effects of load angle on the mean load and energy absorption of the bumper system were investigated. The ability of the system to maintain its energy absorption capacity under increasing load angles was of interest from a practical point of view.

II. ANALYSIS OF RECTANGULAR TUBE

1. QUASISTATIC ANALYSIS:

Finite element analysis is carried out to determine the performance of the rectangular tubes. Software HYPERWORKS is used for pre-processing & post processing LS DYNA is used.

A. Finite Element Model & Meshing

Model of the rectangular tube is as shown in the Fig.4. Meshing is done using Belytschko Tsay shell element. Total No. of Elements was 3760 & No. of Nodes was 3873.

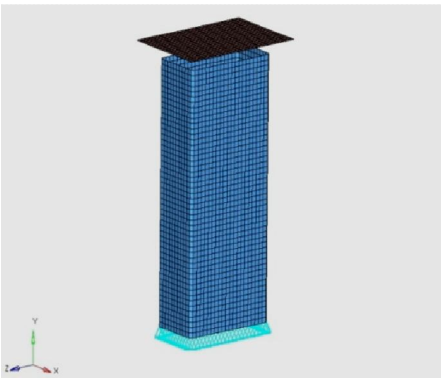

Fig.4 Meshed model of rectangular tube

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A fillet of 3 mm is used at the corners of the model. Element size used was 5 mm x 5 mm as is used by Nagel [5] for a similar geometry. On the top side a rigid plate is modelled.

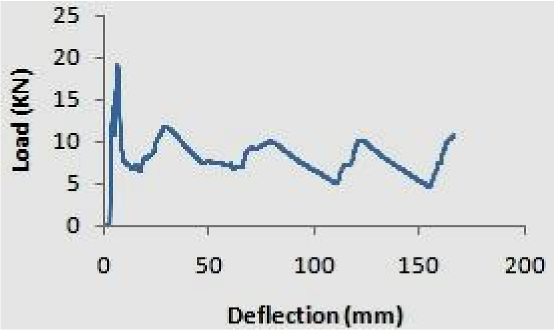

Fig. 5 load-deflection curve for quasistatic analysis

B. Analytical value of Mean Load:

The quasistatic mean load for rectangular tube is obtained using the expression proposed by W. Abramowicz and N. Jones [3].

These equations used for the validation of analysis of rectangular tube are strictly speaking only applicable to square tubes, however it has been found to produce reasonable results for rectangular tubes [7].

The mean crushing load (P_m) is given by

$P_m / M_o = 52.22\ (c/h)^{1/3}$ ……………………………………………………………..(1)

Here c = side length of tube = (110 + 60) / 2 = 85 mm and

h is thickness of tube = 2.5 mm

Here M_o = fully plastic bending moment per unit length for sheet metal

$M_o = \sigma 0\ h^2/4$ …………. Here σ_0 is flow stress (yield stress) of the material.

Thus,

$\sigma_{0\,=}\ (\sigma_{0yield)} = 293.8$ MPa

Hence,

$M_o = 293.8 \times (2.5)^2 / 4 = 459$ MPa

Thus,

$P_m / M_o = 52.22\ (c / h)^{1/3}$

$P_m = M_o \times 52.22\ (c / h)^{1/3}$

$P_m = 459 \times 52.22\ (85 / 2.5)^{1/3}$

$\mathbf{P_m = 77.65}$ **KN**

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Comparison of Result:

TABLE 1.
COMPARISON OF MEAN LOAD VALUES

Type of analysis	**Mean crushing load**		
	Analytical (for square tube) (KN)	**F. E. A. (for rectangular tube) (KN)**	**Diff. %**
Quasistatic	77.65	80.58	3.66

III.DYNAMIC ANALYSIS OF BUMPER SYSTEM

A. Finite Element Model & Meshing:

In this work, the mean crushing load is calculated when the end of column moves 2/3 of column length, before column jams itself.

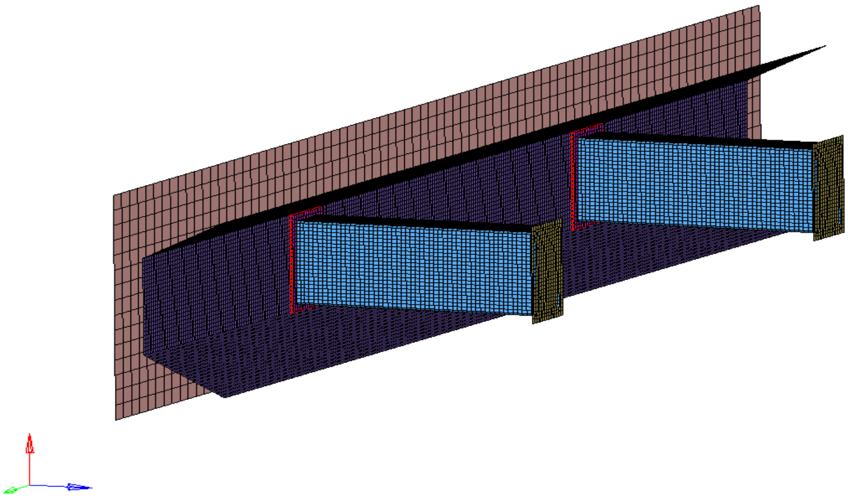

Fig.6.Modelling of bumper System

Fig.6 Shows, The rectangular tube along with bumper assembly and the rigid plate is modelled with 2D shell elements. The element size used is 5mm. The tube attached to the mounting plate which is constrained in all translational and rotational directions. Tube is attached to the bumper using RBE2 elements to represent welds. For both the components, no. of integration points is used as 5 and element type used is BelytschkoTsay shell. The No. of Elements is 29782 and No. of Nodes is 30026.The Mass of the impact plate is 250kgs and Initial velocity of 15m/s is given to the plate with various angles (0^0 to 30^0 in steps of 10^0), the material is Mild Steel and plate is rigid.

DOI: 10.15680/IJIRSET.2015.0405099

IJIRSET

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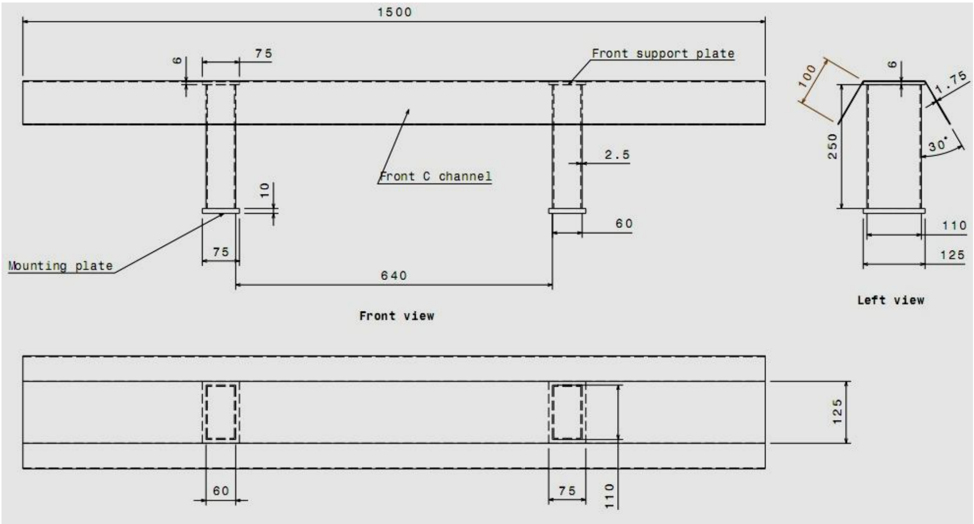
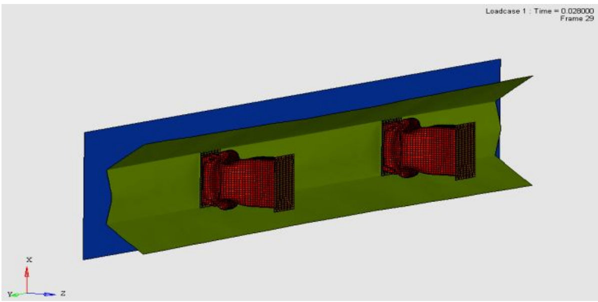


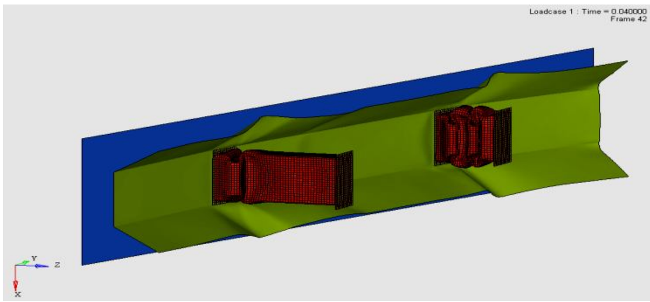
Fig.7 Orthographic View of Bumper System

A fig.7 show the orthographic view of bumper system, the dimensions of bumper system in mm and it is selected from the survey of group of vehicles which has seating capacity is 8-9 passengers.

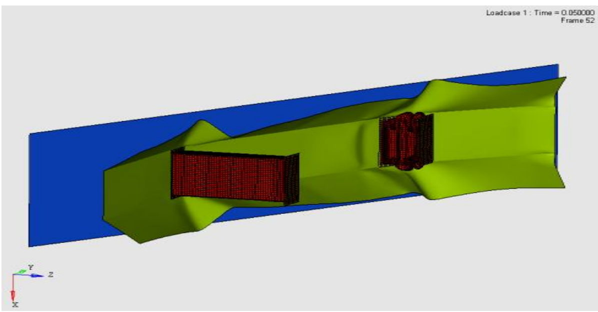
IV.FEM RESULTS AND DISCUSSION



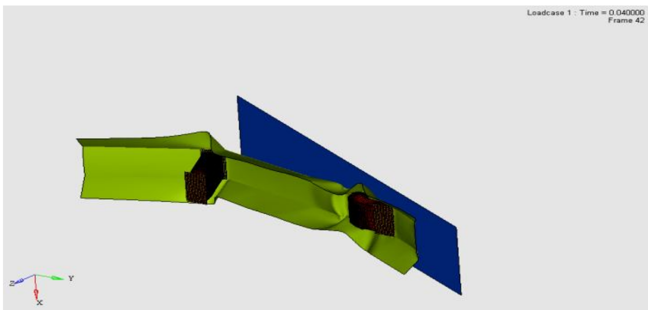
a. For 0^0



b.For10



c. For 20^0



d. For 30^0

Fig.8. Crash analysis of Bumper System for various angles

Fig.8 shows crash analysis of bumper system for various angels.

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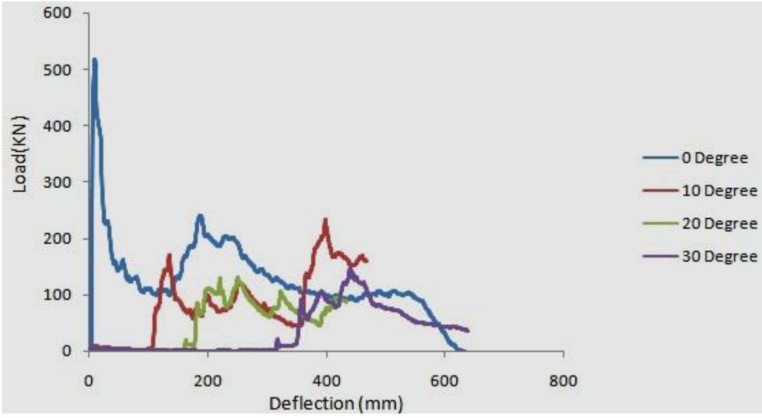
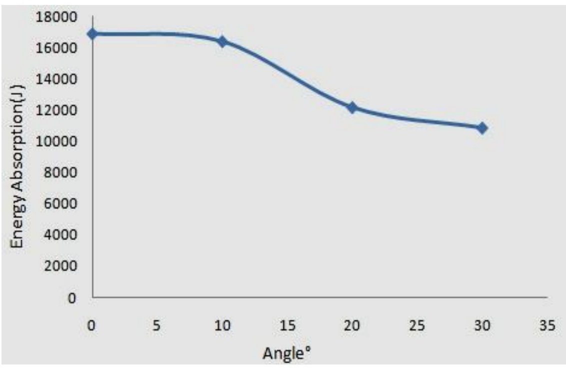
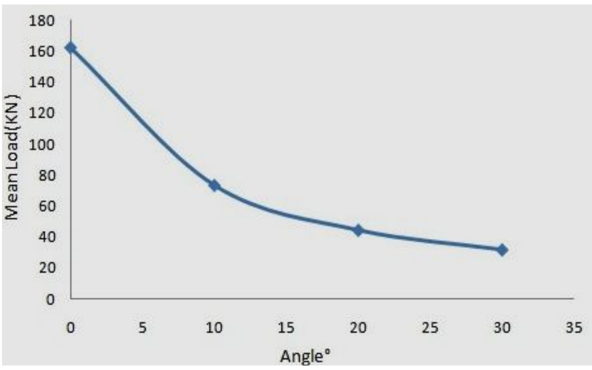


Fig. 9 Load vs. Deflection curves for various angles

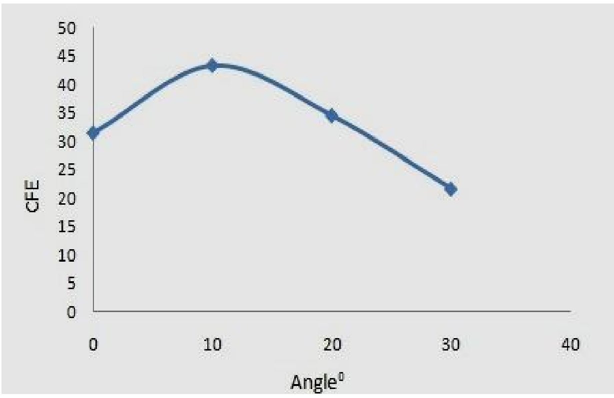
Fig.9 shows the Load vs. Deflection curves for various angles, for 0^0 Load angle the peak load is maximum which is 516.94 KN, and load angel is minimum for 20^0 it is 129.21KN.



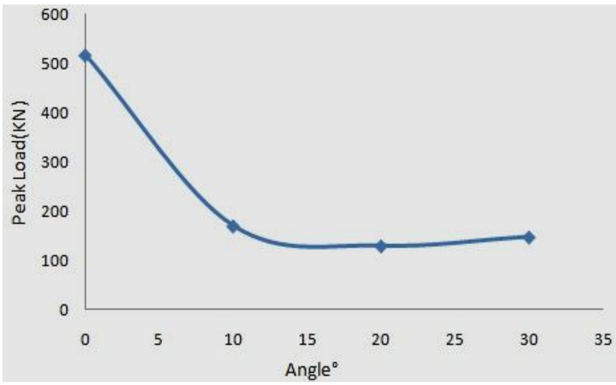
a.



b.



c.



d.

Fig.10. (a) Angle vs. Energy Absorption (b) Angle vs. Mean Load. (c) Angle vs. CFE (d.) Angle vs. Peak Load

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Fig.10.shows, when angle of loading increase with 10^0 then Energy absorption of bumper system is decreases and also decreases mean load and peak load but CFE is increased for 10^0 loading as compare to 0^0 then it also decreases for remaining angles. Energy Absorption, Mean Load, Displacement, Peak Load and CFC for Various Angles.

TABLE 2
Energy Absorption, Mean Load, Displacement, Peak Load and CFE for Various Angles

Angles	Energy Absorption	Mean Load (KN)	Displacement (mm)	Peak Load (KN)	CFE(%)
0^0	16915	162.41	104.15	516.94	31.4176
10^0	16457.12	61.78	223.8	169.93	36.3561
20^0	13051	45.92	283.3	129.21	35.539
30^0	11215	31.94	350.6	147.29	21.6851

V. CONCLUSION

In this paper, the energy capacity of bumper system under oblique load has been studied. When angle of loading increase with 10^0 then Energy absorption of bumper system is decreases. The CFE is maximum for 10^0 angle. For 0^0 Peak Load is maximum and for 20^0 Peak Load is minimum. High peak Load leads to decreased passenger safety. The reduction in energy absorption is due to global bending of tubes. Also the reduction is due to the deformation of only one tube ate start of impact.

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