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Study of Energy Absorption of Rectangular Tube of Bumper of Light Commercial Vehicle during Oblique Loading

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ABSTRACT: Thin walled structures are used as energy absorbers for last few decades. The absorption of energy takes place during progressive folding process of the tube. Tubes with different shapes are studied by many researchers. In this research work, a rectangular steel tube of bumper of light commercial vehicle is subjected to axial & oblique impacts. The mean crushing load determined by using equations of square tube are used to validate the results of finite element analysis. The reduction in energy absorption during the oblique impacts is studied. Effect of oblique loading on mean crushing load, peak load & crush force efficiency are observed during this work.

KEYWORDS: Rectangular tube, energy absorption, oblique loading, mean load, peak load.

I. INTRODUCTION

Crashworthiness of a vehicle is today of great importance. Strict standards need to be adhered to in the industry, in particular to protect human life. In the aim for better performance, the design of vehicles has also evolved to improve protection capabilities. The most important phenomenon in a crush or crash situation is to absorb the kinetic energy. Crash tubes are designed for that purpose and are used in many practical situations. They have the ability to absorb and convert large amounts of kinetic energy into plastic strain energy under severe loading conditions. [1]. A vehicle rarely encounters either completely axial or transverse loads, but rather happens in a combination of oblique (or off-axis) impacting direction [2].So, behavior of the tubes during oblique loading plays important role.

II. LITERATURE REVIEW

An extensive literature review is done as is presented in [3]. It is seen that very less work is done on oblique loading. Also very few researchers have studied behavior of rectangular tube. Thus need is to study the behavior of rectangular tube under oblique impacts.

Light Commercial Vehicles

There are lots of differences in categorization of different vehicles in different countries. Also the official & the general names used for a category of vehicles are differing in many cases.

Light commercial vehicle is the official term used within the European Union, Australia, New Zealand & occasionally in both Canada & Ireland (where Commercial Van is more frequently used) for a commercial carrier vehicle with a gross vehicle weight of not more than 3.5 tonnes. Qualifying light commercial vehicles include pick up trucks, vans and three-wheelers all commercially based goods or passenger carrier.

GVW is defined as vehicle weight plus the rated payload; the rated payload being the maximum weight permitted to be loaded on to the vehicle under the Motor Vehicles Act, 1988. Vehicles with a GVW of less than 7.5 tonnes are classified as LCVs. CVs depending on end-use can be either passenger carriers or goods carriers. [7]

Also in one category, various types of vehicles exist. For the research work, the word Light Commercial Vehicle has been used to define a group of vehicles carrying 8 to 10 passengers (having an average GVW of approximately 2500 kg) which is as per Indian Commercial Ratings & also according to the few other countries. Here passenger

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vehicle is considered because there will be only two persons in case of goods carrier & as the aim was to increase energy absorption of vehicle during the impacts, passenger carrying vehicles are more important than goods carrying vehicles. Also the group of vehicles considered for research fall under a category of jeep as per National Crime Record Bureau, to name a few Force-Trax, Tata-Sumo, Mahindra –Commander, Jeep etc. As contribution of each tube of bumper is nearly 5% of total impact energy, an impact mass of 125 kg (5 % of 2500 kg) is used in this work.

Parameters observed during the research work:

Mean crushing load: It is the average force or load over which the energy absorber deforms in a stable manner, and is obtained for a given deflection by dividing the energy absorbed by the crush distance.

Peak force: It is the force at which first fold starts. It is higher than the mean load.

Crush Force Efficiency: It is the mean crushing force divided by the peak crushing force.

III. ANALYTICAL APPROACH

Before finite element analysis, analytical values of mean crushing load are determined for axial loading of the tube.

Dimensions of tube:

After conducting a survey of the above mentioned vehicles, dimensions of the tube are finalized.

Thickness of tube = 2.5 mm

Cross section: 110 mm x 60 mm and

Length = 250 mm

Material properties:

Mild steel with yield strength of 293.8 MPa and ultimate strength 452.53 MPa is used for the analysis.

Mean crushing load for Quasi-static loading:

The quasistatic mean load (P_m) for rectangular tube is obtained using the expression proposed by W. Abramowicz and N. Jones [4].

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 [5].

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

IV. FINITE ELEMENT ANALYSIS

Quasistatic Analysis:

Finite element analysis is carried out using LS DYNA explicit software.

Finite Element Model and Meshing

Model of the rectangular tube is as shown in the Fig. 1. Meshing is done using Belytschko Tsay shell element. Total No. of Elements was 3760 and No. of Nodes was 3873.

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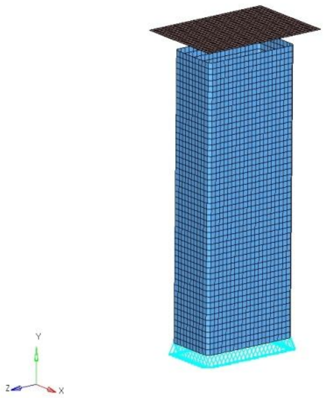

Fig. 1 Meshed model of rectangular tube

A fillet of 3 mm is used at the corners of the model and element size used was 5 mm x 5 mm as is used by Nagel [6] for a similar geometry. On the top side a rigid plate is modelled.

Boundary conditions and Load conditions

The tube is constrained at the bottom in all translational and rotational directions as in Fig. 1. The Rigid plate was given prescribed velocity of 10 mm per minute in vertically downward direction. [6]

The load –deflection curves obtained by quasi-static is shown in following figure. The area under the curve represents the energy absorbed. The mean load is calculated using the energy absorption and corresponding displacement.

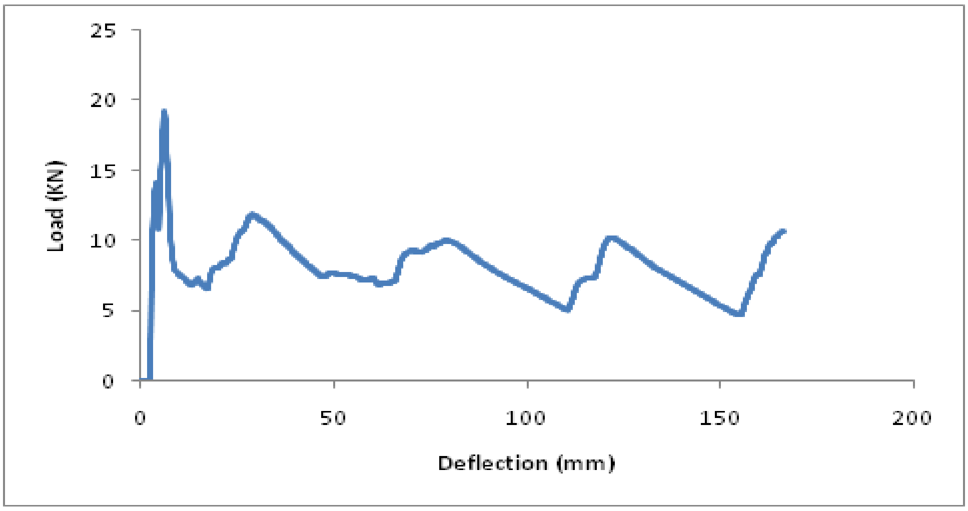

Fig. 2 Load-Deflection curve for quasi-static analysis

The mean load for quasi-static analysis is 80.58 KN. Thus, for quasi-static analysis error was 3.77 %.

Dynamic analysis: For the dynamic analysis, the same meshed model is used.

Energy absorption during oblique loading

During this work, effect of angular impact on energy absorption of rectangular tube is studied. Various angles at which tube was impacted are 0 to 30^{o} in steps of 5^{o}. The plane is inclined such that it will touch larger side of tube first. The same is shown in the figure 3.

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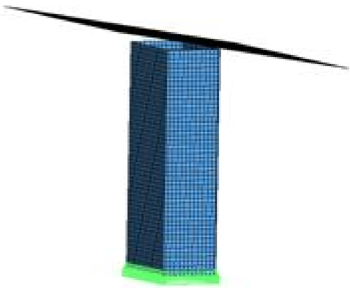

Fig. 3 Plane impacting the tube

V. RESULTS & DISCUSSIONS

Following are the responses given by the tube for various impact loading angles.

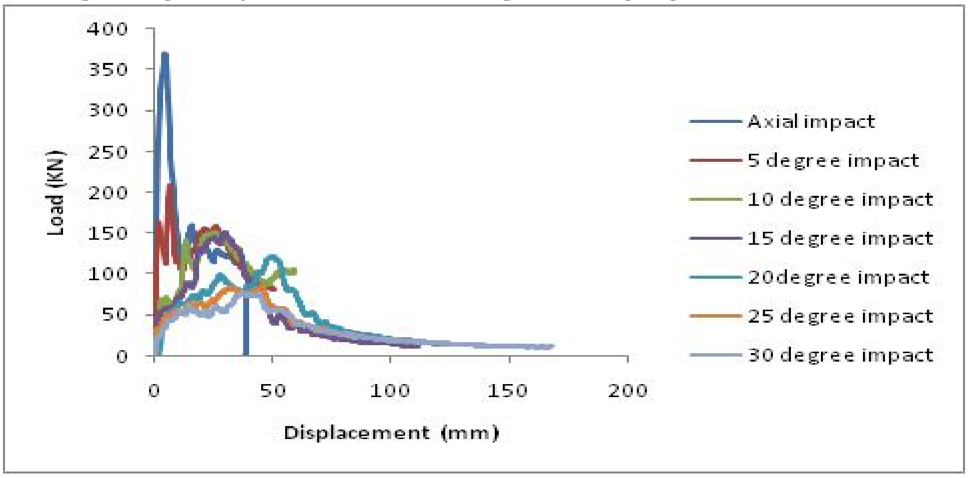

Fig. 4 Response of tube for different angles of impact

From the above curves it is observed that peak load is very much higher for axial loading of the tube. As the angle of impact increases, the load –displacement curves flatten out.

Table 1 Effect of oblique impact on Mean load, Peak load & CFE

Angle of impact (^{o})	Mean crushing load (KN)	Peak load (KN)	Crush Force Efficiency (CFE) (%)
0	157	369	42.55
5	123.75	208.37	59.39
10	105.93	151.45	69.94
15	56.63	151	37.50
20	53.83	120.44	44.69
25	34.82	84.18	41.36
30	31.72	77.18	41.10

Mean crushing load: It goes on decreasing as the angle of impact increases. For 15^o-20^o & 25^o-30^o impact it is nearly same. The rate of decrease of mean load is more when loading shifts from 10^o to 15^o. Mean crushing load at 30^o angle of impact is only 20 % of the mean load during axial impact.

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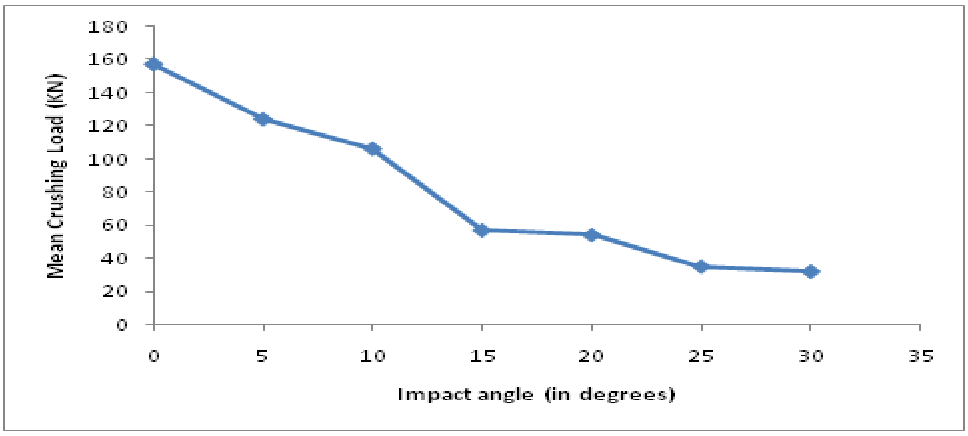

Fig. 5 Mean load for various angles of impact

Peak load:

Peak load decreases as angle of impact increases. Very large reduction in peak load occurs at the angle of impact 5^o. Afterwards the reduction is lesser. Peak load at 30^o is only 21 % of the peak load during axial impact.

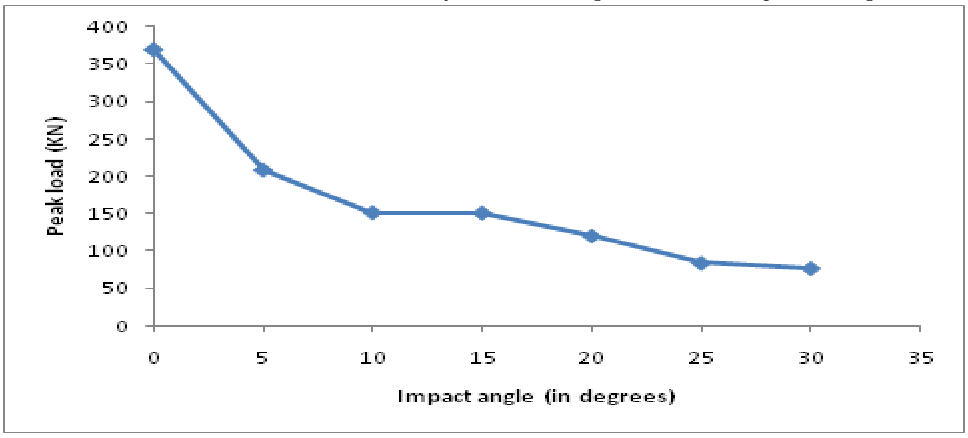

Fig. 6 Peak load for various angles of impact

Crush Force Efficiency (CFE):

CFE fluctuates for various angles of impact. Initially it increases with angle of impact. Then it decreases, followed by small increase, remaining nearly constant at the end.

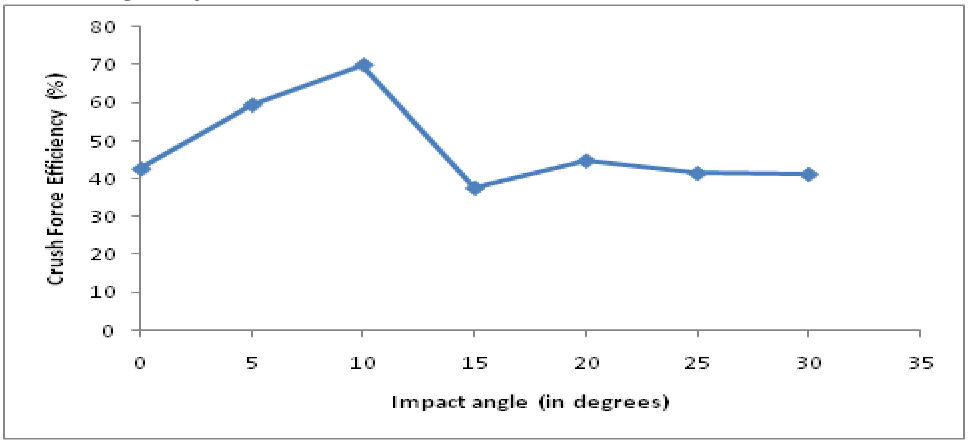

Fig. 7 Crush force efficiency for various angles of impact

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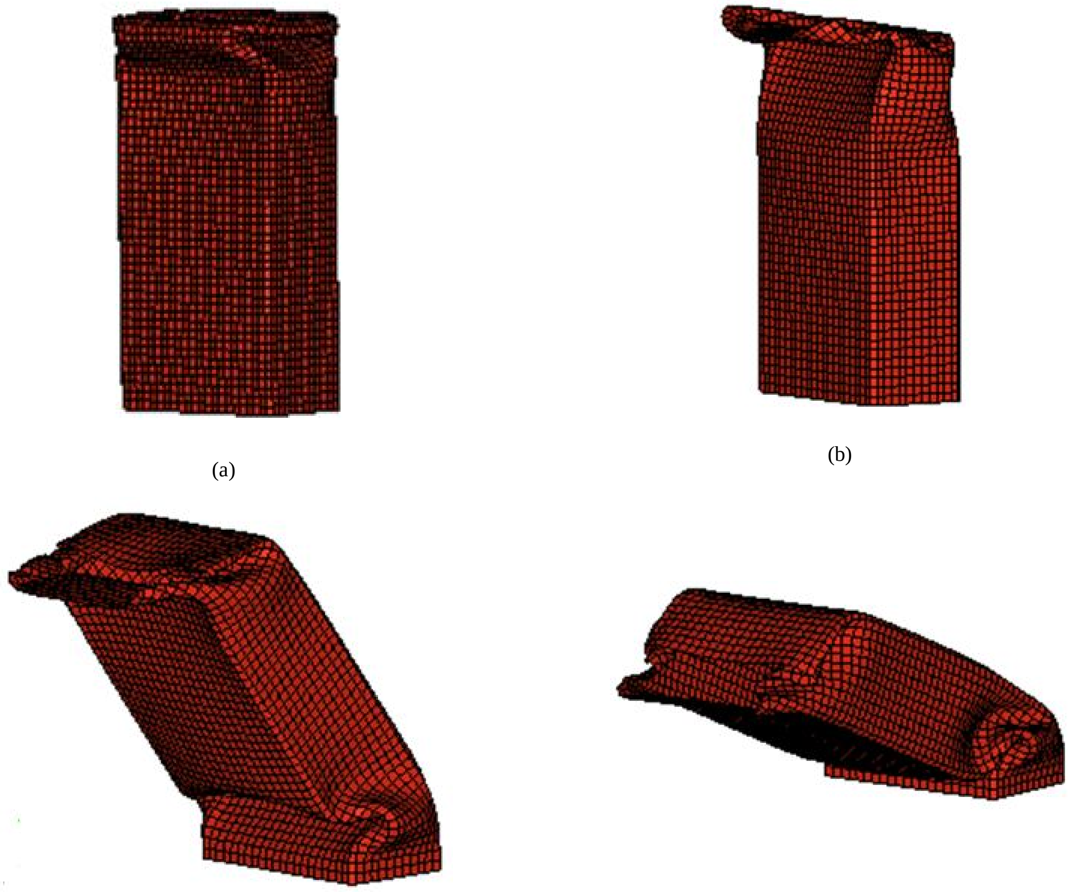
Deformed shapes:

Following figure shows deformed shapes of tube for various angles of impact. It is clearly seen that as the angle of impact increases, tube fails in global bending mode rather than progressive folding mode. Progressive folding is desired mode of deformation & is obtained in axial loading.



(a) (b) (c) (d)

Fig. 8 Deformed shaped for few cases a) 0^o impact b) 10^o impact c) 20^o impact d) 30^o impact

VI. CONCLUSIONS

From the above work, following conclusions can be drawn.

As angle of impact increases, peak load, mean load decrease. Crush force efficiency fluctuates for various angles of impact. This is mainly due to disproportionate decrease in peak load with increase in angle of impact. The tube fails in progressive folding mode during axial loading while it fails in global bending mode during oblique impacts.

Analytical equations for calculations of mean load of square tube give good results for rectangular tube.

Mean crushing load at 30^o angle of impact is only 20 % of the mean load during axial impact.

Peak load at 30^o is only 21 % of the peak load during axial impact.

Crush Force Efficiency increases initially with increasing impact angle & then it falls to a value near to the initial value& then almost remains constant.

Thus energy absorption decrease during oblique loading of the tube & there is need of changing the design of the tube so that it will behave in a similar way as in axial loading.

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REFERENCES

[1] Zafer Kazanc, Klaus-Jürgen Bathe, "Crushing and crashing of tubes with implicit time integration", International Journal of Impact Engineering 42, 80-88, 2012
[2] Yong Zhang et al, "Multiobjective crashworthiness optimization of hollow and conical tubes for multiple load cases", Thin-Walled Structures 82, 331–342, 2014
[3] S.B. Tuljapure, Dr. S.S. Sarawade, "Critical Review of Study of Crushing Tubes", International Journal of Mechanical Engineering and Technology (IJMET), Volume 4, Issue 6, 2013
[4] Abramowicz W. And Jones N., "Dynamic Progressive Buckling Of Circular and Square Tubes", International Journal of Impact Engineering, 4 (4): 243-270, 1986
[5] Wlodzimierz Abramowicz and Norman Jones, "Dynamic Axial Crushing of Square Tubes", International Journal of Impact Engineering, Vol.2,No.2, 179-208, 1984
[6] Gregory Nagel, "Impact and Energy Absorption of Straight and Tapered Rectangular Tubes", Ph. D. Thesis, Queensland University of Technology, 2005
[7] Methodology for Rating Commercial Vehicle Manufacturers, ICRA Rating Feature, *ICRA Limited, New Delhi*, 2009
[8] LS DYNA User Manual, 2013