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Energy Absorption Characteristics of Thin Walled Metallic and Foam Filled Tubular Structure with Different Cross-Sections

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Abstract – *The thin –walled structures are been used widely as energy absorbers in industries such as aerospace, shipping and automobile. The energy absorption behavior of tubular structures depends on various factors in which one of them is cross sectional geometry of tube structures .In this paper Metallic tubular structures and foam filled metallic tubular structures with different cross sections are studied. The tubular structures with different sections such as circular, hexagonal, triangular and square are studied based on the energy absorption point of view. The tubes have the same height, average section area, volume, thickness and material which are subjected to quasi static loading. The effect of foam has been studied during the crushing process since foam can be used for different crash analysis problem. The numerical model has been modeled and meshed using hyper mesh and analyzed using commercial explicit finite element solver Ls-Dyna. Finally the metallic and foam filled metallic tubes analysis results are being compared based on the energy absorption point of view.*

***Key Words*: Specific Energy Absorption, Crushing Load, Piecewise Linear Plastic, Crushable Foam, Quasi Static Process.**

1. INTRODUCTION

Safety of the passenger and driver has become an issue almost from the beginning of mechanized road vehicle development. Vehicle is used extensively and a large number of safety accidents related to them occur widely. Using energy absorbers is an appropriate option for this purpose. As an energy absorber in crashworthiness applications such as cars, ships, trains, aero-planes and other high-volume industrial products, the thin-walled structures have been widely used to ensure crash safety due to their lightweight, low cost and high energy absorption.

Tubular structures provide widest range of possible energy absorbing system for any simple structures. Apart from their use as energy absorbers, their common existence as structural elements implies an in strict energy absorbing capability in the largest part of the aerospace and automobile structures.

Metallic foams is being used in aerospace industry in different components to absorb the energy of an impact or in shielding devices to reduce the shock wave from a blast which might also have complex shapes, Aluminum, nickel, iron, copper, titanium and platinum are some of the common metals which are used to prepare metallic foams.

In this paper, energy absorption capacity of thin walled metallic and foam filled metallic tubes with various section geometries are investigated and studied numerically.

1.1 LITERATURE SURVEY

In order to carry out the entitled work an extensive literature survey was done by collecting and studying the number of relevant journals, articles and technical papers from the available resources.

Tubular structures are been used as energy absorbers in various aerospace and automobile applications. Tubular structures provide high specific energy absorption capability as well as light weight advantage. So it becomes an important part to study the tubular structures with different shapes. The effect of various cell configuration on energy absorption behavior of tubular structures were carried out by the different researchers, the numerical and experimental correlation was given by Ali Alavi Nia et.al [1] and numerical examination was carried out by Younes et.al [2] for thin walled tubes with various section shapes by maintaining same mass for each case and found that the circular tubes has the most energy absorption capacity [1] and the energy absorption capability of tubular structure increases with increase in number of sides [2]. The study is carried out by using foam filled tubular structure which shows better results compared to metallic structures as well as during out of planes impacting condition along with the cell geometry the cell foil thickness, cell side size, cell expanding angle also affects the energy absorption capacity tubular structures [3]. Alexander et.al [4] accomplished the first studies on the collapse mode of cylindrical tubes under axial loads. The theoretical model for collapse of steel conical tubes based on experimental observation was done by Al-Hassani et.al [5] and Mamalis et.al [6]. The average crushing load of square tubes under axial static loads was studied experimentally by Abramowiz and Jones et.al [7]. They also carried out several experiments on circular and square tubes under dynamic loading conditions and presented a modification of Alexander's theoretical model.

In spite of the much research performed on circular thin-walled tubes, the attempt to further improve the crushing behavior of thin walled tubes by designing an efficient energy absorbing material is highly desired. This numerical study aims to improve the energy absorbing capacity of the thin-walled tubes subjected to axial quasi static loading.

1.2 METHODOLOGY

In order to understand the crushing behavior of the tubular structures based on energy absorbing characteristics during impact event, the methodology is adopted. Based on the study of available literature the process of energy absorption behavior of thin walled structures is examined. In order to correlate the numerical analysis the impact study has been carried out on the thin walled structures of metallic as well as foam filled structures by applying the load on the different geometries cross section. For this case the modeling of the tubular structure is done by using the available modeling and meshing tool HYPERMESH V12.0. Then the analysis is carried out by importing the model to available solver tool LS DYNA 971 R 8.0 solver.

2. FINITE ELEMENT ANALYSIS

The Finite Element model consists of tubular structure and two rigid blocks, the tube structures are made up of shell elements and two rigid blocks are taken as solid elements. Modelling is carried out in HYPERMESH and analysis is carried out using LS DYNA.

The geometric model considered for the analysis is as shown in Fig-1 and it consists of Lower block and upper block which are movable and fixed respectively, In between a tubular structure is present which is of 100mm length. The meshed model considered for the analysis is as shown in Fig-2.

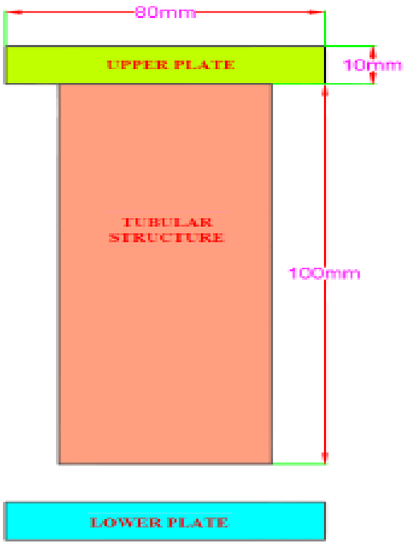


Fig-1 Geometric model of tubular structure

All the tubular sections are having same length, average section area and volume, the specifications of these are as shown in Table-1.

Table -1: Specification of tubular structure

Specimen Shape	Length (mm)	Cross section Dimension (mm)	Thickness (mm)
Triangular	100	Rib: 62.8	1.5
Squarer	100	Rib: 47.1	1.5
Hexagonal	100	Rib: 31.4	1.5
Circular	100	Dia : 60	1.5

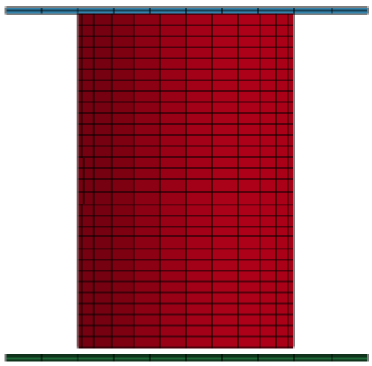


Fig-2 Meshed model of tubular structure

3. BOUNDRY AND LOADING CONDITIONS

The model geometry includes thin walled tubular structure with metallic and foam filled tube between two rigid parts at sits ends. The boundary conditions are the same as the experimental test conducted by the reference [1] the upper block is completely constrained in all directions whereas the lower block can move with a velocity of 100mm/s in the upward direction.

4. MATERIAL PROPERTIES

The material model for the tube, foam and blocks are

*MAT_PIECEWISE_LINEAR_PLASTICITY,
*MAT_CRUSHABLE_FOAM and *MAT_RIGID, respectively.

The material used for the metallic tube structure is Al3003 and foam is of carbon Nano. The material properties of Al3003 tube are tabulated in Table-2.

Table-2 Properties of Al3003

Density	2700 Kg/m^3
Young's Modulus	68.9 Gpa
Poisson's Ratio	0.33
Yield Stress	130 Mpa
Ultimate stress	137.8 Mpa

The carbon Nano foam materials are crushable foam with very less recovery, unlike foam material which is used in most of the automotive and aerospace seating systems. As carbon Nano foams are rigid foams and in this study the strain hardening and strain rate effects of the material are not considered. The material properties for carbon Nano foam are tabulated in Table-3.

Table-3 Properties of Carbon Nano foam

Density	58.166 Kg/m^3
Young's Modulus	185.03 Gpa
Poisson's Ratio	0

In this material model, arbitrary yield stress versus volumetric strain values are defined as shown in Fig-3.

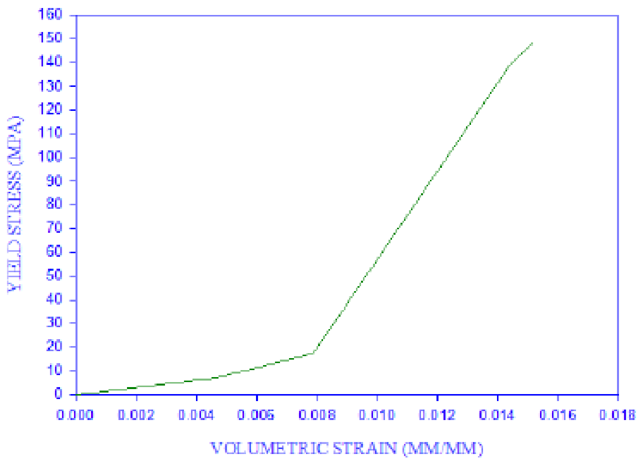


Fig-3 Yield stress versus Volumetric strain

In order to supply appropriate conditions for deformations, "contact automatic surface to surface title" sand "contact automatic single surface title" are used for tube-foam, tubes-rigid part elements and tube elements with each other respectively.

5. FINITE ELEMENT ANALYSIS OF METALLIC AND FOAM FILLED METALLIC TUBES

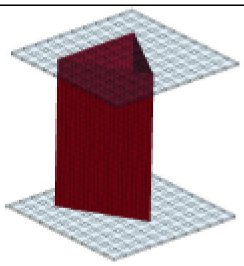
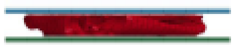
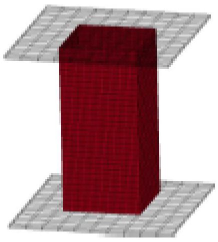
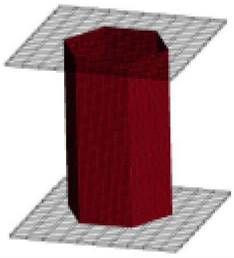
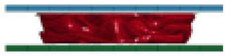
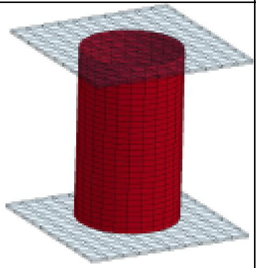
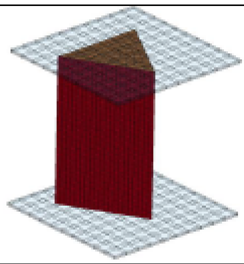
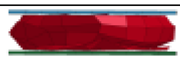
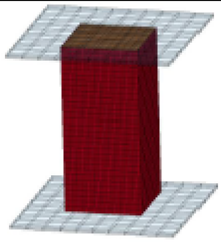
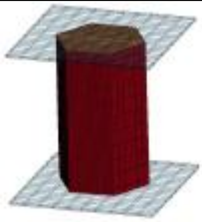
Specimen Shape	Before loading	After loading
Triangular		
Squarer		
Hexagonal		
Circular		

Fig-4 Tube structures before and after loading for metallic tubes

Specimen Shape	Before loading	Before loading
Triangular		
Squarer		
Hexagonal		

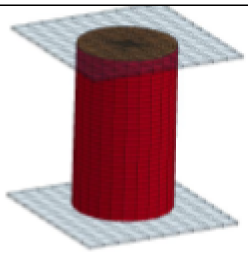
Circular		

Fig-5 Tube structures before and after loading for metallic tubes filled with foam

6. COMPARITIVE ANALYSIS OF METALLIC AND FOAM FILLED METALLIC TUBES

The Chart-1 shows the energy absorption characteristics of metallic tubular structures. From these results it is investigated that the maximum energy absorption is in circular and hexagonal followed by squarer and triangular tubular structures.

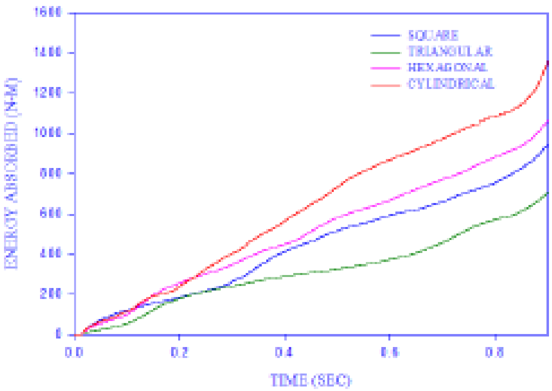


Chart-1 Energy absorption plot for different metallic tubular structures

The results obtained from the finite element analysis for metallic tubular structures filled with foam are compared with the metallic tubular structure sand are as shown in Table-4

Table-4 Comparison of results for metallic tubes filled with foam and metallic tubes

Tubular structure	Energy absorbed by tube structures	
	Metallic tube filled with foam (kNm)	Metallic tube (Nm)
Triangular	198.571	713.451
Squarer	176.286	947.623
Hexagonal	322.143	1072.650
Circular	223.857	1360.940

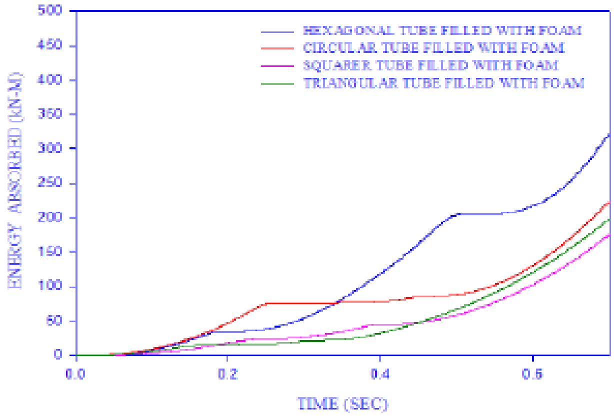


Chart-2 Energy absorption plot for metallic tubular structure filled with foam

7. CONCLUSIONS

This investigation reveals that the energy absorption is maximum for circular metallic tubes and least for triangular metallic tubes which mean that the energy absorption capacity changes with number of sides of tube. The energy absorption increases if the metallic tubes are filled with foam form the above results it can be stated that the energy absorption is more for Hexagonal metallic tubes filled with foam and least for squarer metallic tubes filled with foam. It can be also noted that from the above numerical analysis the metallic tube filled with foam provides better energy absorption compared to metallic tubes.

REFERENCES

(1) Ali Alavi Nia, "Comparative analysis of energy absorption and deformations of thin walled tubes with various section geometries," Thin walled Structures, pp. Vol 48/946-954, 2010.
(2) M.M.Younes, "Finite Element Modeling of Crushing Behaviour of thin tubes with various cross sections," Aerospace sciences and aviation technology ASAT, pp. 1-19, 2013.
(3) Ahmad Partovi Meran, "Numerical and Exprimental study of crashworthiness parameters of honeycomb structures," Thin-walled Structures, pp. Vol78/87-94, 2014.
(4) Alexander, "An approximate analysis of the collapse of thin cylindrical shells under axial loading",Mech Appl Math 1960;(1):10-5
(5) Al-Hassani STS, "Characteristics of inversion tube under axial loading",J Mech Eng Sci 1972;14:370-81
(6) Mamalis AG, "The crumpling of steel thin-walled tubes and frusta under axial compression at elevated strain-rate",Int J Mech Sci 1984;26:537-47
(7) Abramowicz W, Jones "Dynamic axial crushing of square tubes", Int J Mech Sci 1986;28(4):219-29