DESIGN AND ANALYSIS OF IMPACT ENERGY ABSORBING STRUCTURES USING AL-6061

S. Mohith Kumaran[1],N. Ganesh kumar[2]

[1]B.tech, ,Automobile Engineering Department of Automobile Engineering, SRM Institute of Science and Technology
[2]Assistant Professor, Department of Automobile Engineering, SRM Institute of Science and Technology.

Abstract - *The energy absorbing parts in a vehicle are made mostly using various grades of Mild carbon steel. It can be used for manufacturing energy absorbing structures and absorbs considerable amount of energy during the collision and thereby saving valuable human lives and also saves a small percentage of maintenance cost of the vehicle after the collision. Energy absorbing structures that are made using Mild carbon steel adds additional to the vehicle, which in turn reduces the performance of the vehicle.*

Aluminum can be a better alternative for mild carbon steel because of its abundance, light weight characteristics and mainly because of the higher energy absorbing capacity than the Mild Carbon Steel. Aluminum 6061 absorbs more energy than the mild/low carbon steel. Structures like honey comb, circular through holed, pre-bended model absorbs more energy than the traditional hollow tubes. The Aluminum 6061 square tube with circular holes and the square tube with hexagonal holes has the highest energy absorbing capacities due to the effect of both the structure and material applied during the crash analysis. Because of the higher power to weight ratio of the hexagonal structure, it shows an increase in the internal energy over the other structures.

Key Words: Al-6061, FEA, Crumple Zone, Crash box, Ansys.

INTRODUCTION

Vehicle safety has always been considered as one of the most important area of research. Crumple zones are specially designed to deform during the collision, thereby absorbing the maximum kinetic energy possible. With the effective use of crumple zone a lot of human lives can be saved and also the damage can be minimized to the vehicle during collision, thereby saving the repair cost.[1] The specifics of the crumple zone may vary with respect to the size and application of the vehicle. The main goals of a crumple zone are to reduce the initial force of the crash and the second goal is to re-distribute the impact force away from the passenger.[2] Simple change in the design of a crumple zone can include changing the shape of the crash box or the change in material, whereas the advance development may include both the change in geometry of the crumple zone and material that is used for the manufacturing of crumple zone.[3] In the recent years, considerable time and money has been allocated by different auto makers in their respective research and development facility to come up with efficient crumple zone parts.

The material that has been used for the construction of the crash box was steel.[4] Considering the poor mechanical properties of steel over aluminum alloys, the auto makers have started to manufacture crash box using various aluminum alloys. This change in material helps the crash box in absorbing more energy than the primitive steel crash box.

As the change in geometry of the crash box would result in either decrease or increase in the energy absorbing characteristics, it should be designed in such a way that it absorbs more energy than the existing model of the crash box. This helps in improving the energy absorption characteristics of the crash box.[5] The size and dimensions of the crash box depends on the size of the vehicle. Usually the crash box is located at both front end and rear end of the vehicle.

The crash box is the first part to make contact during the collision.

Therefore, it is important to design and manufacture the crash box in a very efficient manner and ensuring that the crash box absorbs maximum kinetic energy during collision. [6]The construction of the crash box is simple in geometry. It is made of thin cylindrical box and it is attached to the frame of the vehicle at both the front and the rear end.

MATERIAL AND METHODOLOGY

Mild carbon steel was used in the manufacturing of the crash boxes in the automobile. Mild/low carbon steel is also known as plain carbon steel. It is a very common form of steel due to its pricing. It has a very small percentage of carbon, which makes the steel strong and tough but not really tempered. Relatively it has a low tensile strength, while the surface hardness can be increased through carburizing.[7] Low-carbon steels suffer from yield-point elongation where the material has two yield points. The first yield point (or upper yield point) is higher than the second and the yield point drops dramatically after the upper yield point.[8] If the low-carbon steel is only stressed to some point between the upper and lower yield point then the surface develops Luder bands. Low-carbon steels contain less carbon than other steels and are easier to cold-form, making them easier to handle.

The valuable properties of aluminum alloys occur in a very rare combination. Aluminum has high corrosion resistant property because of the presence of very strong oxide layer on its surface.[9] Its corrosion and scratch resistance can be improved by anodizing. Aluminum doesn't magnetize and has an appreciable alloy formation almost with all metals. Aluminum is known for its electricity conducting properties and also for its recyclability.[10] Some aluminum alloys can match or even exceed the strength of commonly used construction steel. Unlike carbon steels, Aluminum retains its toughness at very low temperatures. Aluminum is formed using a variety of forming techniques including deep-drawing and roll forming.[11] Aluminum can be easily processed using pressure both when it's hot and when it's cold. It can be rolled, pulled and stamped. Aluminum doesn't catch fire, it doesn't need special paint and unlike plastics it's not toxic.[12] It's also very pliable so sheets just 4 microns thick can be made from it, as well as extra thin wire. The physical properties of aluminum can be changed by adding very small amount of mixtures, thereby enabling the use of aluminum over the variety of applications.

Finite element analysis is used for determining the energy absorbed by the proposed and the existing crash box during collision. The materials that have been chosen are Mild carbon steel and Aluminum 6061. The Mild carbon steel is the existing material, whereas the Aluminum 6061 is the proposed material. The Aluminum is chosen over the steel for the following reasons. The final element analysis section has been carried out with the help of ANSYS 16.0.

The following structures were designed and analyzed for given displacement of 100mm.

A square tube with circular holes of dimension 100*100mm and pore size of 5mm is used for constructing the crash box model for both Mild carbon steel and Al-6061 material.

Mesh has been done for the below structure and the mesh details are:-

Mesh Type- Shell

Mesh Element Size- 5mm

Number of Nodes obtained-16018

Number of Elements Obtained – 22686

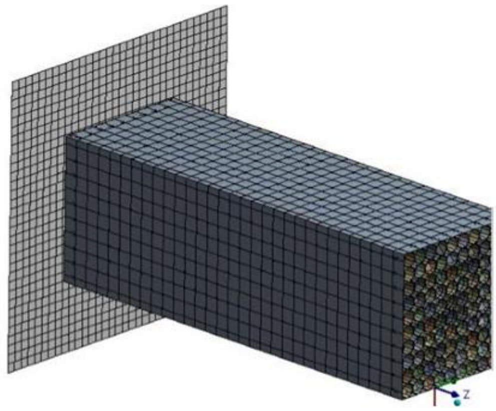

Fig-1: Square Tube with circular holes Meshed Model.

A square tube with hexagonal holes of dimension 100*100mm and pore size of 5mm is used for constructing the crash box model for both Mild carbon steel and Al-6061 material. Mesh has been done for the below structure and the mesh details are:-

Mesh Type- Shell

Mesh Element Size- 5mm

Number of Nodes obtained-20385

Number of Elements Obtained – 31281

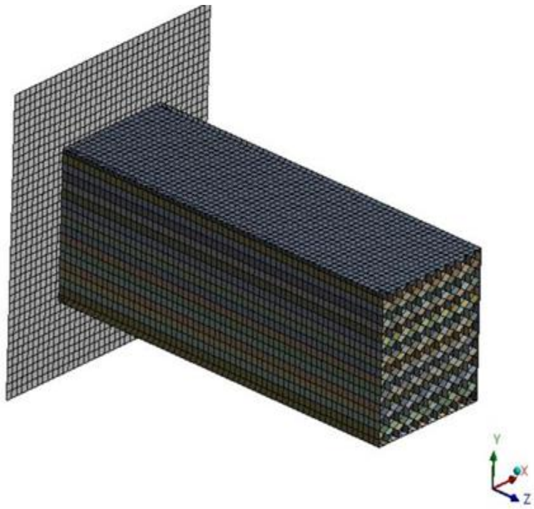

Fig-2: Square Tube with circular holes Meshed Model.

FINITE ELEMENT ANALYSIS

The structures were given initial displacement of 100mm and the results were analyzed using ANSYS 16.0 are as follows

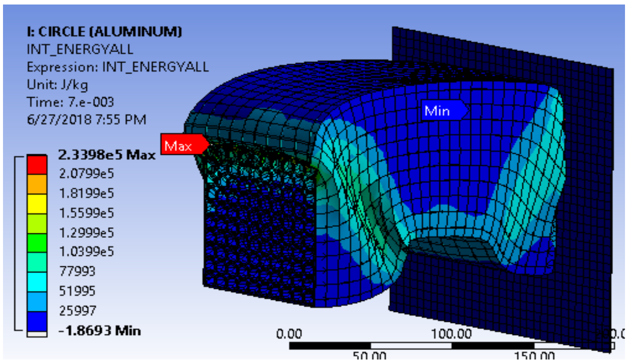

Fig-3: Internal Energy absorbed by Square Tube with circular holes for Al-6061.

The analysis shows that the internal energy absorbed by Square Tube with circular holes for Al-6061 with the maximum and a minimum values of 2.34x 10^5 J/Kg and 1.8693 J/Kg respectively were observed.

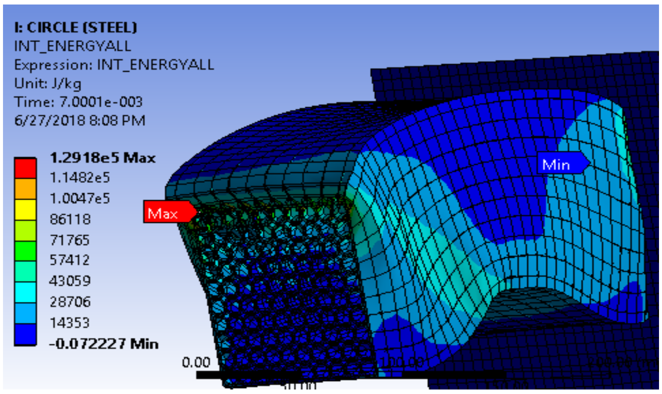

Fig-4: Internal Energy absorbed by Square Tube with circular holes for Mild Carbon Steel.

The analysis shows that the internal energy absorbed by Square Tube with circular holes for Mild Carbon Steel with the maximum and a minimum values of 1.29x 10^5 J/Kg and 0.0722 J/Kg respectively were observed.

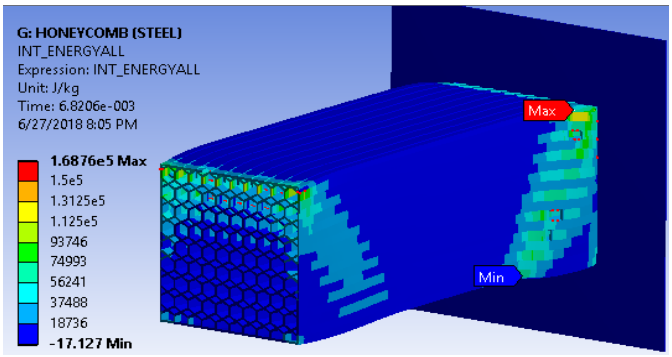

Fig-5: Internal Energy absorbed by Square tube with Hexagonal holes for Mild carbon steel.

The analysis shows that the internal energy absorbed by Square Tube with hexagonal holes for Mild Carbon Steel with the maximum and a minimum values of 1.307x 10^5 J/Kg and 17.27 J/Kg respectively were observed.

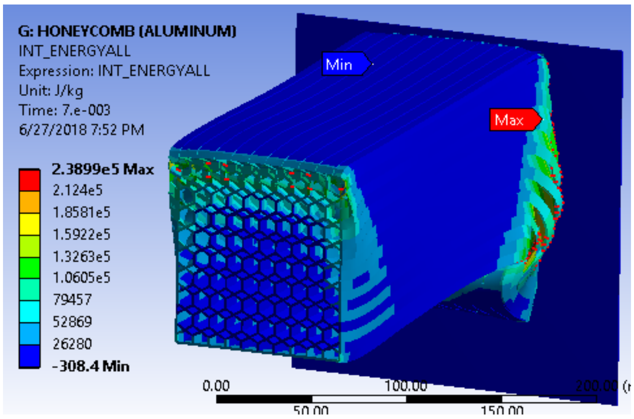

Fig- 6: Internal Energy absorbed by Square tube with Hexagonal holes for Mild carbon steel.

The analysis shows that the internal energy absorbed by Square Tube with hexagonal holes for Al-6061 with the maximum and a minimum values of 2.38x 10^5 J/Kg and 308 J/Kg respectively were observed.

RESULTS AND DISCUSSION

The internal energy absorption for aluminum and mild carbon steel has been performed with different structures.

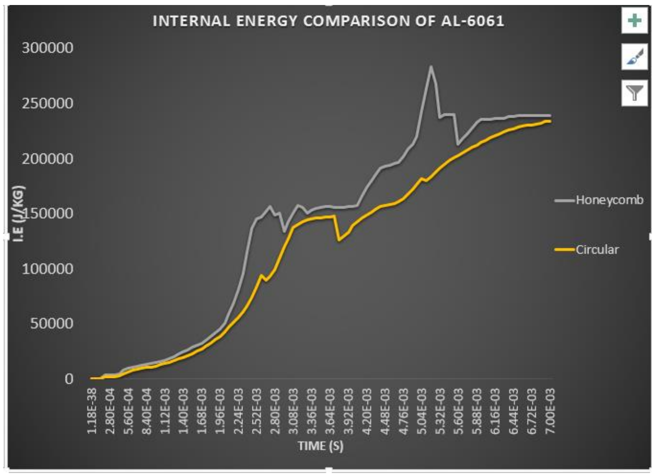

Fig-7: Internal Energy (I.E) comparison between proposed aluminum structures.

The graph shows that the internal energy absorbed by the square tube with hexagonal holes attained the peak value around 160000 J/Kg but the peak value of square tube with circular holes lies around 120000 J/Kg. Hence, the graph reveals that the maximum internal energy absorbed by hexagonal structure are higher than the circular structure.

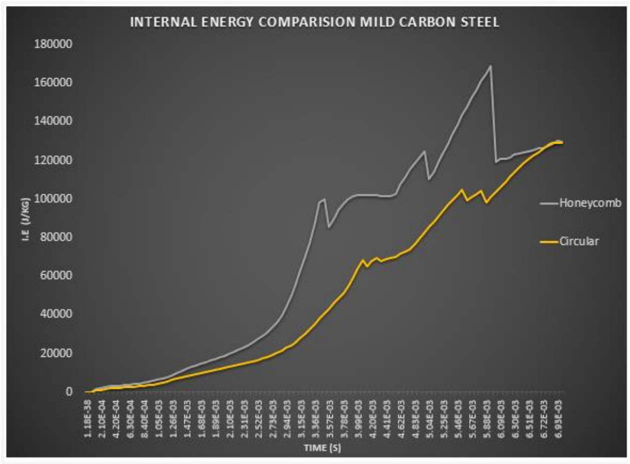

Fig-8: Internal Energy (I.E) comparison between Mild carbon steel structures.

The graph shows that the internal energy absorbed by the square tube with circular hole more uniformly distributed through the structure but the internal energy is less absorbed when compared with hexagonal structure. On the other hand the curve shows the sporadic peaks were observed in the hexagonal holed structure above 25000 J/Kg.

Table-1: Minimum and Maximum values of the internal energy obtained during FEA process

	Mild Carbon Steel		Al-6061	
	Min.	Max.	Min.	Max.
Square tube with circular holes	0.0722 J/Kg	1.29x 10^5 J/Kg	1.8693 J/Kg	2.34x10^5 J/Kg
Square tube with hexagonal holes	17.27 J/Kg	1.307x 10^5 J/Kg	308 J/Kg	2.38x10^5 J/Kg

CONCLUSION

The internal energy absorbed by the hexagonal holed square tube made from aluminum-6061 is greater than the energy absorbed by the hexagonal holed square tube made from mild carbon steel. Sometimes during collision, the structure tends to twist within itself thereby resulting in the increase in the material thickness over a particular area. When the thickness of the structure increases, the density also will increase and increase in density results in decrease in internal energy.

REFERENCES

1. Omkar Garud , Krishna S. Pawar , Prashant K. Thorat , Amit M. Waghmare and Sagar P. Chopade, Analysis and Experimental Validation of Crash Box for the Energy Absorption Capacity, Vol. 7 Issue 1 , Jan 2018, page 11-14
2. H. Özera , Y. Canb and M. Yazıcıa, Investigation of the Crash Boxes Light Weighting with Syntactic Foams by the Finite Element Analysis, Vol. 132(2017), page 734-737
3. G.M. Nagel and D.P. Thambiratnam, Computer simulation and energy absorption of tapered thin-walled rectangular tubes, Vol. 43 Issue 8, August 2005, page 1225-1242
4. H. Zarei and Matthias Kroger, 2008,"Optimum honeycomb filled crash absorber design", Materials and Design, 29(1) , pp193-204.
5. M. Costas , J. Díaz , L.E. Romera , S. Hernándezand A. Tielas,2013, Static and dynamic axial crushing analysis of car frontal impact hybrid absorbers, Vol. 55 , page 367-378
6. Liu Yan-jie, Xia Chun-yan and Ding Lin,Liu Chun-hua,Influence of Material on Automotive Crash-box Crashworthiness Subjected to Low Velocity Impact, Vol. 655-657 ,January 2013 , page 169-172
7. Dhananjay, D.Desai and Prof.M.A.Kadam,Analysis and development of the energy absorbing crash box, Vol. 2 Issue 3 ,2016 , page 3776-3882
8. Dipen Kumar Rajak, L.A.Kumarasamidas and S.Das ,An energy absorption behavior on foam filled structures, Vol. 5 ,2014 , page 164-172
9. Levent Aktay, CemÇakırolu and Mustafa Güden, Quasi-Static Axial Crushing Behavior of Honeycomb-Filled Thin-Walled Aluminium Tubes, Vol. 5 ,2014 , page 184-193
10. Jovan Obradovic, SimonettaBoria and Giovanni Belingardi, light weight design and crash analysis of composite frontal impact energy absorbing structures, Vol. 94 Issue 2 ,January 2012 , page 423-430
11. T. J. Reddy, Y. V. D. Rao and V. Narayanamurthy, Thin walled structural configurations for enhanced crashworthiness, https://doi.org/10.1080/13588265.2017.1306824
12. N.S.B Yosuf, S.M.Saupun, M.T.H.Sultan, M.Jawaid and M.A.Maleque, Design and Material Development of Automotive crash box, Vol. 29 Issue 3 , September - December 2017 , page 129-144