

ENERGY ABSORPTION OF RECTANGULAR AND HEXAGONAL SECTION AUTOMOTIVE CRUSH CAN FOR QUASI STATIC AXIAL LOADING

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Abstract—In the event of crash, the specific structures such as bumper, crush can and front end carrier undergo plastic deformation. The frontal crash is the most dangerous situation and for which the crash energy management in frontal crumple zone of the automotive body is one of the key elements for the design of automotive structure. Thus, the design and analysis of structural behaviour of crumple zone components is of prime importance. Improving the energy absorption characteristics reduce the magnitude of the force transferred to the occupant compartment. Quasi static analysis and dynamic analysis are used for studying the crushing behaviour of the crush cans. The selection of cross sectional shape and material is very important for obtaining maximum performance of crush can. Crush cans are used as replaceable energy absorbing devices. This work is concerned with comparative study of rectangular and hexagonal crush can under quasi static axial loading. The hexagonal section crush can show better performance than rectangular section. FEA results are obtained using LS-DYNA as solver.

Keywords— Specific energy absorption (SEA); Mean load; Peak load; Crush can

1. INTRODUCTION

The increasing emphasis over the last few decades on building lighter and faster vehicles by auto manufacturers, researchers have resulted into lot of opportunities to improve crashworthiness of vehicles by exploiting the structural and material optimization approaches. The crush cans are mounted between bumper and front end carrier. They are used as replaceable energy absorbing devices. The design of crush can should facilitate progressive collapse. Steel is most widely used material for the crush can. The use of light weight CFRP crush cans has better Specific Energy Absorption (SEA) than Hollow section beam but the mode of failure is not progressive and results into catastrophic failure. Thus, for a cost-effective solution fulfilling the functional requirements selection of optimal cross section and material are very crucial. Aluminium serves as a good alternative for steel because aluminium offers high energy to weight ratio and is cheaply recyclable. Square and Rectangular section are conventionally used for crush can.

2. LITERATURE REVIEW

Zonghua Zhang et.al [1] studied rib-reinforced thin-walled hollow tube-like as a potential application in vehicle front bumper. They investigated the bending behaviour of tubes under impact loads, they compared rib-reinforced beam with thin-walled hollow tube like beams filled with and without foam materials (empty beam and foam-filled beam) in crashworthiness.

Sanjeev Kumar [2] studied axial crush characteristics of rectangular tubes under dynamic loading condition using Finite element analysis (FEA) and Design of Experiments

(DOE). He also studied effect of section size and taper angle on crush characteristics.

Omar Faruque et.al [3] studied different topologies of extruded aluminium crush can topologies for maximizing the specific energy absorption.

Bryan J. Stewart et. al. [4] studied the design and development of a more cost effective, mass efficient approach to the “stick-in” crush can which is independent of both material and forming technology. Their proposed design eliminates the need for any added brackets which leads to about 21 % mass reduction and approximately 8 % cost savings from a base-line stick-in crush can design that uses the bracket.

Jurgen Hirsch [5] published in paper in 2011 regarding the study of use of Aluminium in the Auto-mobiles. The paper focuses on the study of usage of Aluminium in BIW, Chassis, Doors, Closures and outer panels.

Bhaves A Bohra and Prof. D.B. Pawar [6] studied variables like material, structures, shapes and impact conditions are studied for analysis of the bumper beam in order to improve the crashworthiness during collision. They gave more emphasis on selection of bumper material.

V. JandaghiShahi et.al [7] published in paper in 2012 regarding the crush behaviour of segmented circular tubes under quasi-static axial loading. The investigation was carried out analytically and experimentally. According to their work, the energy absorption capacity can be increased using the thin walled Tailor Made Tubes (TMT). Also, the performance of the energy absorbing components can be controlled by varying the thickness along the length. The

maximum crush force can be shifted towards the end of the crush range.

G. Belingardiet. al. [8] studied the detail design aspects and method of analysis considering the application of composite materials to automotive front bumper subsystem, crash box and bumper beam. For better crashworthiness, they considered innovative de-sign of integrated crash box and bumper beam. The solutions proposed by them were of great interest from subassembly cost and effective production process point of view.

C. Ramesh Kannanet. al. [9] studied regarding the vehicle safety i.e. the structural crashworthiness and reduction in occupant fatalities and harm. Their work included the study of different shapes for the crush can. LS-DYNA was used for the crash test. The approach and design presented by them can be employed for further optimization and development of other innovative design solutions.

Sekhar Reddy et.al [10] studied to improve energy absorption efficiency of thin-walled columns by introduction of extra stable corners in the cross-section. They studied several profiles of multi-corner thin-walled columns and their crashworthiness capacities under axial crush loading analytically, experimentally, and numerically. They carried out CAE simulations performed by explicit non-linear finite element code through LS-DYNA.

M. R. Said et.al [11] published in paper in 2016 regarding the measurement and analysis of energy absorption characteristics of the manually fabricated tubes. They used quasi-static axial crushing test to carry out the investigation. According to their work, hexagonal tube has the highest energy absorption value.

SatishJaju et.al [12] studied about the reduction of cost of product design by using unit analysis compared to full vehicle simulation. Using this approach complexity of work is reduced from high to low and CPU run time cost is reduced.

3. OBJECTIVE

The main objective of this work is to study the behaviour of rectangular and hexagonal crush can under Quasi - Static axial loading. The force VS displacement curves are derived from Tests and FEA are compared. The Mean crushing load is the appropriate criteria for comparison.

The models are meshed using the ANSA V16.2 tool and the analysis is done using the LS-DYNA as solver.

4. EXPERIMENTAL SETUP

The Quasi Static test was performed using a Universal servo-electric test apparatus with 100 KN capacity. The test was performed at a stable speed of 10 mm/min.



Fig. 1: Universal servo-electric test apparatus

Fig. 1 shows the Universal servo-electric test apparatus for calculating the Energy absorbed by the crush cans.

5. RESULTS AND DISCUSSION

The length and perimeter of both rectangular and hexagonal section crush cans was kept constant so that the results can be compared. FEA analysis was conducted using LS-DYNA. The element mesh size chosen is 3 x 3 mm.

The Fig 2 shows the deformed shapes of rectangular and hexagonal crush cans obtained from testing and FEA. The Fig 3 shows the deformed shapes of rectangular and hexagonal crush cans obtained from testing and FEA.

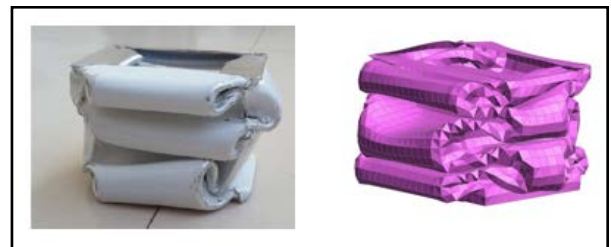


Fig 2 Deformed shapes of rectangular crush cans obtained from testing and FEA.



Fig 3 Deformed shapes of hexagonal crush cans obtained from testing and FEA

The mean crushing loads obtained from tests are 4.6 kN and 6.9 kN for rectangular and hexagonal crush can.

The Fig.4 shows the comparison of force vs displacement curves for rectangular and hexagonal crush can obtained from FEA. The curve is shown in red colour for hexagonal crush can.

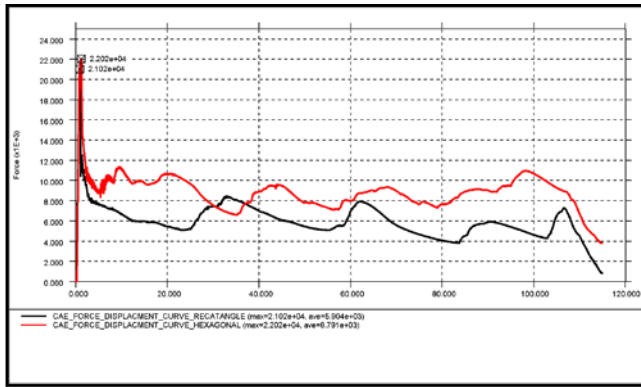


Fig. 4: Comparison of Force Vs displacement for Rectangular and Hexagonal section crush can.

Table.1 shows the mean crushing load values obtained from Tests and FEA for rectangular and hexagonal crush can for Quasi Static axial loading

Type of analysis	Mean crushing load		
	Section	Test (kN)	FEA (kN)
Quasi Static	Rectangular	4.6	6.2
	Hexagonal	6.9	8.26

Table 1. Comparison of Mean crushing loads for rectangular and hexagonal section crush can.

6. CONCLUSION

Following conclusions were drawn from the results obtained from Tests and FEA.

- The results from the test and FEA show good correlation.
- The mean crushing loads obtained from test and FEA for rectangular section are 4.6 kN and 6.2 kN.
- The mean crushing loads obtained from test and FEA for hexagonal section are 6.9 kN and 8.26 kN.
- From the test results 33.33% rise in mean load is obtained if rectangular section is replaced by hexagonal section.
- From the FEA results 25 % rise in mean load is obtained if rectangular section is replaced by hexagonal section.
- The variation in results may be due to experimental error or non-uniformity of material properties or due to manufacturing error.
- Thus, hexagonal section performs better than the rectangular section under Quasi-Static axial loading.

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