International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 05, May-2018

Design and Fabrication of Impact Attenuator for Formula SAE car

Harsh Vardhan Tripathi, Maneesh Kumar Mishra, Rahul Singh,
Utkarsh Kumar Pandey, Mr. Devesh Kumar,
Department of Mechanical Engineering,
Madan Mohan Malaviya University of Technology,
Gorakhpur (UP)-273010, India

Abstract - **The automobile industries are craving for structures which could absorb large amount of impact energy. It's a challenge to design and produce advance crash safety systems and protect the driver and vehicle from fatal injuries in an accident. Impact attenuator is a device which is intended to debilitate the damage done to the vehicle and passengers by absorbing energy by progressive deformation. This plastic deformation holds assimilates major part of the impact energy. The main aim of this paper is to design and fabricate a lightweight, cost-effective Impact Attenuator for Formula SAE cars made up of used cola and beer (aluminum) cans. The initial design was made on the CREO Parametric 2.0 and tests were done on the Universal Testing Machine available in the university's laboratory. All the requirements were set in accordance with the 2017 Formula SAE rules. Quasi-static testing of the model qualifies the functional requirements of average & peak deceleration and energy absorbed as mentioned in the rulebook.**

Index Terms— Crash safety system, CREO Parametric 2.0, Formula SAE, Impact Attenuator, Quasi-static Testing.

INTRODUCTION

As Automobile industry progressed through different phases, another branch of it evolved in 1950's. Since then Motorsports, Auto racing have been most followed sports in the world. Plenty human beings get attracted towards this dangerous sport. Many have lost their lives in fatal crashes. Racecars roll over the track and with parts airborne in all ways as the vehicle is simply shattered, is a clichéd image at car race accidents. Therefore, it is inevitable for engineers to design impact attenuators to protect the driver from serious wounds. Impact attenuators have to achieve 2 safety goals: To diminish the initial force of the impact and they redistribute the force before it reaches the vehicle's passengers. For design and manufacturing of impact attenuators in race cars, structural weight saving is one of the major considerations. The prime intension is to present a design of impact attenuator which can be used in Formula SAE racecars. This is mounted on front bulkhead of racecar as most intensive load develops in head on collision. According to FSAE rulebook, attenuator should have specified minimum dimensions and mounting constraints. Generally, Aluminum Honeycomb structure or carbon fiber monocoque structure is used as impact attenuator. Another option of using foam gives lightweight and effective crash system. The testing can be carried out by two ways:

1. Dynamic load Testing
2. Quasi- Static Load Testing (Gradual Loading)

Quasi-static Testing is preferred over Dynamic Testing due to its availability and cost of testing. This paper presents testing by gradual loading.

I. LITERATURE REVIEW

The dynamic test is done to determine the energy absorbing capacity of impact attenuator during crushing. The most commonly used method for impact testing is drop test. The drop test is done by dropping an object of known mass from a known height onto the full-scale impact attenuator while measuring the deformation of the specimen. To test an attenuator dropping a weight from a calculated height is an easy and effective method. So in that context Abrahamson Chad et al. [2] tested two specimens of impact attenuator designed according to SAE 2010 formula rules, by drop weight test method. The dimension of first specimen was (10 x 8 x 5inches) while the dimension of second specimen was (10 x 10 x 4 inches). Both the specimens were made of Plascore PCGA-XR1-5.2-1/4-P-3003 aluminum honeycomb. The test was performed using 661 lb of impact mass. The impact mass was dropped from 8.3ft. height with impact velocity of above 23ft/sec. The peak deceleration and average deceleration of first specimen was 46.88 g's and 17.86 g's, while of the same of the second specimen was 36.2 g's and 14g's.

May 3rd, 2018.

Harsh Vardhan Tripathi, is a B.Tech student at Mechanical Engineering Department , Madan Mohan Malaviya University of Technology, Gorakhpur, UP, India

Maneesh Kumar Mishra, is a B.Tech student at Mechanical Engineering Department , Madan Mohan Malaviya University of Technology, Gorakhpur, UP, India

Utkarsh Kumar Pandey, is a B.Tech student at Mechanical Engineering Department , Madan Mohan Malaviya University of Technology, Gorakhpur, UP, India

Rahul Singh, is a B.Tech student at Mechanical Engineering Department , Madan Mohan Malaviya University of Technology, Gorakhpur, UP, India

Devesh Kumar, is an Assistant Professor at Mechanical Engineering Department , Madan Mohan Malaviya University of Technology, Gorakhpur, UP, India

Further the team of researchers Kumar Devender et al. [3] selected the elliptical shaped impact attenuator made of Aluminum 6063 T6material for performing experimental test. The simulation was done in finite element analysis software package LS-DYNA. While the experimental test was done by impact testing, the impact test was conducted considering face to face direct collision. The simulation result showed average deceleration was 18.8g on the other hand the average deceleration recorded from experimental drop testing was 13.15g.Both the average deceleration where under formula SAE rule of 20g.

Further, Zarei Hamidreza et al. [4], designed an optimum filled crash absorber design. This involved axial and oblique experimental crash tests of the tube. Correlation was carried out with LS-DYNA giving satisfactory outcome. Multi-design optimization (MDO) technique has been applied to maximize absorption of energy and specific energy absorption of square, rectangular and circular tubes.

Description of problem

As per rules, mentioned in FSAE rulebook 2017 for impact attenuator.

T3.21.1 The Impact Attenuator must be:

a. Installed forward of the Front Bulkhead.

b. At least 200 mm (7.8 in) long, with its length oriented along the fore/aft axis of the Frame.

c. At least 100 mm (3.9 in) high and 200 mm (7.8 in) wide for a minimum distance of 200 mm (7.8 in) forward of the Front Bulkhead.

d. Such that it cannot penetrate the Front Bulkhead in the event of an impact.

e. Attached securely and directly to the Front Bulkhead and not by being part of non-structural bodywork.

T3.21.2 The attachment of the Impact Attenuator must be constructed to provide an adequate load path for transverse and vertical loads in the event of off-center and off-axis impacts.

T3.21.4 On all cars, a 1.5 mm (0.060 in) solid steel or 4.0 mm (0.157 in) solid aluminum “anti-intrusion plate” must be integrated into the Impact Attenuator. If the IA plate is bolted to the Front Bulkhead, it must be the same size as the outside dimensions of the Front Bulkhead. If it is welded to the Front Bulkhead, it must extend at least to the centerline of the Front Bulkhead tubing.

The Impact Attenuator Data Requirement:

T3.22.1Test data must show that their Impact Attenuator, when mounted on the front of a vehicle with a total mass of 300 kg (661 lbs.) and run into a solid, non-yielding impact barrier with a velocity of impact of 7.0 m/s (23.0 ft. /sec), would give an average deceleration of the vehicle not to exceed 20 g’s, with a peak deceleration less than or equal to 40 g’s. Total energy absorbed must meet or exceed 7350 Joules [1].

II. DESIGN OF IMPACT ATTENUATOR

Aluminum Can Impact Attenuator

We designed a shell of aluminum sheet for accommodating the cans. The dimensions of the shell were in accordance with the requirements of the Impact Attenuator as mentioned in the FSAE rulebook. The shell was designed in two stages in the shape of cuboids as described below:

Fig. 1. Geometry of Impact Attenuator

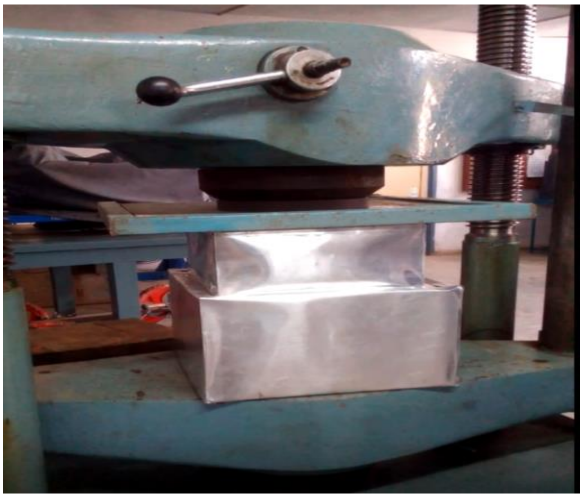
A two-stage impact attenuator:

- The lower shell was a cuboid with accommodated with sixteen beer cans. Each can has a diameter of 65mm and length of 170mm. The shell occupied with these cans had a cross section of 267mm*267mm and a height of 180mm.
- The upper shell was a cuboid with accommodated with sixteen cola cans. Each can has a diameter of 50mm and length of 102mm. The shell occupied with these cans had a cross section of 220mm*220mm and a height of 110mm.

The cans were oriented in parallel with the frame of the vehicle. A base plate made of mild steel was used as the anti-intrusion plate. With the above dimensions the design of the IA was made using CREO Parametric 2.0.

III. TESTING

After the fabrication of the designed Impact Attenuator the quasi-static testing was performed on the Universal Testing Machine in the University’s Laboratory. The load capacity of the UTM was 200kN. The deflection of the Impact Attenuator was noted down for the load applied. While compressing the Load vs Displacement readings were taken and a graph was obtained. The area under the load vs displacement was used to calculate the energy absorbed.



(a)

(b)

Fig. 2. Testing on UTM (a) before (b) after

IV. OBSERVATION AND CALCULATIONS

Fig. 4 shows LOAD Vs DISPLACEMENT curve of the tested specimen of Impact Attenuator. This graph is important for calculating peak deceleration and average deceleration. Given that:

Mass of the vehicle= 300 kg,
Total energy absorbed = Avg. load *total deflection

Average load = 3280kg = 32.17kN
Peak Load =7792kg =76.44kN.
Total energy absorbed=32.17kN*230mm=*7400.6J*

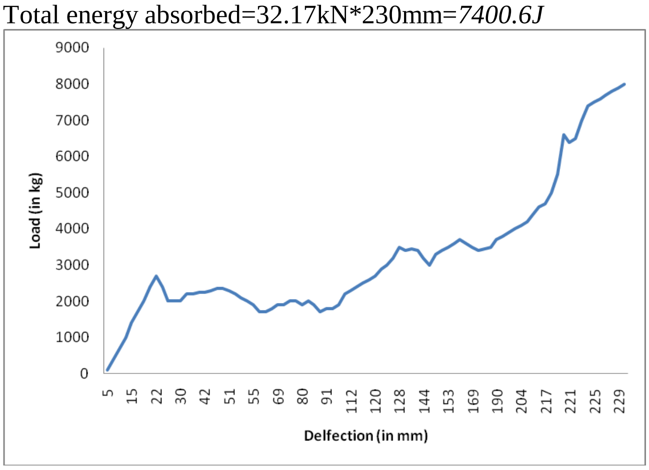


Fig. 4 Load vs Deflection graph

Peak Deceleration:
Here, Load= load_peak
load_peak= 76.44 KN
Load = mass*acceleration
Acceleration = Load / mass
= 76.44 (KN) / 300 kg
= 78440 (N) / 300kg
= 254.8 /9.81
= 26g.

Average Deceleration:
Here, Load= load_average
load_average= 32.17 KN (calculated)
Load= mass*acceleration
Accleration = Load / mass
= 32.17 (KN) / 300 kg
= 32170 (N) / 300 kg
= 107.25 /9.81
= 10.93 g.

V. RESULT

The load vs deflection graph shows that when the value of absorbed energy reaches or just crosses 7350J, corresponding value of force is *74.44kN*. The fabricated Impact Attenuator absorbs the required amount of energy (7350J) before total crushing of the device. Also, the peak deceleration is *26g* and average deceleration is *10.93g* both of which lied within the specified limits of *40g* and *20g* respectively.

VI. CONCLUSION

The behavior of an Impact Attenuator for Formula SAE racecar has been described with detailed material selection, design methodology and physical testing procedure. Based on the calculated results, it is found that Impact Attenuator made up of aluminum cans satisfies all functional requirements and design rules set up by Formula SAE. This attenuator provides better energy dissipation. Miscellaneous advantages of the same Impact Attenuator are reduced weight, less volume occupied and flexibility in nose design of car.

ACKNOWLEDGMENT

We thank Mr. Devesh Kumar, Assistant Professor, Mechanical Engineering Department, MMMUT for being a constant source of motivation and his extended supports in writing the research paper. We also thank team Speed Wagon Cruisers, MMMUT for being a helping hand in carrying out the research on Impact Attenuator.

REFERENCES

[1] SAE, Formula SAE Rules 2017, Published by SAE, available from SAE website: https://www.fsaeonline.com/content/2017-18-FSAE-Rules-091317.pdf
[2] Abrahamson Chad, Bruns Bill, Hammond Joseph &Lutter Josh (2010). “Formula SAE Impact Attenuator Testing,” pp. 35-46.
[3] Kumar Devender and Khanna Naman, “Drop Test Analysis of Impact Attenuator for Formula SAE Car,” International Journal of Scientific and Research Publications, Vol. 02 (10), pp. 01-04, 2012.
[4] H. Zarei and M. Kroger, “Optimum honeycomb filled crash absorber design,” Germany: University of Hannover, Materials & Design, pp. 193-204, 2006.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 7 Issue 05, May-2018

[5] Jain Mayank and Ved Kalia Aman, "Study and Design of Impact Attenuator for Passenger Vehicle" International Journal of Scientific and Research Publications, Volume 4, Issue 11, pp. 01-04, 2014.Journal of the Serbian Society for Computational Mechanics / Vol. 4 / No. 1, 2010 / pp. 52-65
[6] Gagandeep Singh, Naman Khanna, Sachin Kumar, Devender Kumar, "Design, Fabrication and Testing of Impact Attenuator for Formula SAE Car", National Conference on Recent Innovations in Engineering & Technology, March 2012.
[7] Vehicle dynamics by Reza N. Jazar