TO DESIGN AND ANALYSIS OF ATTENUATOR STRUCTURE FOR FSAE CAR

Dokhe C. S.[1], Patil A.R.[2]

[1]PG Student, Mechanical Engineering Department, SVCET, Rajuri, Pune, Maharastra, India
[2] Associate. Prof. Mechanical Engineering Department, SVCET, Rajuri, Pune, Maharastra, India

ABSTRACT

An impact attenuator is a structure used to decelerate impacting vehicles gradually to a stop by gradually decelerating the racecar, the frame and driver are protected from significant deformation and injury. One of the types of energy absorber, having relatively limited focus in various available literatures was the proper dimensioned honeycomb impact attenuator structure as per FSAE regulations. Such a structure is essential to absorb maximum amount of energy with the required acceptable deceleration level. FSAE specifies that each car in operation must have an attenuator that meets specifications and testing criteria Impact Attenuator when mounted on the Front Bulkhead, would give an average vehicle deceleration of less than 20g while hitting a non-yielding surface. The data requires the vehicle is traveling at 7 m/s during the impact with a total mass of 300 kg. The peak deceleration during the impact must be under 40g. Aim of this paper is to compare computer simulated result of different material honeycomb structure & Baseline model that simulation is carried out by using LS-DYNA & HYPERMESH Software.

Keyword: - *Attenuator, Crash Cushion, Structures, Honeycomb, FSAE.*

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1. INTRODUCTION

Automobile industry has progressed through different phases. As a part of this progression since 1950's, Motor sports and Auto racing are the most famous sports in the world. Despite of being a dangerous sport, a lot of people get attracted towards it. Many drivers have lost their lives in the fatal crashes occurring during these sports. Racing cars may roll over the track causing the car to be shattered, which is one of the clichéd images at any car racing accident. Hence, it is very important to design impact attenuators in order to protect the driver from any serious wound, in case of any mishap. An impact attenuator structure can be used to decelerate impacting vehicles slowly to a stop. Huge amount of impact energy is transferred in the deformation of impact attenuator structure. The impact attenuators can be placed either on vehicle or on the road barriers for absorbing huge impacts to protect people and frames. FSAE requires that each car in the operation must have an impact attenuator that meets testing and specifications criteria.

2. LITERATURE SURVEY

Ashab et al. (2016) they has studied mechanical behavior of aluminum hexagonal honeycombs subjected to out-of-plane dynamic indentation and compression loads has been investigated numerically using ANSYS/LS-DYNA. The finite element (FE) models has been verified by previous experimental results in terms of deformation pattern, stress-strain curve, and energy dissipation. The verified FE models were used in comprehensive numerical analysis of different aluminum honeycombs. It was found that the plateau stress, dissipated energy, and tearing energy increase with the t/l ratio. [1]

Chavan (2016), he has carried out material testing of honeycomb, polyethylene foam and polyurethane foam. In that he studied polyurethane foam was giving better energy absorption. By using polyurethane foam design and fabrication of impact attenuator was carried out. Compared Drop testing deceleration result with simulation result on LS-DYNA. Finally concluded it was safe to use polyurethane foam as an impact attenuator. [8]

Sharavan et.al. (2014), They has compare the computer simulated results of energy absorbing capabilities of Aluminium 6082 T6 foils for impact attenuator using ANSYS with that of the actual drop test values performed in the structural mechanics laboratory of IIT Madras. The analysis results was found in good agreement with experimental results obtained from crash testing in real time and that validates our design of the attenuator. Concluded that average deceleration of impact was less than 20 g as per the requirement of SUPRA SAE design rules. [5]

Zarei Mahmoudabadi et.al. (2009), They were introduces a modification on Wierzbicki's model based on considering two above mentioned parameters in estimating the mean crushing stress and the wavelength through implementation of the energy method. They worked on, an analytical study on crushing behavior of metal hexagonal honeycombs under out of plane quasi-static loading has been presented. Comparison of the obtained proposed model has decreased the mean crushing stress. [9]

3. RESEARCH GAP

In Formula SAE (Society of Automotive Engineering) racing cars, may roll over the track causing the car to be shattered, which is one of the clichéd images at any car racing accident. Hence, it is very important to design impact attenuators in order to protect the driver from any serious wound, in case of any mishap. From literature survey four type of impact energy absorber are used thin walled tube & column, Nose cone, Foam filled, Honeycomb structure for attenuator. Most of authors concluded that honeycomb structure is better energy absorber hence we selected this type of structure for design attenuator. As per FSAE 2009-2010 rules for car attenuator should be light in weight, avg. decelerate up to 20g. From literature survey we get aluminium 5052-H111 material is giving good result hence this material is used to attenuator for improve impact performance by reducing deceleration.

4. OBJECTIVE

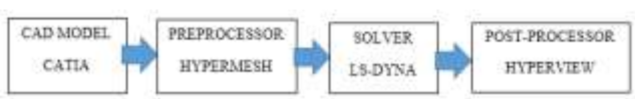
1. To review the literature on design of attenuator, crash analysis and attenuator requirements for FSAE car.
2. To analyze geometric model of standard FSAE impact attenuator (baseline model) to understand the crash results as per FSAE regulatory requirements.
3. To design and analyze different structures of honeycomb attenuator with different material to improve the impact performance.
4. To compare the analysis results of base line attenuator design with honeycomb attenuator design.
5. To analyze results of attenuator to achieve desired FSAE regulation.

5. PROBLEM STATEMENT

a. The surface of the attenuator must be over 200mm long (fore/aft of the frame), 100mm high, and 200mm wide. This will allow the Impact Attenuator to be a minimum distance of 200mm from the Front Bulkhead.

b. Impact Attenuator when mounted on the Front Bulkhead, would give an average vehicle deceleration of less than 20g (where $g = 9.8\ m/s^2$) while hitting a non-yielding surface. The data requires the vehicle is traveling at 7 m/s during the impact with a total mass of 300 kg. The peak deceleration during the impact must be under 40g.

6. METHODOLOGY



a. Books, journals and conference proceedings were reviewed to understand the design of attenuator, crash analysis and attenuator requirements for FSAE car.

b. Literature study was done to identify Energy absorption, Deceleration in crash, Specifications and Design of different impact attenuator structures using CAD and CAE tools.

c. Finite Element Analysis of baseline model and honeycomb structure (Two different design) was done using:

a. Pre-processing in *Hypermesh*, simulation in *LS-Dyna* and post processing in *Hyperview.*
   i. Meshing the CAD
   ii. Assigning material (in Dyna deck)
   iii. Applying boundary conditions
   iv. Applying load case i.e, initial velocity of 7m/s (approximately 25km/h)

d. Analysis results were validated with FSAE regulations and Baseline model.

7. IMPACT ATTENUATOR

Impact attenuator is a device to reduce damages to structure, vehicle, and motorist resulting from the vehicle collision. It is designed to absorb the kinetic energy of colliding vehicle. When the race car is gradually decelerating, the driver and frame will be protected from major injury and deformation. This is done by achieving two safety goals:

- Diminishing the initial force of the impact.
- Redistributing the force before it reaches the passenger.

Fig. 1 Impact attenuator attachment to front bulkhead.

A. Geometric Modelling

To perform any type of worthwhile analysis, the design team decided the geometrical limits of the impact attenuator should be determined. The FSAE rules require the impact attenuator have minimum dimensions of 200 mm by 200 mm by 100 mm (depth by width by height, respectively). With impacts, however, if the collision distance is increased, the acceleration values will decrease.

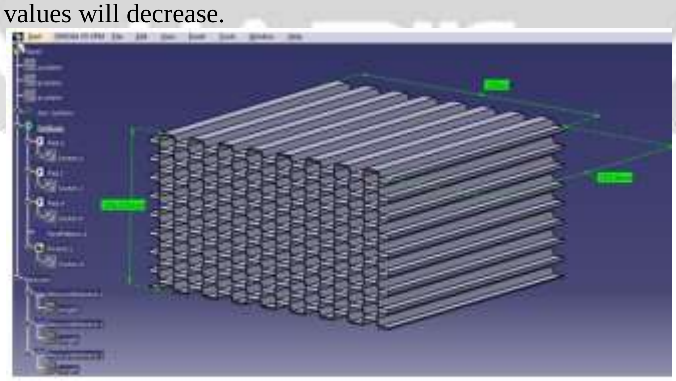


Fig.2 Honeycomb Impact Attenuator model

Therefore, the design team attempted to maximize the distance of the collision, or equivalently, maximize the depth of the impact attenuator. The only constraint for the maximum volume of the impact attenuator is the nose cone of the racecar. The impact attenuator must be completely enclosed by the nose cone. The maximum volume, for a rectangular prism, allowed within the nose cone of the car is 8 in by 9 in by 7 in (depth by width by height, respectively).

Preliminary Calculations:
Initial Conditions:
$V_{impact} = 7$ m/s
$V_{Final} = 0$ m/s
$G = 9.8$ m/s^2
$M = 300$ kg
$Ac = 20xG = 196$ m/s^2
Kinetic Energy:
$KE = 1/2 \times M \times (V_{impact})^2 = 7.35 \times 103$ (kg* m^2/s^2)
= 7350 J
By Conservation of Energy, Kinetic Energy is equal to potential energy
KE = PE

8. SIMULATION OF IMPACT TESTING

Case-I) Catia Baseline Model of Impact Attenuator.

This is standard Baseline Model from FASE rule book.

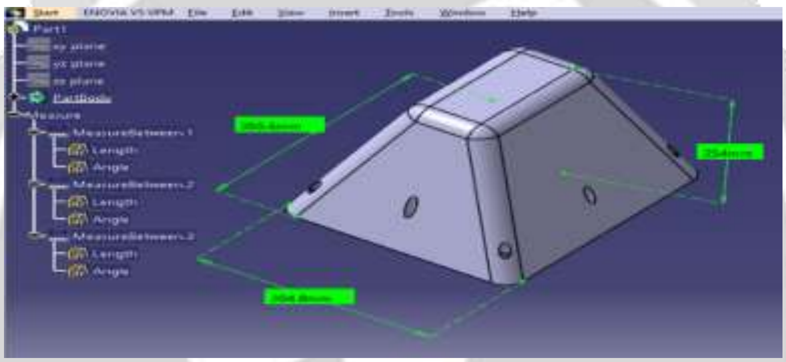


Fig.3 Baseline Model

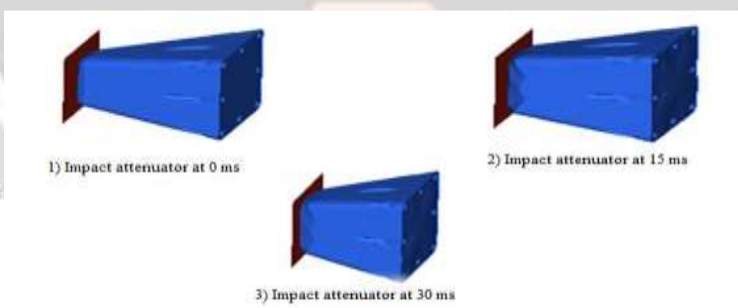


Fig.4 Impact attenuator at 0, 15, & 30 millisecond

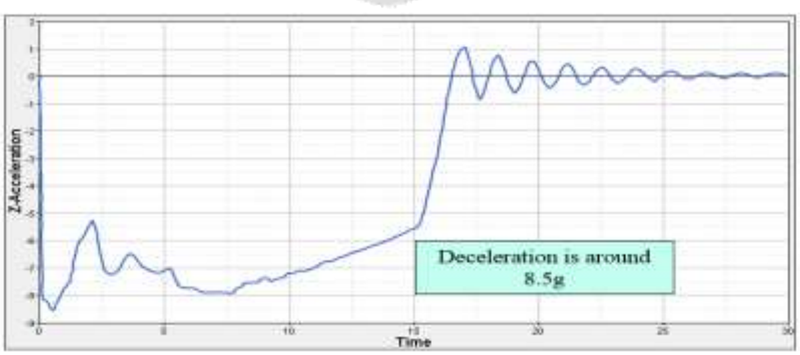


Fig.5 Decceleration plot

It is clearly visible from above plot that the peak deceleration is around 8.5g and it is 57.5% less than the FSAE requirement which is 20g. So this baseline impact attenuator model with aluminum material is meeting FSAE requirements.

Case-II) Honeycomb Impact attenuator Simulation with Aluminum material. (Non-Uniform)

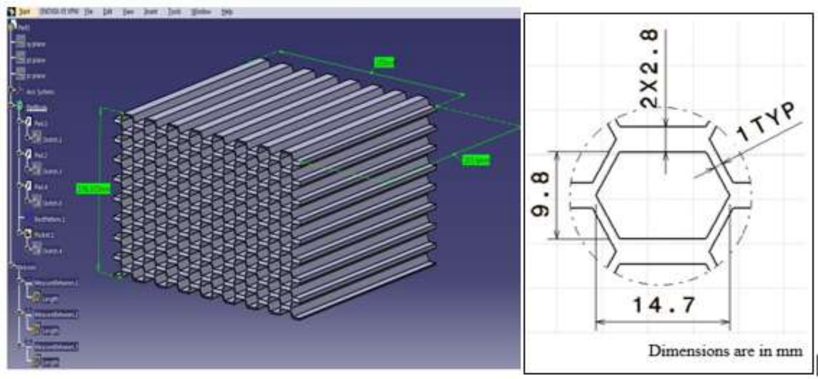


Fig.6 Non-Uniform thickness honeycomb structure

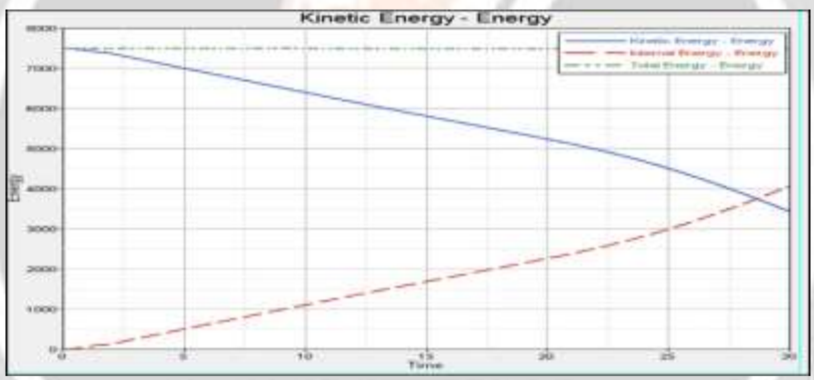


Fig.7 Energy plot

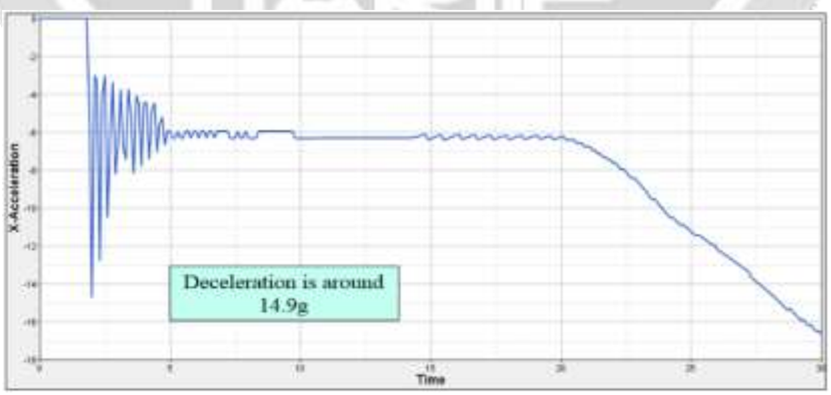


Fig.8 Deceleration plot

It is clearly visible from above plot that the peak deceleration is around 14.9g and it is 25% less than the FSAE requirement which is 20g. So this Honeycomb impact attenuator model with aluminum material (Case-II) is meeting FSAE requirements.

Case-III) Honeycomb Impact attenuator Simulation with Steel material.

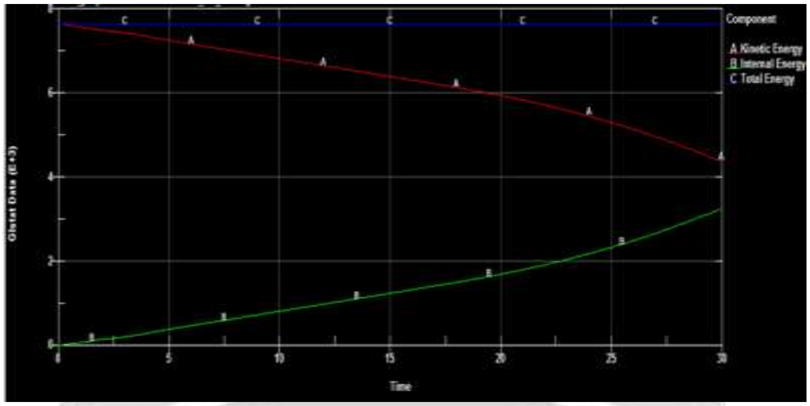


Fig.9 Energy plot

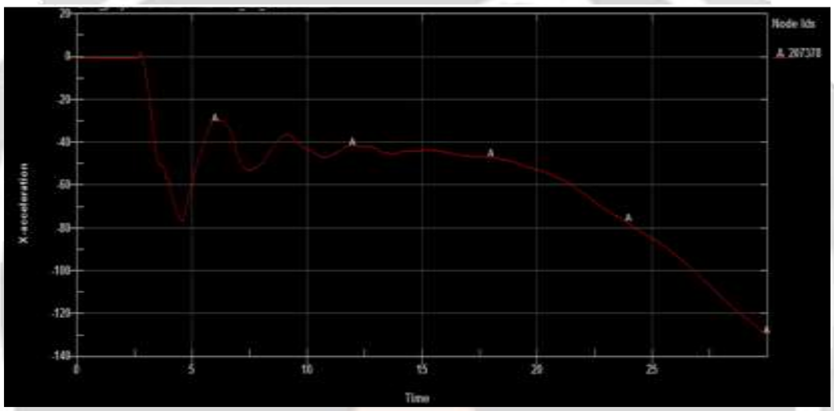


Fig.10 Deceleration plot

It is clearly visible from above plot that the peak deceleration is more than 40g and it is against the FSAE requirement. So this Honeycomb impact attenuator model with steel material (Case-III) is not meeting FSAE requirements.

Case-IV) Honeycomb Impact attenuator Simulation with Aluminum material (AA 5052- H111) with Uniform thickness.

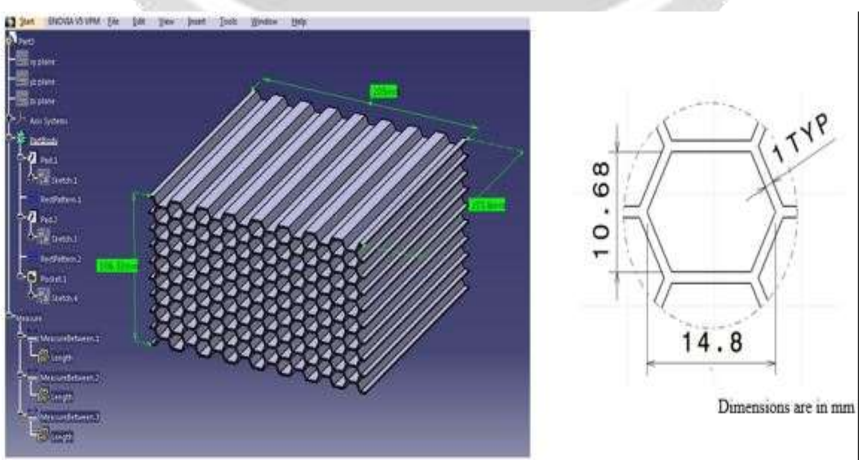


Fig.11 Uniform thickness honeycomb structure

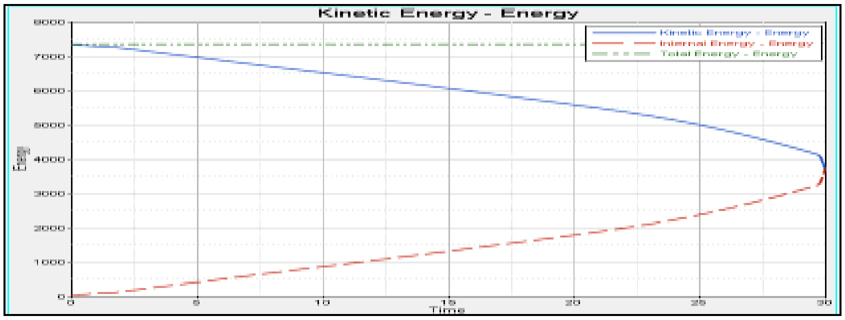


Fig.12 Energy plot

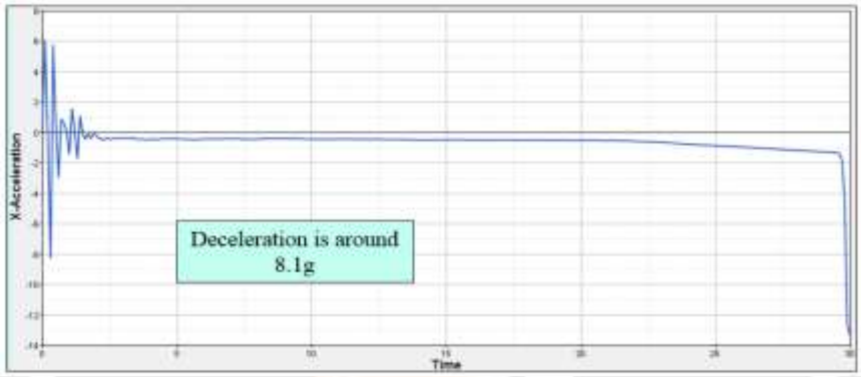


Fig.13 Deceleration plot

It is clearly visible from above plot that the peak deceleration is around 8.1g and it is 60% less than the FSAE requirement which is 20g. So this Honeycomb impact attenuator model with aluminum material (Case-IV) is meeting FSAE requirements.

Table No.1: DECELERATION FOR DIFFERENT MATERIAL

SR. NO.	Material	Deceleration as per FSAE requirements (min. 20g)	% less than FSAE requirements
1	Aluminum for Baseline model	8.5g	57.5%
2	Aluminum (AA-5052- H111) Non uniform honeycomb thickness	14.9g	25%
3	Steel honeycomb structure	78g	Not meeting FSAE requirement
4	Aluminum (AA- 5052- H111) Uniform honeycomb thickness	8.1g	60%

9. CONCLUSION

It is clearly visible from case-I Deceleration plot the peak deceleration is around 8.5g and it is 57.5% less than the FSAE requirement which is 20g. So this baseline impact attenuator model with aluminum material is meeting FSAE requirements.

From Case- II the peak deceleration is around 14.9g and it is 25% less than the FSAE requirement which is 20g. So this Honeycomb impact attenuator model with aluminum material is meeting FSAE requirements.
From Case – III the peak deceleration is more than 40g and it is against the FSAE requirement. So this Honeycomb impact attenuator model with steel material is not meeting FSAE requirements.
From Case - IV the peak deceleration is around 8.1g and it is 60% less than the FSAE requirement which is 20g. So this Honeycomb impact attenuator model with aluminum material is meeting FSAE requirements. From above all cases we concluded that (AA 5052- H111) aluminum honeycomb structure is having better impact performance as the impact attenuator.

10. REFERENCES

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