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To Design and Analysis of Attenuator Structure for Better Impact Performance of FSAE Car

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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.

Keywords - *Attenuator, Crash Cushion, Structures, Honeycomb, FSAE.*

I. 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 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. The bulk of impact energy is transferred into the deformation of the impact attenuator structure Attenuators can be placed on vehicles or on road barriers to absorb large impacts to protect frames and people. FSAE specifies that each car in operation must have an attenuator that meets specifications and testing criteria. The Impact Attenuator is an energy absorber device. Its purpose is to absorb as much energy as possible in case of collision. It provides a load path for transverse and vertical loads in the event of off-centered and off-axis impacts.

The design of this device requires consideration of the followings engineering metrics:

a) Low weight
b) Small size
c) Fire resistant
d) Cost
e) Energy absorption capability

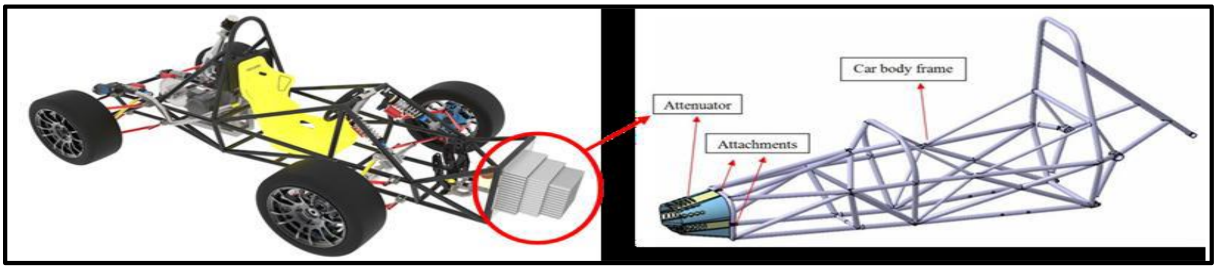


Fig. 1 Impact attenuator attachment to front bulkhead.

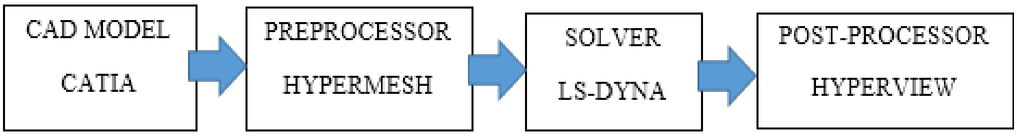
II.OBJECTIVE

1. To design and analyze attenuator structure for better impact performance of FSAE car.
2. To reduce weight of impact attenuator.
3. To improve energy absorption capacity.

III.PROBLEM STATEMENT

The Scope of research includes designing and crash analysis of an impact attenuator, which is a deformable, energy absorbing device situated in front of the Front Bulkhead of Formula SAE car. According to the FSAE rules, the Impact Attenuator must be:
a) Installed forward of the Front Bulkhead.
b) 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.
c) An impact shall not cause the Impact Attenuator to penetrate the Front Bulkhead. It should be mounted directly to the Front Bulkhead and not be part of non-structural bodywork.
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**.**
The Impact Attenuator in this Project has to be been designed and analyzed by considering all these rules and conditions. [8]

IV.METHODOLOGY



V.SIMULATION OF IMPACT TESTING

1. Geometric Modelling

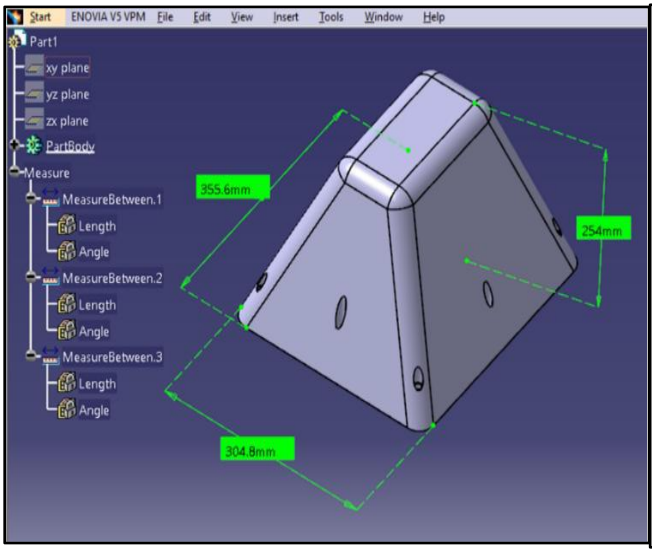
To perform any type of worthwhile analysis, the design team decided the geometrical limits of the impact attenuator should be determined. The FSAE rules require the impact attenuator have minimum dimensions of 200 mm by 200 mm by 100 mm (depth by width by height, respectively). With impacts, however,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

1.1 Requirements of Impact Attenuator As Per FSAE Rules

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:
$KE = 1/2 \times M \times (V_{impact})^2 = 7.35 \times 10^3\ (kg*\ m^2/s^2)$
= 7350 J
By Conservation of Energy, Kinetic Energy is equal to potential energy
KE = PE
Calculating the Desired Drop Height:
PE = M x G x H
H =PE / M x G
= 7350 / M x G
H = 2.5m =8.2 ft
Time of Impact: $t = V_{impact}/Ac$
t = .036s
Impulse and Force: $I_m = M (V_{impact}-V_{final})$
$I_m = 6.3 \times 10^5\ (kg)/s^2$
$F = I_m / t$
F = 58,800 N [8]

1.2 Case Study

Case-I) Catia Baseline Model of Impact Attenuator.



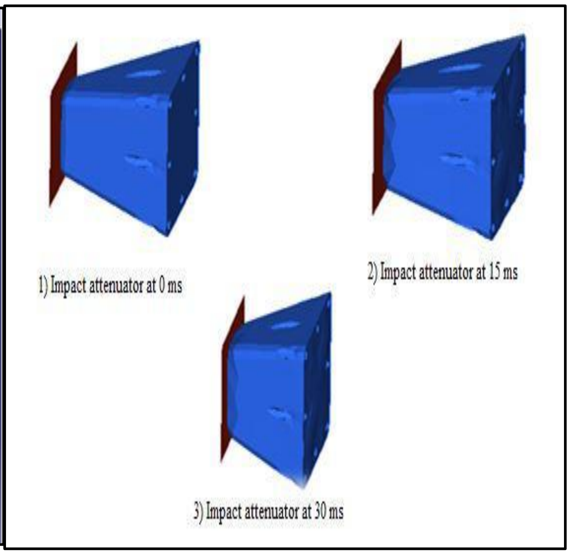
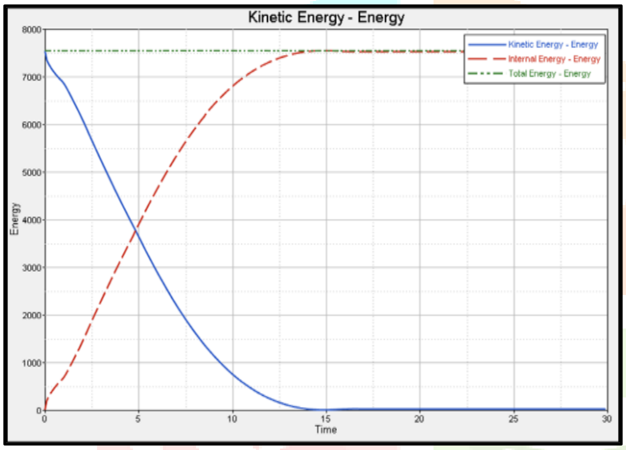
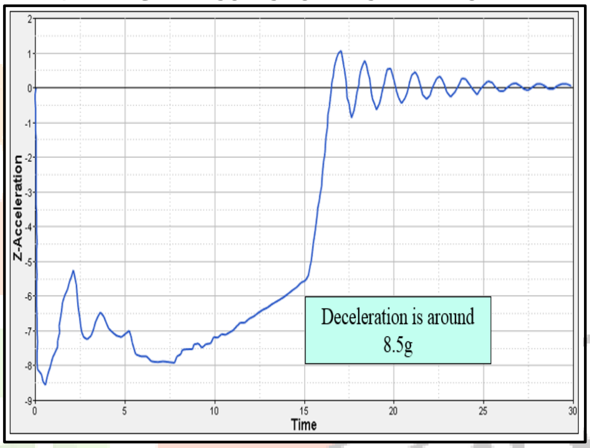


Fig.2 Baseline Model

Fig.3 Impact attenuator at 0, 15, & 30 millisecond

GRAPHICAL RESULTS FOR BASELINE MODEL



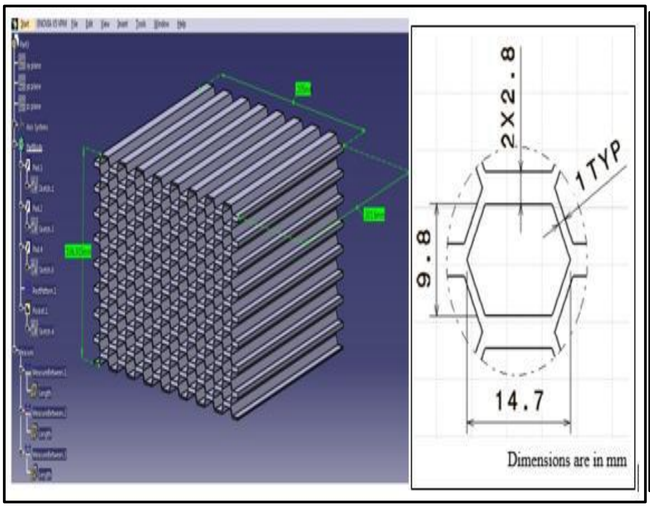


Graph – 1 Energy Plot

Graph- 2 Deceleration 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.



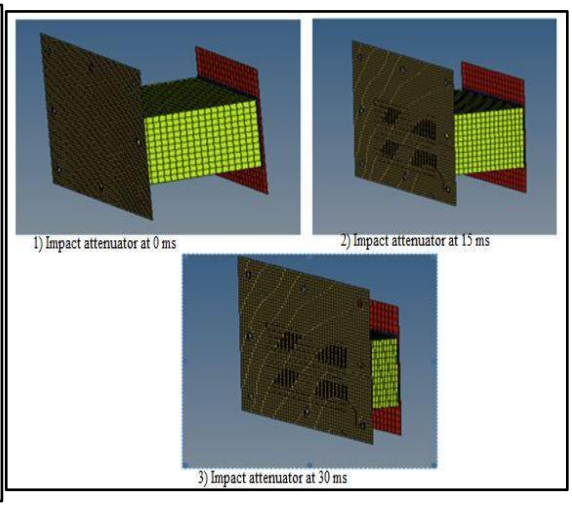
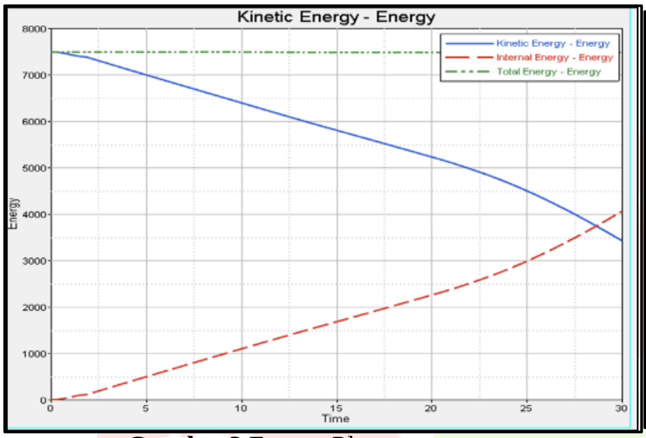
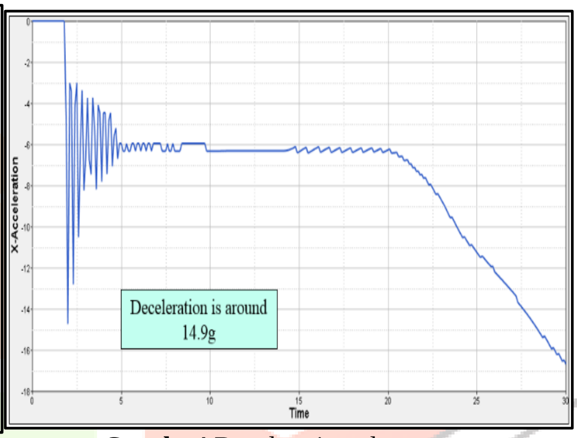


Fig.4 Non Uniform thickness honeycomb structure

Fig.5 Impact attenuator at 0, 15, & 30 millisecond



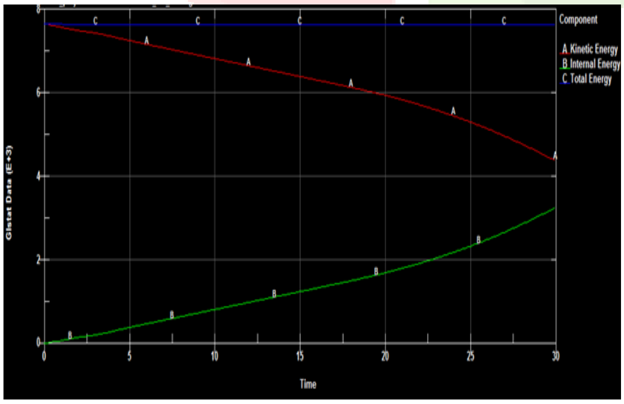
Graph – 3 Energy Plot



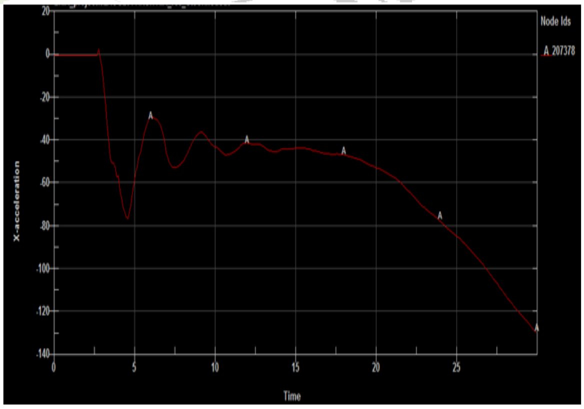
Graph- 4 Deceleration plot

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 results.



Graph – 5 Energy Plot



Graph- 6 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.

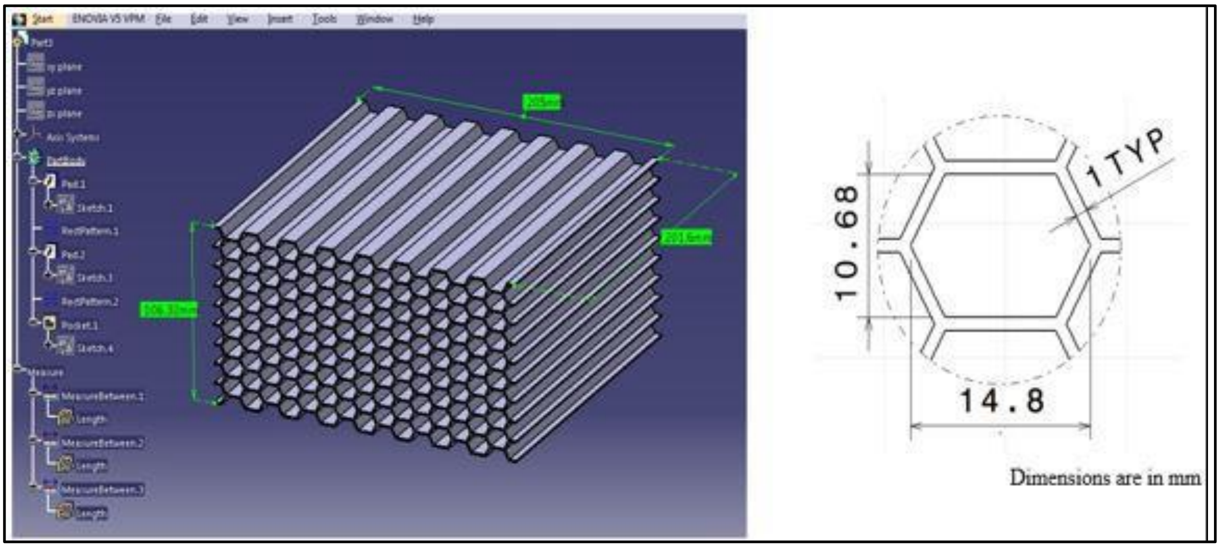
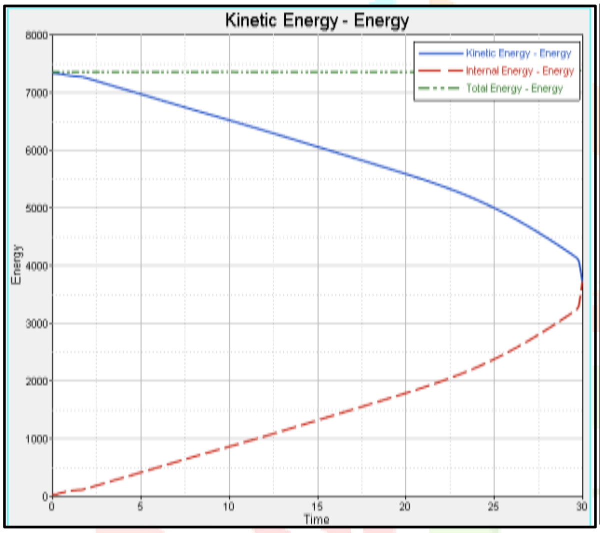
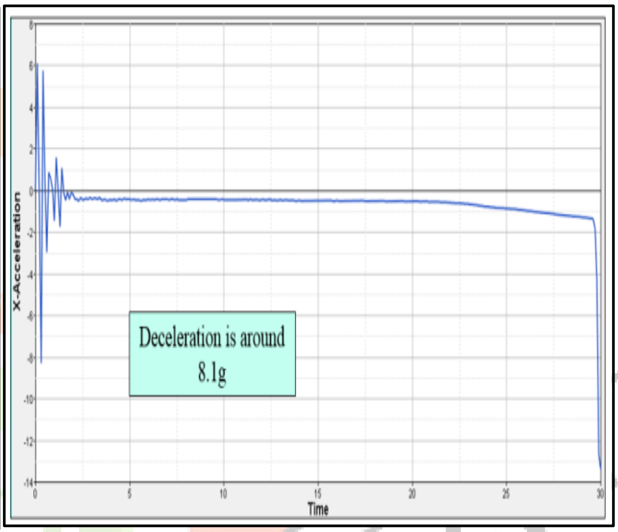


Fig.6 Uniform thickness honeycomb structure





Graph – 7 Energy plot **Graph – 8** 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.

2. Result & Discussion

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%

VI.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.

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