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Design and Crash Analysis of Frontal Impact Energy Absorbing Structures For SUPRA SAEINDIA Competition

Akshay N.Dhiware

Department of Mechanical Engineering, Walchand College of Engineering, Sangli, Maharashtra, India

Abstract: **The SUPRA SAEINDIA STUDENT FORMULA competitions challenge teams of university undergraduate and graduate students to conceive, design, fabricate, develop and compete with small, formula style, vehicles. The purpose of this paper is to present the steps to follow in order to design honeycomb sandwich structure impact attenuators. Impact attenuator is a deformable, energy absorbing structure located at the front of the vehicle whose sole purpose is to absorb the kinetic energy of the race car and limit the deceleration acting on the human body. Also this paper discusses the crash analysis of the designed attenuator in order to determine the safety of the design. The analysis is done using LS-DYNA whereas the design is carried out using theoretical calculations. Initial requirements were set in accordance with the Supra SAEINDIA Student Formula 2012 rules and they were satisfied with the final configuration crash analysis.**

Keywords: **Design, crash analysis, Impact attenuator, Honeycomb, Supra SAEINDIA, Student formula.**

I. INTRODUCTION

Supra SAEINDIA is a National level formula one style design, fabrication and race competition, annually organised by Society of Automotive Engineers (SAE). The selected Under Graduate & Post Graduate Engineering Student teams are asked to design, model, fabricate and compete with a small open-wheel, open cockpit style race car. More than 150 colleges/universities participate every year from all over India.

In order to ensure the safety of the driver in case of high speed crashes, special structures are designed to absorb the race car's kinetic energy and limit the deceleration acting on human body as well as prevent damage to the structure and the vehicle. For attenuator, design and construction depends upon the type of attenuator selected. There are various types of impact attenuator e.g. honeycomb attenuator, foam, composite etc. Honeycomb sandwich structure attenuator is specifically selected because it provides excellent structural efficiency i.e. with high ratio of strength to weight. Other advantages offered by honeycomb structure are elimination of welding, design versatility and insulation qualities. Even if the concept of sandwich construction is not very new, it has been used for the non-strength part of structures in the last decade. The aim of the present study is to design and investigate the dynamic behaviour of impact attenuator build of aluminium alloy material.

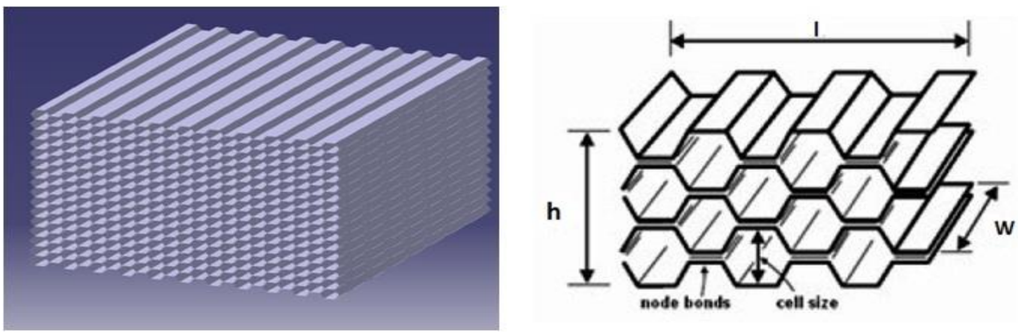

Fig. 1 Honeycomb sandwich structure

II. DESIGN DEVELOPMENT

A. Selection of Material:

The Supra SAEINDIA student formula competition has a clear constrain as to the overall cost of the vehicle, as well as the budget of a team. Further being a race car one of the main objectives is to achieve best performance to weight ratio. Hence reduction in any area will help in improving the overall performance of vehicle.

Considering the above factors the only material realistically being considered are aluminium alloys and alloy steel. This is due to the mechanical properties, availability, weight to strength ratio and the cost. Aluminium alloy 5056 (Honeycomb specification: *CR III- 15- 5056- 1- 50)* was selected as it excels all the required pre-requisites for the material choice as well its easy availability.

B. Design Specifications:

In order to meet the competition requirements of Supra SAEINDIA student formula 2012, the attenuator must guarantee specific performances in terms of average deceleration value and minimum acceptable dimensions during impact. In addition to this the assembly of the sacrificial structure is subjected to following conditions,

1. The impact attenuator must be installed forward to the front bulkhead.

2. The minimum length, width and height of impact attenuator must be at least 200 mm, 200 mm and 100 mm respectively.

3. When attenuator mounted at the forward of front bulkhead and vehicle of weight 300 kg runs into the solid, non-yielding impact barrier with the velocity of impact is 7 m/s, would give an average deceleration of the vehicle not to exceed 20g.

III. DESIGN OF IMPACT ATTENUATOR

TABLE I: NOMENCLATURE

u	Initial velocity	h	Height of attenuator
v	Final velocity	w	Width of attenuator
m	Total mass	s	Stopping distance
G	Deceleration	f	Honeycomb crush strength
K.E	Kinetic energy	A	Cross sectional area
I	Length of attenuator		

A. Style of Specification:

When hexagon honeycomb is specified following information is needed to be given,

Material - Cell size – Alloy - Foil thickness - Density

According to above specification the selected configuration is as follows,

CR III- 15- 5056- 1- 50

Where,

CR III- signifies that the honey comb is treated with a corrosion resistance coating.

15- Cell size in mm.

5056- is the aluminum alloy used.

1 – Is the normal reference foil thickness in mm.

50- Density in kg/m^3.

B. Design calculations:

Let, u = 7 m/s

v = 0 m/s

m = 300 kg

G = 16g ……………………….(***Assumption*** [considering a force to withstand more than 16G's wouldn't make sense, Since any force greater than that would not be survivable.])

K.E = (1/2)*m*u^2

= (1/2)*300*49

K.E = 7350 J

Let,

$v^2=u^2 + 2as$ ……………………… (1)

Here, a= G= 16g,

From (1) we get,

s = 0.156 m.

Taking,

s= 70% of I

I= s/0.7

I = 0.223 m.

- ***Finding Cross Sectional Area of Attenuator:***

f = 1172*10^3= 1172000 N/m^2

We have according to impact test,

KE= toughness= f*A*s …………………….. (2)

A = Cross sectional area of honeycomb.

= KE/ (f*s)

= 7350/ (1172000*0.156)

A = 0.0402 m^2

We have,

A= w*h **…………………. (Assuming w= 0.2m)**

h = 0.0402/0.2

h = 0.204 m.

Mass of Attenuator Excluding Plates

Mass= ρ*A*l

= 50*0.0402*0.223

Mass= 0.448 kg

Hence, theoretically the cross sectional area of hexagonal sandwich type impact attenuator comes out to be 0.0402 m^2 and the overall mass comes out to be just 0.448 kg.

IV. DYNAMIC SIMULATION RESULTS OF IMPACT ATTENUATOR

The inputs from the theoretical calculations are further used for modelling and carrying out the crash analysis of the honeycomb sandwich type impact attenuator in LS-DYNA. The LS-DYNA simulations results showed good agreement with the theoretical calculated cross sectional area, in terms of displacement, velocity and deceleration. The simulation results can be observed as below,

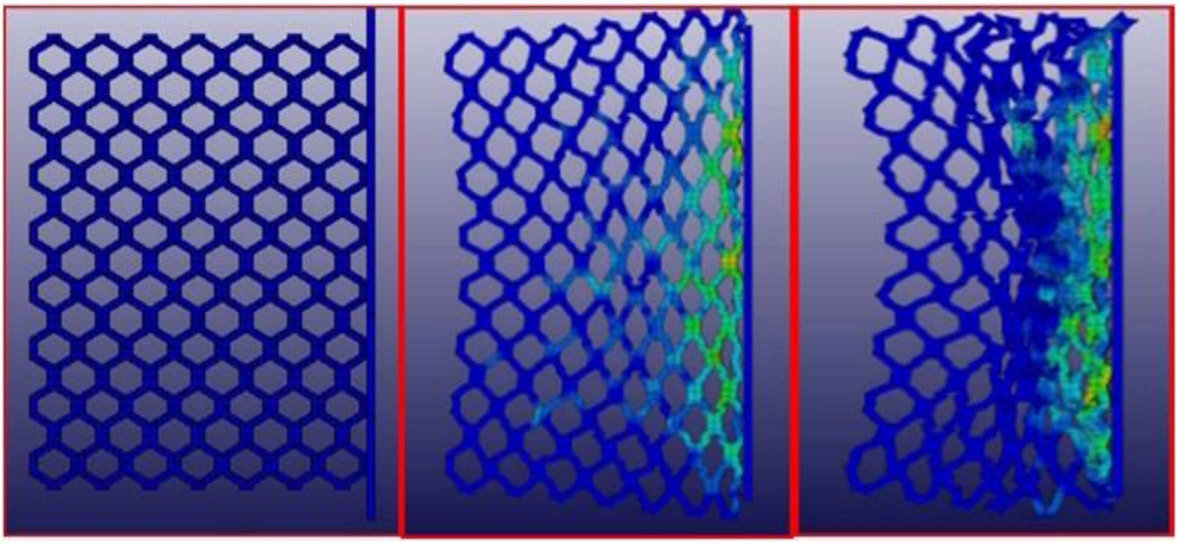

Fig 2. Stepwise images of impact attenuator during impact

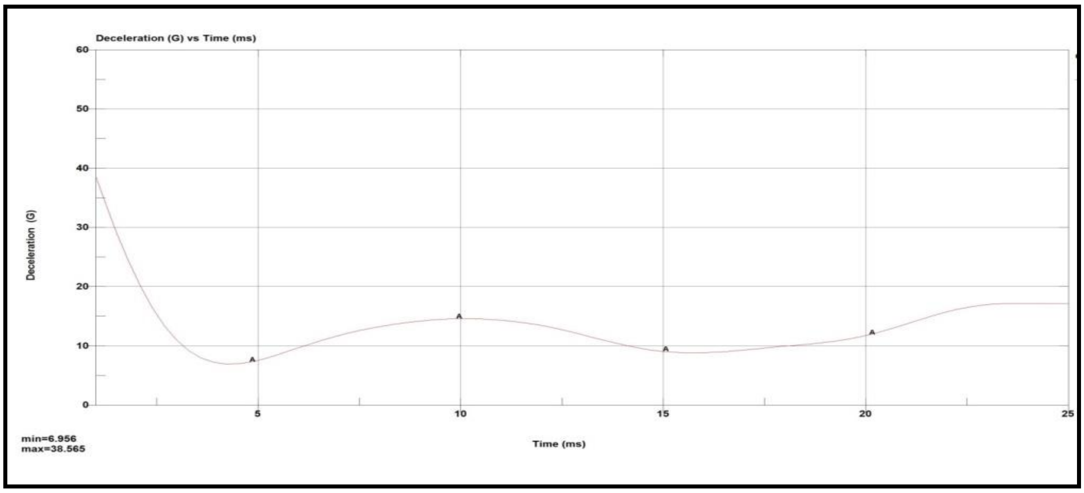

Fig 3. Deceleration (G) vs. Time in milliseconds

The average deceleration= 15.42 G

Maximum deceleration= 38.56 G.

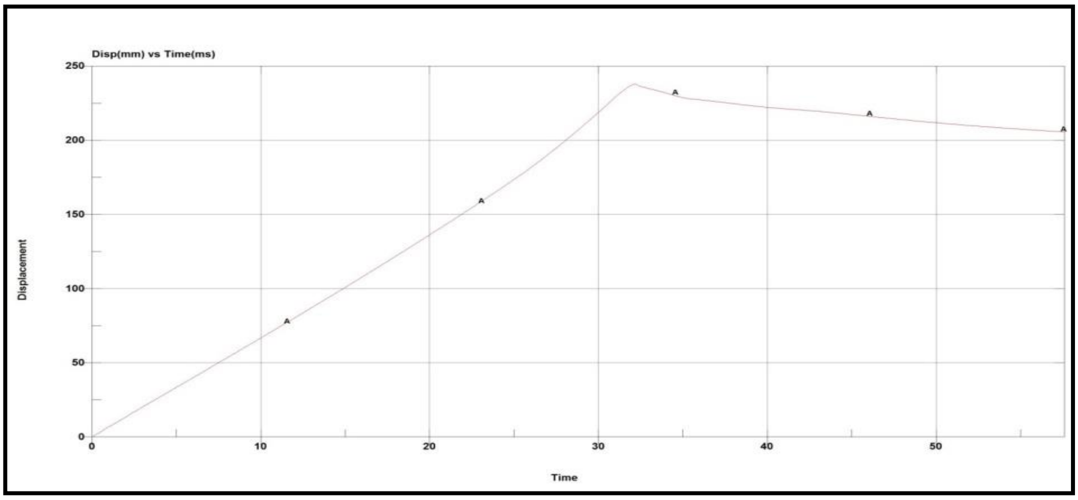

Fig 4. Displacement in millimeter v/s Time in millisecond

Maximum displacement = 230mm

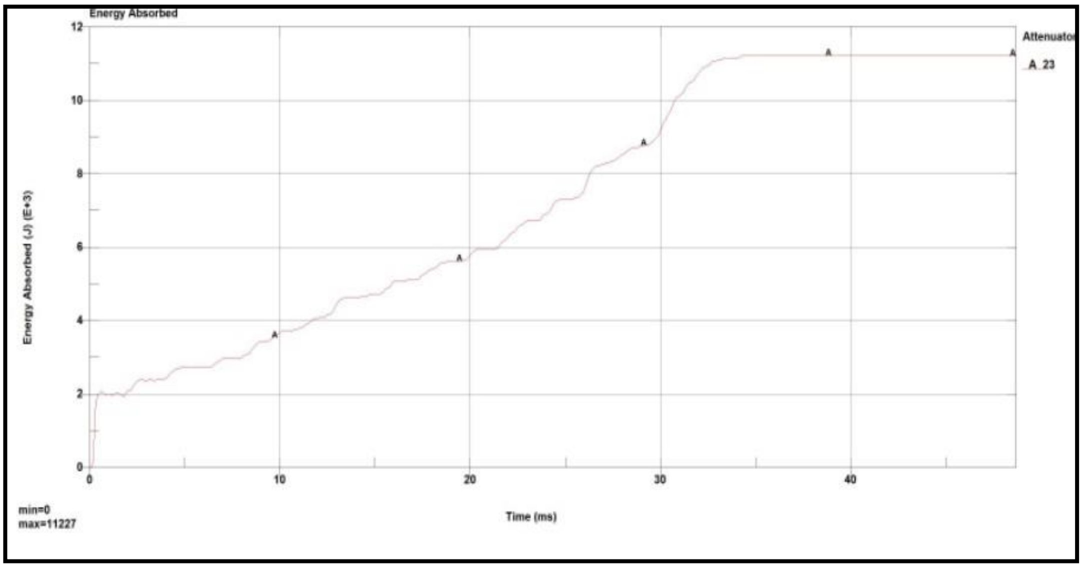

Fig 5. Energy absorbs in joules v/s time in millisecond

The maximum energy absorbed is 11,227 joules.

V. CONCLUSION

The present paper describes an approach to theoretically design and analyze the safety of the design by determining the energy absorbed by a honeycomb sandwich structure type impact attenuator. Aluminium honeycomb impact attenuator is designed to determine the material failure modes and to characterise them with the help of LS-DYNA. The analysis results further guarantee that the designed impact attenuator is safe and is able to perform as per the prescribed performance requirements.

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