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Design and Analysis of Impact Attenuator for SUPRA SAEINDIA

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Abstract - *Vehicle safety is one of the major fields of research in automotive industry. There are many systems available in market that can be used for the safety of vehicle as well as driver like ABS and air bags but the most redundant and rudimentary method of driver safety is still the use of an Impact Attenuator for the purpose of dissipation of the energy produced during a collision. To shrink the cost of the current solutions by a big margin I started experimenting with different articles like soda cans and other waste products which can be turned into an effective, cheap and reliable crash protection component.*

Key Words: Impact Attenuator, UTM Machine, Honeycomb structure, Crash-Worthiness, Beverage Tins.

1. INTRODUCTION

An Impact Attenuator, which is also known as a Crash Attenuator or Cowboy Cushions, is a device which is intended to reduce the damage to structures, vehicles and motorist resulting from a motor vehicle collision. Impact Attenuator is designed to absorb the colliding vehicle's kinetic energy. Basic requirement for the efficient impact attenuator is it should absorb and release energy at a same time.[1]

i. This Impact Attenuator is designed for SAE SUPRA competition 2016 under the design criteria as per the rule book of SAE SUPRA 2016 listed as follows:

ii. Impact attenuator when mounted on the front of a vehicle with the total mass of 300 kg and run into solid non-yielding impact barrier with a velocity of 7 m/sec, would limit the average deceleration of the vehicle within 20g's, with the peak deceleration less than or equal to 40g's.

iii. Total energy absorbed must meet or exceed 7350 joules.

iv. Impact attenuator should be at least 200 mm long, 100 mm high and 200 mm wide.

v. There should be 1.5 mm solid steel or 4 mm aluminium 'anti-intrusion plate' integrated into the impact attenuator.

vi. During the test, the attenuator must be attached to the anti-intrusion plate using the intended vehicle attachment method. The anti-intrusion plate must be spaced at least 50 mm (2 inches) from any rigid surface. No part of the anti-intrusion plate may permanently deflect more than 25.4 mm (1 inch) beyond the position of the anti-intrusion plate before the test.[5]

Instead of buying impact attenuator from market I had decided to design and manufacture my own impact attenuator from aluminium plate and soft drinks tins which fulfil the rules of competition and at the same time is cost effective and easy to manufacture since the standard attenuator available made from impact foam costs around (Rs.23, 500). So by arranging the aluminium tin in a specific manner I designed the attenuator and then tested it on UTM machine, and by observing behaviour of deformation I predicted the error in design and thus redesigned it by trial and error method.

1.1 LITERATURE SURVEY

This survey includes different core structures of impact attenuator, different materials for the impact attenuator and some resources discuss on the use of different cans for an energy absorbing unit.

I. The paper entitled "CRASH ANALYSIS OF AN IMPACT ATTENUATOR FOR RACING CAR IN SANDWICH MATERIAL". Written by Boria, Simonetta, Forasassi, Giuseppe discusses the crash test results on impact attenuator having sandwich structure with hexagonal core. The basic structure was made from aluminium honeycomb sandwich structure. Specimen consist two materials, namely A5052–H111 for honeycomb cores and A6082–T6 for facing skins. The different tests and software simulation is carried out and the results are as follows:

In the quasi static test, compressive stress is almost constant to 2 MPa. The crash test was carried out on crash-box of a CN2 prototype and the front part of the survival cell are subjected to an impact against a solid and vertical barrier at the velocity of 12 m/s. then got average deceleration near about 25g and got same result for software simulation in LS-DYNA also. [7]

II. The paper entitled "Drop Test Analysis of Impact Attenuator for Formula SAE Car". Written by Devender Kumar, Sachin Kumar, Gagandeep Singh, Naman Khanna discusses the design of an impact attenuator using aluminium sheets of 1.5 mm. The basic design of this impact attenuator was as shown in figure (1) having dimension of 250*250*250 mm^3 and this material is highly weld able using tungsten inert gas welding. Drop test and impact test was carried out (As per rule)and the results are as follow:[8]

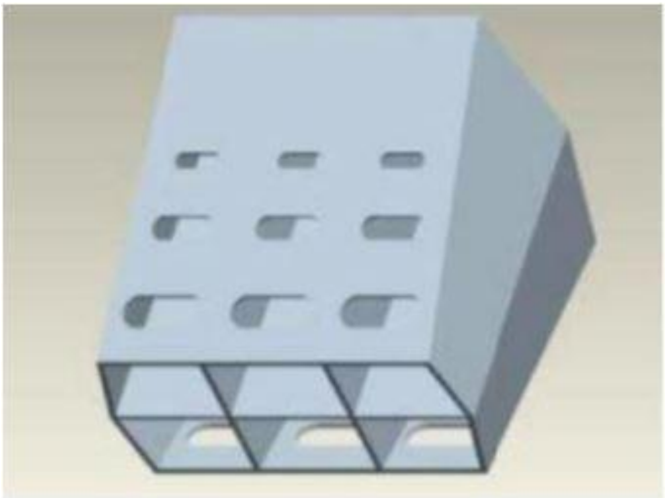

Figure – 1:

Test type	Average deceleration	Peck deceleration
Impact test in LS-DYNA Software	18.8g	29g
Drop test in ARAI Pune	13.15g	≈38g (from graph)

Table - 1: Test type and its results

III. The paper entitled " Design of the Impact Attenuator for a Formula Student Racing Car: Numerical Simulation of the Impact Crash Test". Written by Giovanni Belingardi and Jovan Obradovic discusses the design of an impact attenuator on conical nose shape using two different materials, steel S275JR UNI EN 10025 (Fe430) and 6082T6 aluminium alloy (As shown in figure 2). Basic design of the impact attenuator is as shown in figure (2) having cell thickness 1.5 mm, beam thickness 3mm and attachment thickness 3mm, test was performed in ANSYS software and results are as follow:[9]

Test	Average deceleration	Peak deceleration
ANSYS Analysis	14g	52g

Table - 2: Test results

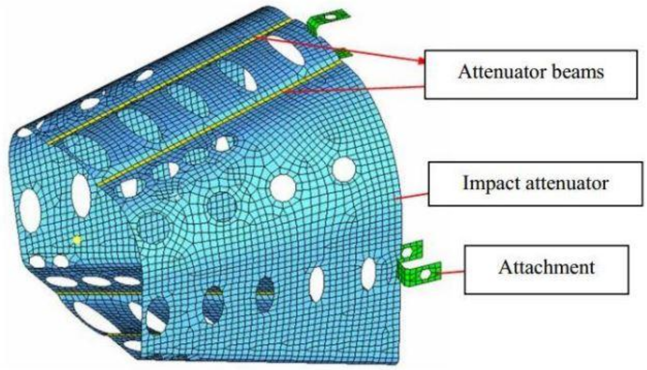

Figure – 2:

IV. The paper entitled "Cost Effective & Innovative Impact Attenuator for Formula SAE Car with Drop Test Analysis". Written by Arpit Singhal, and Vignesh S. Subramanium discusses the design of an impact attenuator for SAE SUPRA competition by cans and cold drinks bottle. The basic design of this impact attenuator has 2 layers. There are 6 bottles (3 row 2 column) or cans in first layer, welded along its edges to the center of base plate. And in second layer 11 bottle or cans (4 in first and third row and 3 in second row).

They made impact attenuator by using four different cans and bottles. In first design, there were only empty shell, no cans or bottles, in second, there were beer cans, in third 600mL cold drink Bottle, in fourth 330mL Coca Cola can. The drop test was carried out (according to rule) with impact force 150 kg from the height of 5 m; so the kinetic energy of the force is about 7350 j which is mentioned in rule book. The test result of the drop test is as follows: [10]

Can Type	Average Deceleration
Empty Shell	0.63g
Beer Can	0.42g
600mL cold drink Bottle	0.50g
330mL Coca Cola Can	0.38g

Table - 3: Can types and its average deceleration

From the above data, it can be seen that the deceleration is minimum in the case of the two step shell with 330mL Coca Cola cans. Thus, this was chosen as the final Impact Attenuator. During the testing, it was realized that the sheet metal shell was creating problems in deformation. Thus, holes were made in the side faces of the shell for the final design.

Here, they are using same design of different energy absorbing unit, but I wanted to find can or bottle which is having higher strength for different arrangement and same energy absorbing unit. So I can get higher amount of energy absorption. I changed bonding material of cans and plate to reduce the weight. Average deceleration of the design is only 0.38g which is very low so I increased it by some amount. Cans are welded from one side so there is higher strength at welded portion so I did some slots on can for weight reduction purpose and to reduce the strength of welded portion so cans can deform uniformly throughout its length.

2. Material selection:

i. Most of the teams make an impact attenuator with materials like aluminium layers, impact foam in honeycomb structure.

ii. As an innovation in order to reduce the cost and to multiply the practicality of the design, I have decided to construct an attenuator with "BEVERAGE TINs".

iii. The search commenced with use of Pepsi tins, medicine containers, Amul tins and the results are as follows: which is also shown in graph.

Type of tin	Compressive strength
Medicine container	95 N/mm^2
Amul tin	180.955 N/mm^2

Table - 4: Test result of different tins

iv. The material of the tins is aluminium alloy with compressive strength of 180.955 N/mm^2 which was able to help me minimize the risk of any kind of collateral damage was selected as my basic material of crushable.

v. As a bonding material I used adhesive like araldite, Meta set bondtite.[3] [4]

vi. For the Anti-intrusion plate I used an aluminium plate of 4mm thickness as it was lighter compared to the 1.5mm solid steel plate. Aluminium plates were also used for the layers. Aluminium 6061 was used because of its easy availability.[2] [14]

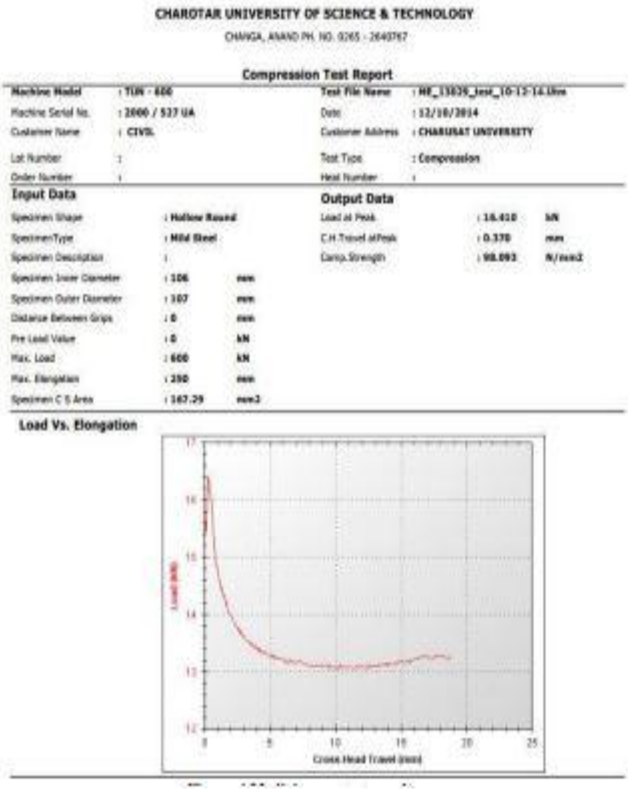

Chart – 1: Medicine can test result

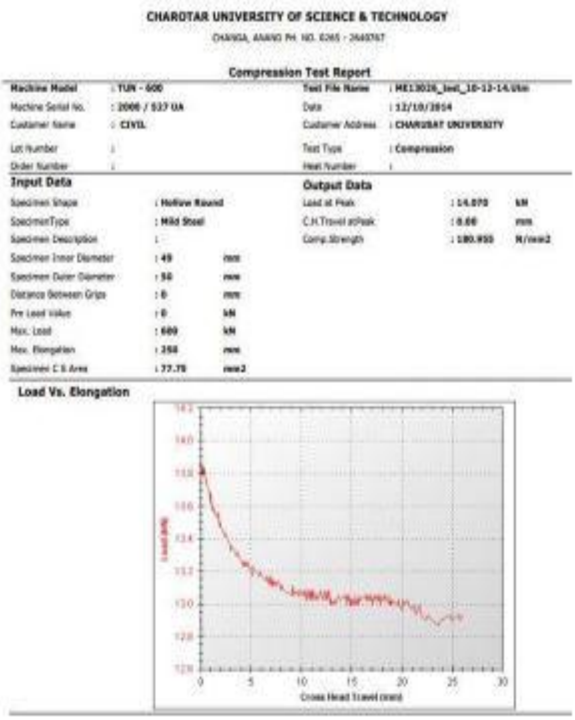

Chart – 2: Amul tin test result

3. Design and Testing procedure:

Basic steps for the design and testing procedure are as follow:

i. For frontal bulkhead dimensions of 350*250 mm, I chose an AI plate having dimensions 360*260 mm and then I tried different arrangement of tins and I performed test on every design and based on the results I selected a final design. all the cad models were made in SolidWorks.

ii. During the test, the attenuator must be attached to the anti-intrusion plate using the intended vehicle attachment method. The anti-intrusion plate must be spaced at least 50 mm (2 inches) from any rigid surface. No part of the anti-intrusion plate may permanently deflect more than 25.4 mm (1 inch) beyond the position of the anti-intrusion plate before the test (SAE SUPRA Rulebook).

iii. I tested all the attenuators on UTM machine under compressive load. The test arrangement is as shown in figure(6)

iv. Amul tins are welded from one side so, it has higher strength at welded side, which does not allow axial deformation under load, so I removed strip from the tin to reduce its strength and for weight reduction.

4.1. Design 1:

The first design of my impact attenuator is shown in figure-3. I had used araldite to join tins with the aluminium plate and such there Ire three layer of tin. There are 12 tin in first layer, 9 in second layer and 6 in third layer. Arrangement of tin is 3 rows and 4 columns in first layer then in second layer a tins are placed such that the center of one tin lies between the other two tins and in the next layer the tins were arranged in the similar fashion.

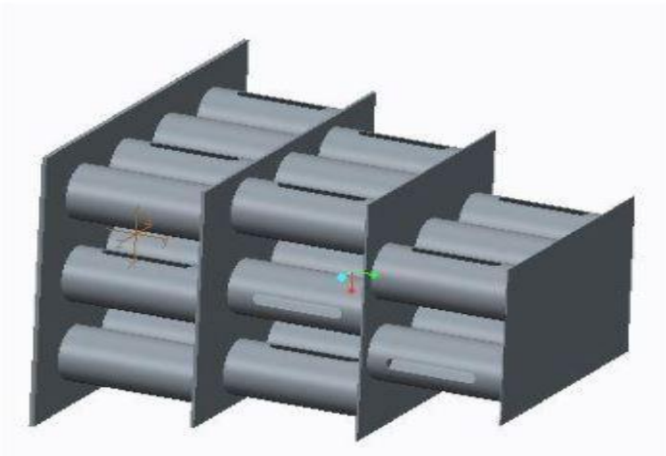

Figure -3: Impact attenuator with three layer

Figure -4: Testing of Design 1 & 2

4.2. Design 2:

The adhesive I used could not hold the tins in their positions so well under shear load developed during its testing so I switched to Metaset aluminum by keeping the same design as shown in figure 3 and the test results were quite successful. As shown in figure:

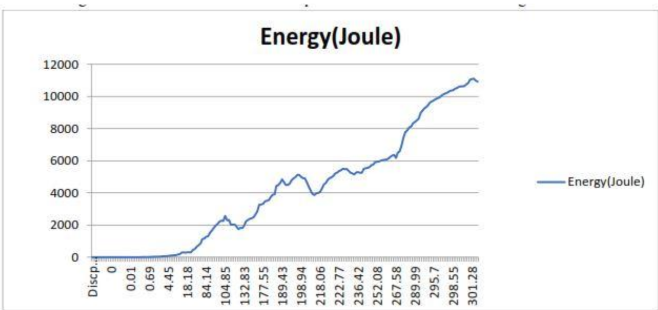

Chart – 3: Test result of design 2

4.3. Design 3:

The energy absorbed by the previous design was around 10k joules which was a lot more the required value as per the rules and also the length was too much which reduced the vision cone of the driver. So I moved on to find another design with only two layers. For the design of a two layer attenuator I used 12 tins in the first layer and 6 in the second layer such that the centerline of the tins in second layer was coinciding with the center of four tins in the lower layer as seen in the following figure.(5).

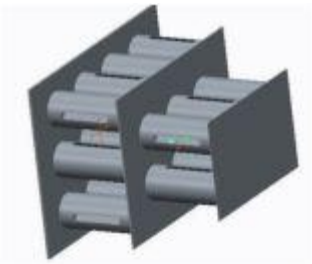

Figure - 5: Impact attenuator design 3

4.4. Design 4:

The results of the first two-layer design was not satisfactory as the energy absorbed was around 5031J which was lesser than the required amount as per SAE rules. So the design was modified to 12 tins in the lower layer and 9 in the next with their centerline lying between two tins in the lower layer.

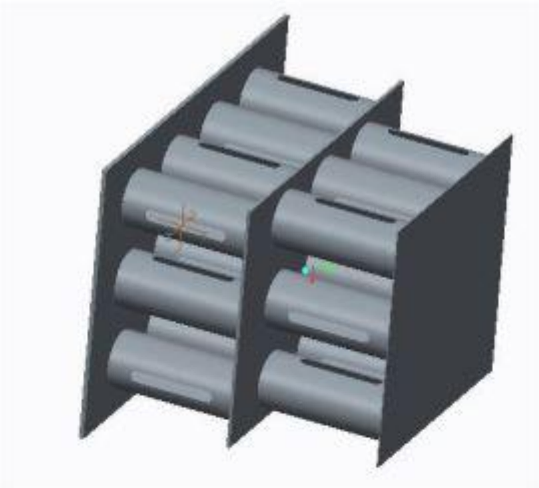

Figure – 6: Impact attenuator design 4

Figure – 7: Testing of design 4

4.5. Design 5:

The design still lacked the required strength and the energy absorption capacity so I further increased the number of tins in the upper layer and the next design was using 12 on 12 tins.

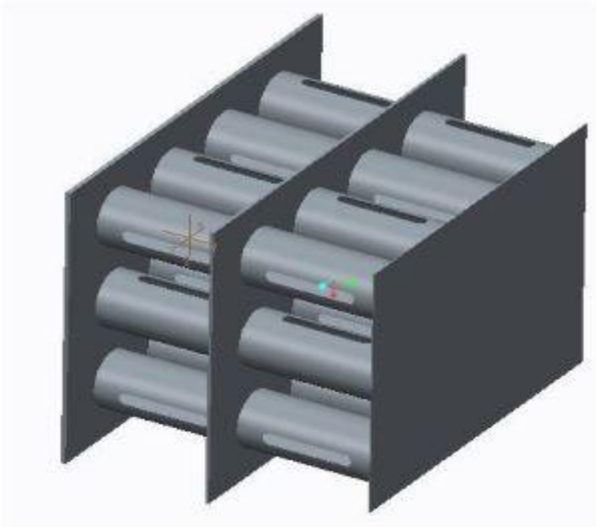

Figure – 8: Impact attenuator design 5

Figure – 9: Testing of design 5

4.6. Design 6:

The results of the previous design couldn't bear enough impact energy so I decided to provide an aluminium housing of 2mm over the first two layer design with 12 tins in the base plate and 6 above it. To reduce the additional weight due the housing and the controlled axial crushing Of the attenuator I removed strips from the surface of the housing and the welding was carried out only at the nodal points to reduce the strength of the aluminium housing's structure. The energy that absorbed by this design was 9490 joules

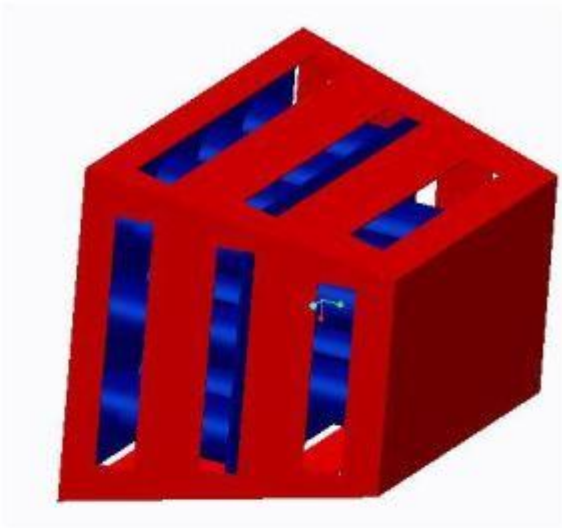

Figure - 10: Impact attenuator design 6

Figure – 11: Testing of design 6

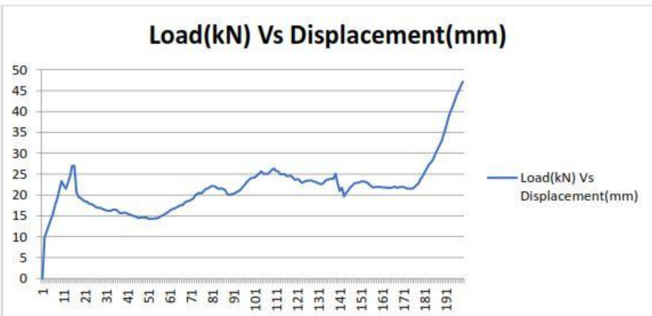

Chart – 4(a): Graph of final attenuator test

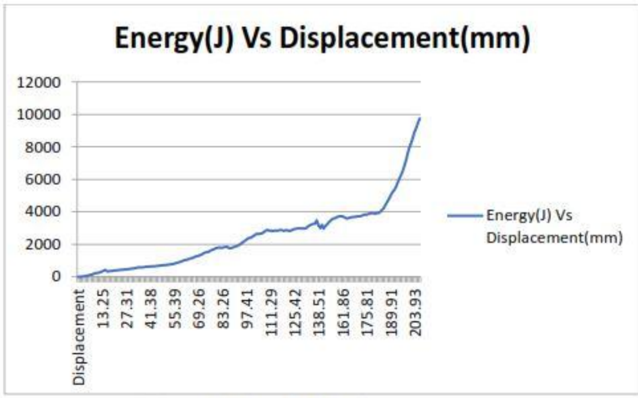

Chart – 4(b): Graph of final attenuator test

5. CONCLUSIONS

Out of all the designs that I tested under the UTM results were satisfactory two designs; one with 3 layers (Design 3 energy 10k J) and 2 layers (Design 6 energy 9490 J). Since the beginning, it was my motive to design an attenuator which is cost effective (whole assembly is made with in 1800rs which is much lesser than the attenuators which are available in market.), easy to manufacture and light weight. Because of this reason I decided to use the two layered attenuator with housing instead of the three layered one.

SUGGESTIONS

The energy absorbed by the final design was 9490 joules which is much more than that is required according to rules of SAE SUPRA which is 7350 joules. So instead of aluminium some other material can be used which is lighter in weight compared to aluminium.

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