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Cost Effective Impact Attenuator for a Formula Student Car

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Abstract

Vehicle safety is one of the major fields of research in automotive industry. While the use of SRS, Dual Stage Airbags, etc. have become prevalent nowadays, designing of a Crash-worthy structure such as impact attenuator still stays one of core and efficient system. There are many impact attenuators available in the market basically made from aluminum or impact foam material. The basic structure of this impact attenuator is the honeycomb structure, but a major problem is the cost of the manufacturing and compatibility with the rules that we have to follow for the competition. So, we decided to use the "BEVERAGE TINS" which are also made up of aluminum alloys. The final design was a result of the various arrangements of tins that we tested on an UTM. The report mainly concerns with the design and development of an impact attenuator for the Formula Student Car being economic, innovative and easy to manufacture.

Keywords: Impact Attenuator, Formula Student, Crash-Worthiness, BEVERAGE TINs.

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]

This Impact Attenuator is designed for SAE SUPRA competition 2015 under the design criteria as per the rule book of SAE SUPRA 2015 listed as follows:

1. 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.
2. Total energy absorbed must meet or exceed 7350 joules.
3. Impact attenuator should be at least 200 mm long, 100 mm high and 200 mm wide.
4. There should be 1.5 mm solid steel or 4 mm aluminum 'anti-intrusion plate*' integrated into the impact attenuator.
5. 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 we had decided to design and manufacture our own impact attenuator from aluminum plate and soft drinks tins, which fulfill the rules of competition and at the same time is cost effective and easy to manufacture because the standard attenuator available made from impact foam costs around Rs.23,500. So by arranging the aluminum tin in a specific manner we designed the attenuator and then tested it on UTM machine, and by observing behavior of deformation we predicted the error in design and thus redesigned it by trial and error method.

MATERIAL SELECTION

- Most of the teams make an impact attenuator with materials like aluminum layers, impact foam in honeycomb structure.
- As an innovation in order to reduce the cost and to multiply the practicality of the design, we decided to construct an attenuator with "BEVERAGE TINs".
- The search commenced with use of Pepsi tins, medicine containers, Amul tin and the results are as follows: which is also shown in graph.

Table 1: Test result of different tins

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

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

- As a bonding material we used adhesive like araldite, Meta set bondtite.[3],[4]
- For the Anti-intrusion plate we used an aluminum plate of 4mm thickness as it was lighter compared to the 1.5mm solid steel plate. Aluminum plates were also used for the layers. Aluminum 6061 was used because of its easy availability.[2],[14]

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Compression Test Report

Machine Model	**: TUN - 600**	**Test File Name**	**: ME_13029_test_10-12-14.Utm**
Machine Serial No.	**: 2000 / 527 UA**	Date	**: 12/10/2014**
Customer Name	**: CIVIL**	Customer Address	**: CHARUSAT UNIVERSITY**
Lot Number	:	Test Type	**: Compression**
Order Number	:	Heat Number	:

Input Data

Specimen Shape	**: Hollow Round**	
SpecimenType	**: Mild Steel**	
Specimen Description	:	
Specimen Inner Diameter	**: 106**	**mm**
Specimen Outer Diameter	**: 107**	**mm**
Distance Between Grips	**: 0**	**mm**
Pre Load Value	**: 0**	**kN**
Max. Load	**: 600**	**kN**
Max. Elongation	**: 250**	**mm**
Specimen C S Area	**: 167.29**	**mm2**

Output Data

Load at Peak	**: 16.410**	**kN**
C.H.Travel atPeak	**: 0.370**	**mm**
Comp.Strength	**: 98.093**	**N/mm2**

Load Vs. Elongation

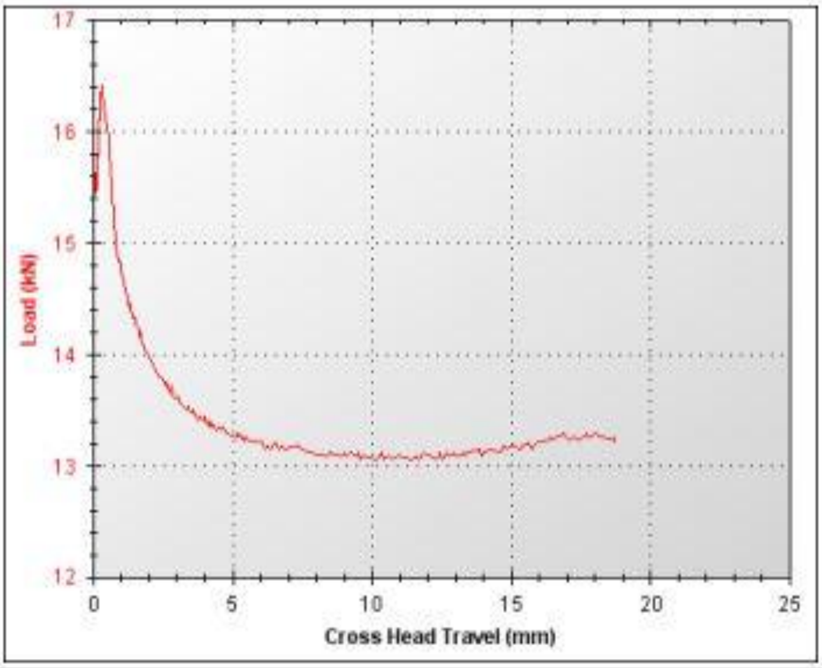

Figure 1. Medicine Can Test Certificate

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Compression Test Report

Machine Model	: **TUN - 600**	**Test File Name**	: **ME13026_test_10-12-14.Utm**
Machine Serial No.	: **2000 / 527 UA**	Date	: **12/10/2014**
Customer Name	: **CIVIL**	Customer Address	: **CHARUSAT UNIVERSITY**
Lot Number	:	Test Type	: **Compression**
Order Number	:	Heat Number	:

Input Data

Specimen Shape	: **Hollow Round**	
SpecimenType	: **Mild Steel**	
Specimen Description	:	
Specimen Inner Diameter	: **49**	**mm**
Specimen Outer Diameter	: **50**	**mm**
Distance Between Grips	: **0**	**mm**
Pre Load Value	: **0**	**kN**
Max. Load	: **600**	**kN**
Max. Elongation	: **250**	**mm**
Specimen C S Area	: **77.75**	**mm2**

Output Data

Load at Peak	: **14.070**	**kN**
C.H.Travel atPeak	: **0.00**	**mm**
Comp.Strength	: **180.955**	**N/mm2**

Load Vs. Elongation

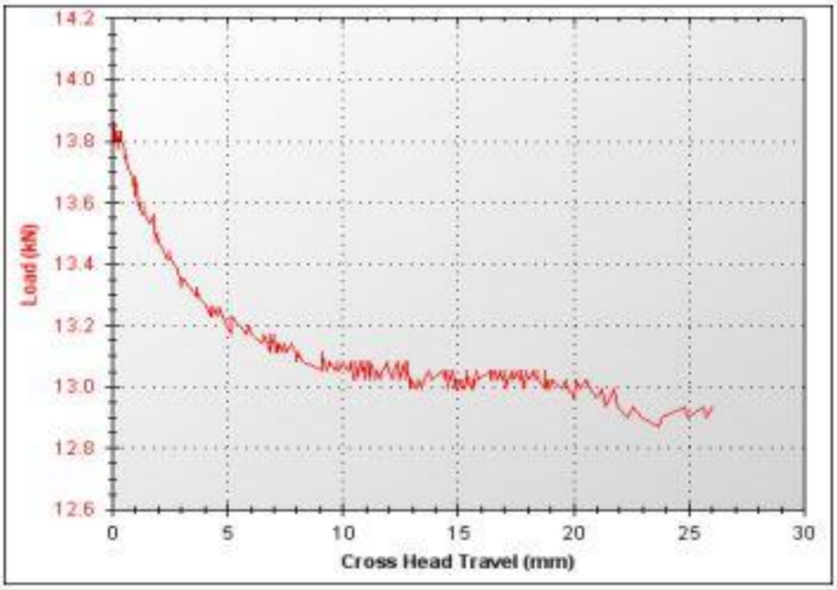

Figure: 2. Amul Tin Test Certificate

DESIGN AND TESTING PROCEDURE

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

- For frontal bulkhead dimensions of 350*250 mm, we chose an AI plate having dimensions 360*260 mm and then we tried different arrangement of tins. Later on we performed test on every design and based on the results we selected a final design. All the cad models were made in SOLIDWORKS.
- 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).
- We tested all the attenuators on UTM machine under compressive load. The test arrangement is as shown in figure(3)
- Amul tins are welded from one side, so it has higher strength at welded side which does not allow uniform axial deformation under load. So we

drilled slots on the welded strip from the tin to reduce its strength and provide uniform axial deformation under impact. This also contributes to weight reduction.

Figure 3. UTM Test Setup.

- ***DESIGN - 1***

The first design of our impact attenuator is shown in figure (4). We had used araldite to attach tins with the aluminum plate and such there were three layer of tins. There are 12 tins 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 tins are placed such that the center of one tin lies in-between the other two tins(of the layer below it) and in the next layer the tins were arranged in the similar fashion.

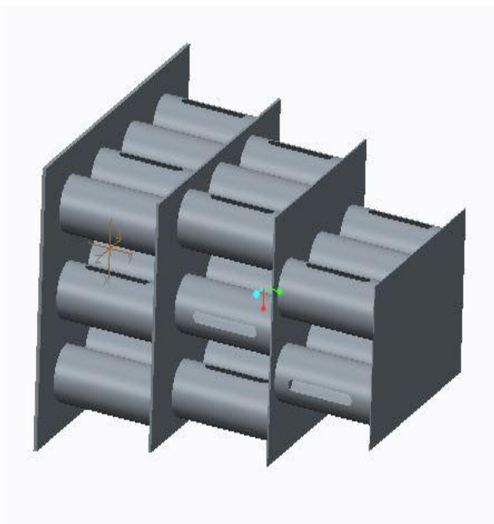

Figure 4. Impact attenuator with three layer

Figure 5. Testing of Design 1 & 2

- ***DESIGN – 2***

The adhesive we used could not hold the tins in their positions properly under shear load developed during its testing so we switched to Metaset- aluminum by keeping the same design as shown in figure 5. And the test results were quite successful. As shown in figure:

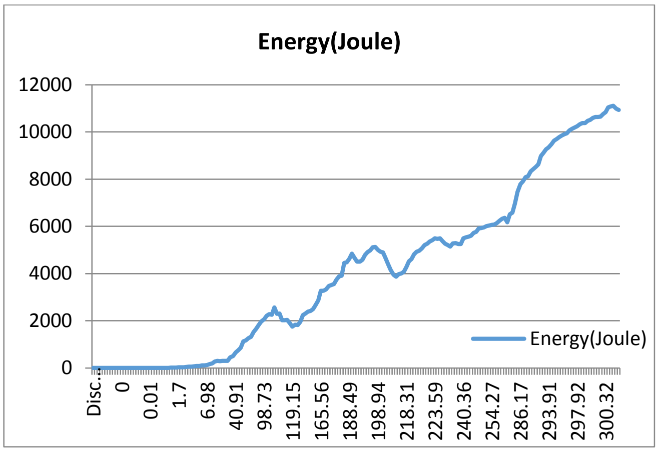

Figure 6. Test result of design 2

- ***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 we moved on to find another design with only two layers. For the design of a two layer attenuator we 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.(6).

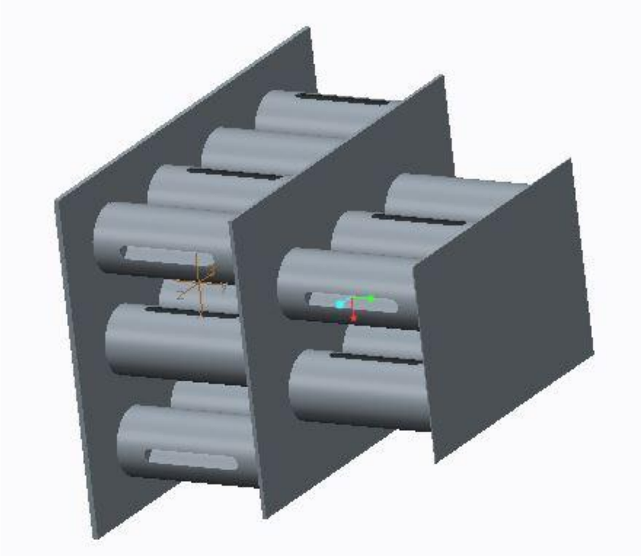

Figure 7: Impact attenuator design 3

- ***DESIGN 4***

The results of the first two-layer design was not satisfactory as the energy absorbed was around 5031 J 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.

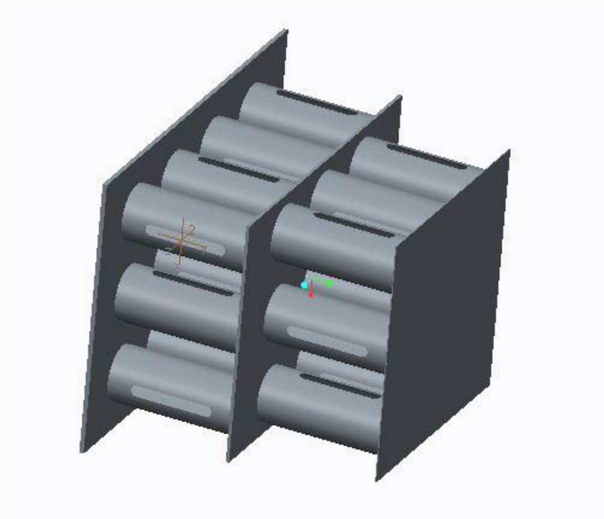

Figure 8. Impact attenuator design 4

Figure 9. Testing of design 4

- ***DESIGN 5***

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

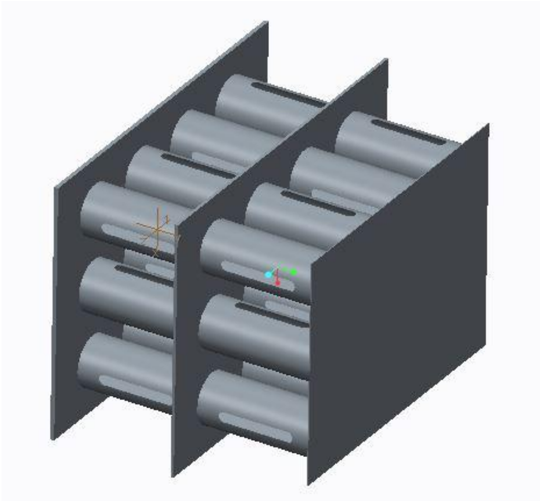

Figure 10. Impact attenuator design 5

Figure 11. Testing of design 5

DESIGN 6

The results of the previous design couldn't bear enough impact energy so we decided to provide and 2mm aluminum housing 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

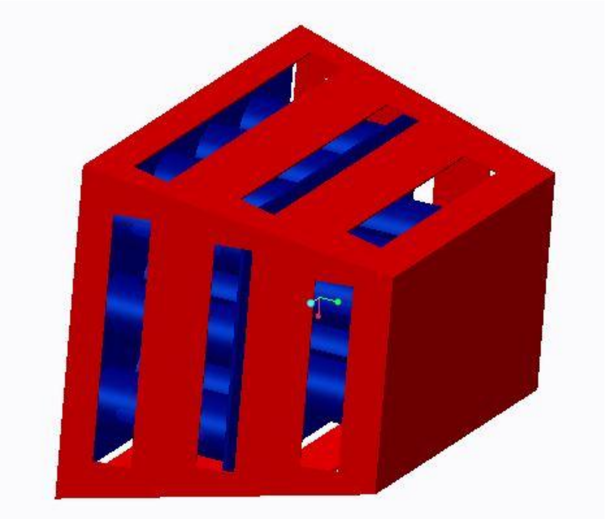

Figure 12. Impact attenuator design 6

Figure 13. Testing of design 6

Of the attenuator we 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 aluminum housing's structure. The energy that absorbed by this design was 9490 joules

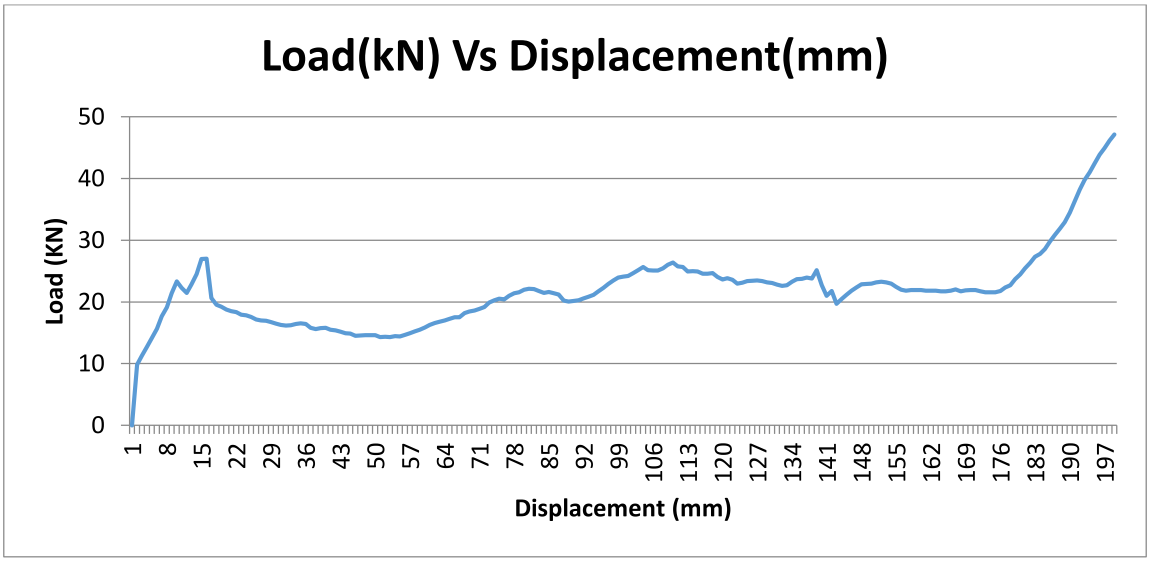

Figure 14. Graph of final attenuator test

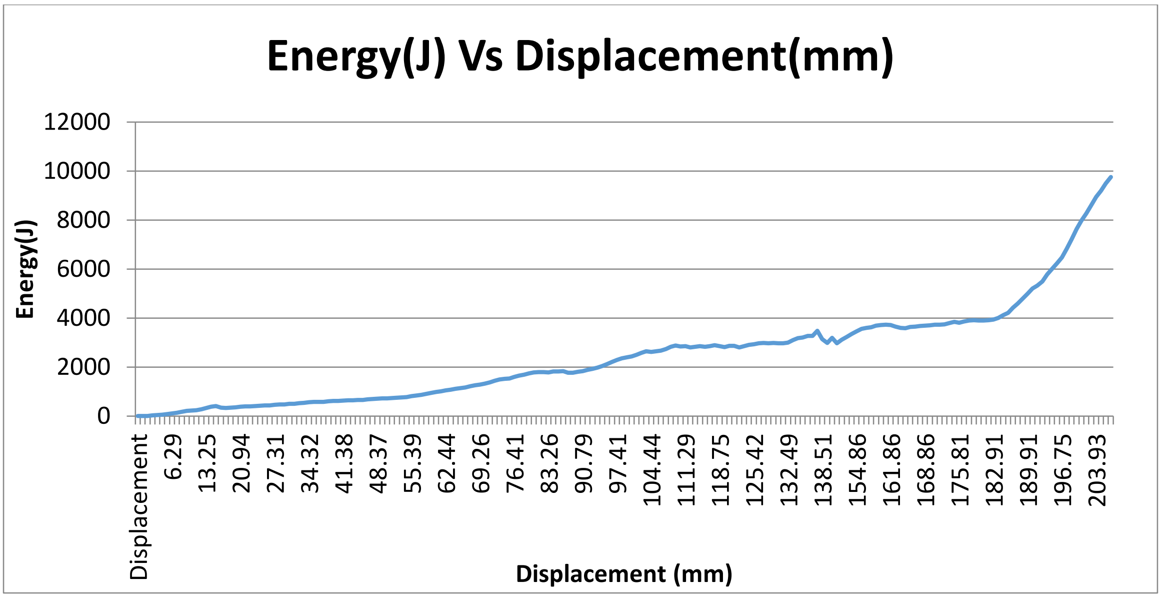

Figure 15. Graph of final attenuator test

COST ANALYSIS

Table 2. Cost Analysis

Cost Report						
Materials		**Fasteners**		**Processes**		**Total**
Crushable	free	Adhesive(metaset)	Rs. 500	Drilling	Rs. 108	Rs.1808
Housing Plate	Rs. 966	Bolt	Rs. 8	Welding	Rs. 254	
Al Plate	Rs. 168	Nut	Rs. 4			

CONCLUSION

Out of all the designs that were tested under the UTM results were satisfactory two designs one with 3 layer (Design 2 - energy 10k J) and 2 layer (Design 6 - energy 9490 J). Since the beginning, it was our motive to design an attenuator which is cost effective (whole assembly is made with in 1800 rupees which is much lesser than the attenuators which are available in market.), easy to manufacture and light weight. Because of this reason we 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 aluminum some other material can be used which is lighter in weight compared to aluminum.

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