ISSN 2250-3153

Study and Design of Impact Attenuator for Passenger Vehicle

Mayank Jain*, Aman Ved Kalia**

Faculty Guide: R.C. SAINI (Asst. Professor)
Department of Mechanical Engineering
MAHARAJA AGRASEN INSTITUTE OF TECHNOLOGY, G.G.S.I.P. UNIVERSITY DELHI

***Abstract* -** In a modern day vehicle, usually a monocoque chassis is preferred which is designed and manufactured as a single structure. Such a chassis in case of acollision absorbs the impact energy by getting deformed itself and also reduces thedeceleration to an appreciable extent such that no fatal damage is impinged on thepassenger.In the motorsport world, a mechanical structurecalled an Impact Attenuator is used to prevent extreme damage to the vehiclechassis in the event of collision.

The working of an Impact Attenuator is based on the energy conservation principle which states that energy can neither be created ordestroyed but can only be transformed from one form to other. In case of an ImpactAttenuator, the kinetic energy (K) of the vehicle just before impact gets transferredinto the Internal energy or Strain energy (S) of the attenuator after velocity of thevehicle ceases to zero. The aim of the paper is to study the working of an Impact Attenuator by understanding the underlying physics and mathematics responsible for its working followed by formulating a design for a passenger vehicle chosen for the project as reference and analysing its effect under a probable situation of collision which is within our approach. The CAD platforms used for the purpose are SOLIDWORKS for 3d modeling and ANSYS for working out the simulation of the cad model for optimizing the design so as to yield the best possible results.

The paper is conceptualized around the possibility of using an Impact Attenuator for passenger vehicles. A passenger vehicle can vary in weight from as low as 600 Kg to as high as 2000 Kg depending on the class.

Index Terms- Impact Attenuator, Passengers Safety, Impact Test, Formula FSAE, ANSYS.

I. INTRODUCTION

A vehicle is sold by the manufacturer for its highlighting features like engine performance, mileage, passenger carrying capacity, boot space and many more exciting features or in plain words those attributes which are visible to the naked eye. But in addition to all these features, safety provided by a vehicle in an event of collision to the passengers is of utmost importance. This attribute is included during the vehicle design and testing stage by the vehicle engineer so that the vehicle is able to withstand the impact force during collision.

Collision is a very plausible scenario in case of vehicles, owing to over speeding and reckless driving by the driver. As per research and real events it has been observed that in absence of safety equipment like seat belts and airbags a passenger undergoes a deceleration of more than 30*G's* in case of collision which is fatal for humans. After several tests, it has been affirmed by doctors that for deceleration less than 20*G's* the human body can sustain the impact force without any extenuating damages. This forms the benchmark for designing the *Impact Attenuator* for vehicles.

In the motorsport world, especially in F1 racing vehicles a mechanical structure called an *Impact Attenuator* is used to prevent extreme damage to the vehicle chassis in the event of collision.

II. PRINCIPLE AND MATHEMATICAL FORMULAE

Mechanical energy conservation principleThe principle states that if the net work done by nonconservativeforces is zero, the total mechanical energy of anobject is conserved; that is, it doesn't change.Applying this principle between two points on a racing track — Point 1 and Point 2 — so that the car is at two different heights and two different speeds at those points because mechanical energy is the sum of the potential energy

$$\left(\text{mass} \times \text{gravity} \times \text{height}\right)$$

And kinetic energy

$$\left(\frac{1}{2}\text{mass} \times \text{velocity}^2\right),$$

The total mechanical energy at Point 1 is

$$ME_1 = mgh_1 + \frac{1}{2}mv_1^2$$

At Point 2, the total mechanical energy is

$$ME_2 = mgh_2 + \frac{1}{2}mv_2^2$$

What's the difference between *ME*2 and *ME*1? If there's no friction (or another non-conservative force), then *ME*1 = *ME*2, or

$$mgh_1 + \frac{1}{2}mv_1^2 = mgh_2 + \frac{1}{2}mv_2^2$$

Further, this kinetic energy on impact gets mostly transferred into the strain energy (*U*) of the body and causes the body to deformpermanently. The remaining energy (if it remains) is distributed to theenvironment as heat or sound. The relation for strain energy is givenas:
U=1/2(k*dx^2)

III. MATERIAL SELICTION

After understanding the theoretical concepts behind the working of anImpact Attenuator the next step was to determine the suitable materialfor manufacturing the attenuator. Several factorsconsidered in selecting a suitable material are weight, strength,cost, availability and manufacturability.On a cursory look upon the attenuators made in the past the mostobvious materials were Steel and its alloys, Aluminium and its alloys. On further, detailed study for the mechanicalproperties of materials we shortlisted two materials for our project,namely Galvanised Iron sheet (GI sheet) and Aluminium 2024 sheet.
The table given below compares the two materials on various attributeswhich were necessary during the selection process.

ATTRIBUTES GI Sheet AL 2024 Sheet	**GI Sheet**	**AL 2024 Sheet**
Density (kg/m^3)	7850	2780
Ultimate Tensile(MPa)	640	220
Yield Strength(MPa)	448	95
Shear Modulus(GPa)	79.9	28
Poisson Ratio	0.29	0.33
Cost (per Kg in INR)	140	190
Availability	Easily Available	Easily Available
Manufacturability	Easily to manufacture	Easily to manufacture

TABLE 1

As the material has to be subjected to impact force and the intention isto deform the object made from the material so as to provide thenecessary outcome, then based on the details provided in the table thefinal choice for the material was AL 2024 sheets being commercially available, light in weight and the sheets are easily weldable using tungsten inert gas welding.

IV. DESIGN AND VIRTUAL ANALYSIS

A two step deign is adopted so that the crushing would occur in steps and the impact gets distributed on to the second member in a uniform pattern. Furthermore, the design incorporates slots so that the sheets can undergo fracture or deformation easilywithout any resistance from the material itself. In material science alsoit is observed that cuts and slots on a material increase stressconcentration in the region which is helpful in this scenario.The aluminium sheets are available in varying thickness but we settled for a thickness of 1mm, reason being that for thickness <1mm the attenuator was so flexible that it couldn’t provide deceleration to the impacting body and for thickness >1mm the attenuator acted as a rigid body and provided an extremely large amount of deceleration.
Therefore, after analysing each and every design we finalised Design shown belowas the one to be manufactured as the final product:

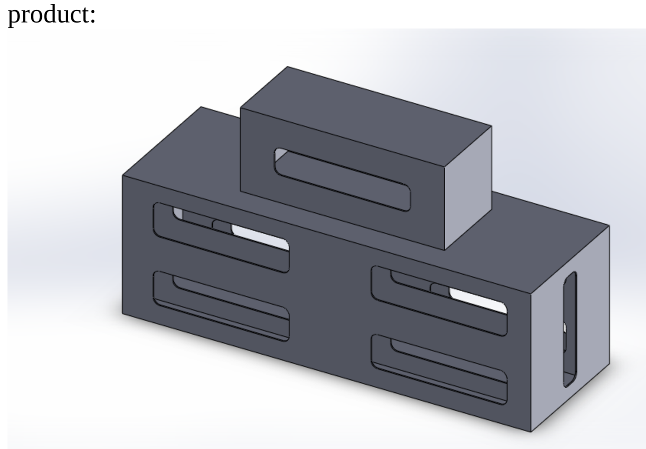

FIGURE 1.

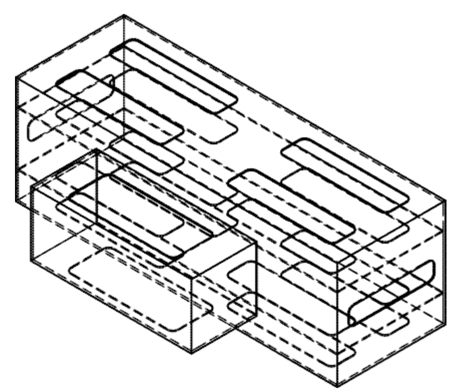

FIGURE 2.

V. ANALYSIS OF THE DESIGN

Simulation of a CAD model requires
The analysis of the design was conducted using the ANSYS analysissoftware. Among the various packages available

Explicitdynamics package for Non – Linear calculations is used. It uses AutoDynsolver to solve the problem which works with microsecond increments.For the analysis an .IGES file of the CAD model of the attenuator was
first designed in Solid works and then imported into ANSYS workbench.To simulate the drop test a cuboidal shape was created in ANSYS suchthat it was in a position of impact with the attenuator. Structural steelNL was selected as the material for the cuboidal shape which made thedrop weight equal to 600 Kg (similar to our reference vehicle).

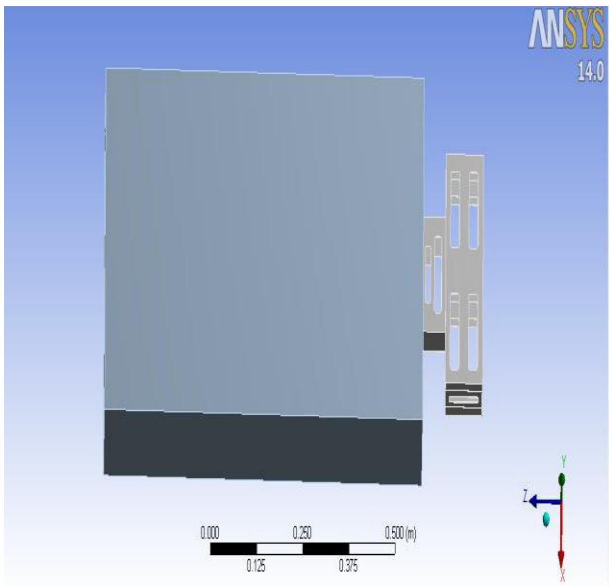

FIGURE 3.

After setting the appropriate boundary conditions as per rule andmentioned previously analysis was conducted to determine the Totalacceleration of the cuboidal shape (replica of vehicle) and Totaldeformation of the attenuator. The results were obtained as graphs as shown here in fig 4 & 5 andthe same are provided for the designs considered

V. RESULTS AND DISCUSSION

The results obtained from the virtual analysis of the Impact attenuator subjected totwo testing conditions are provided here as per the ANSYS report generated. The results obtained for simulating an Impact of a vehicle of weight 600 Kg havingan impact velocity of 4.95 ms-1 are given as follows:

Deceleration vs Time plot.

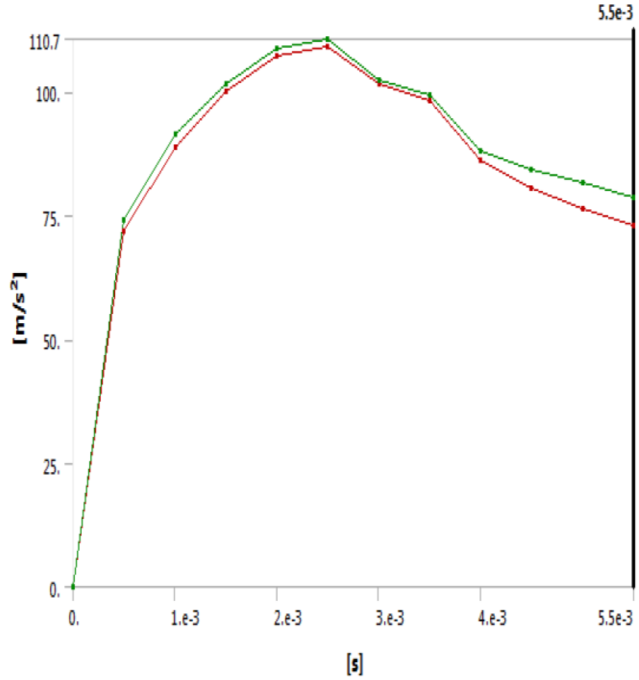

FIGURE 4.

As it can be clearly observed from the Deceleration v/s Time plot that the peakdeceleration obtained is 110.7 ms-2 which is equivalent to 11.3G. This valueobtained is within the 20G limit and this suffices the goal of the paper.The results were also obtained for simulating a plausible situation wherethe velocity of impact was 11.11 ms-1 (40 km/h). Similar, to the previous casegraphs for deceleration and deformation were obtained and the same areprovided below.

Deceleration vs Time plot.

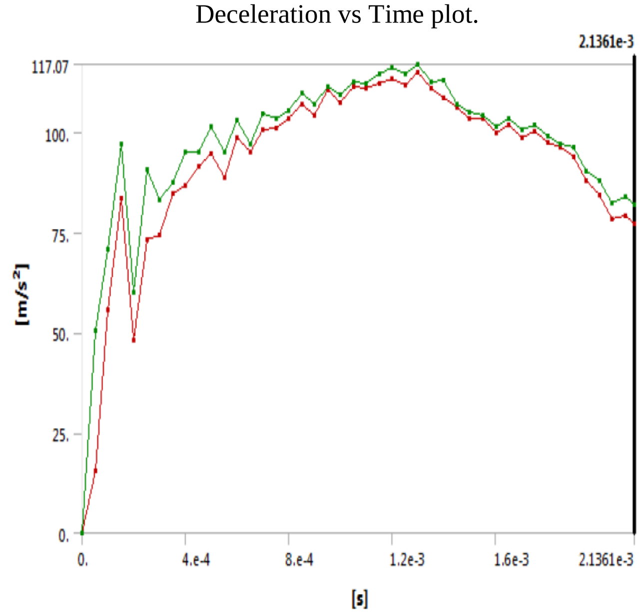

FIGURE 5

The plot clearly shows that the peak acceleration after impact is 117.07ms-2 which is equivalent to 12G. Once again this value is within the20G limit as mentioned previously andalso fulfils the goal of this paper.

The analysis results obtained from the virtual analysis of the Impact Attenuatorconducted using ANSYS software – AUTODYN solver and Explicit Dynamicspackage for two different impact velocities has provided with peak decelerationresults of 11.3G and 12G, respectively.When compared to the results published by other researchers in papers addressingImpact Attenuator design and analysis for FSAE vehicles the results obtained fromour study are closer to the results published in the research paper published byPolitecnico de Torino, Italy students. There deceleration came out to be 14G which iscloser to our results.Furthermore, as per the rule book for FSAE published by SAE International themaximum deceleration possible is *20G.* Our result, for the test conducted for theboundary conditions yield a maximum deceleration of *11.3G* which isagain within the specified limits.

VI. CONCLUSION

On successfully completing all the phases and obtaining the desired results as mentioned it can be concluded that the goal set at the beginning i.e. *to provide an average deceleration of maximum 20G* is attained and proved by the reports of analysis conducted.Further, it can be concluded that this Impact Attenuator if used in the reference vehicle will provide necessary safety to the passenger and the vehicle in case of any frontal collision**.**

REFERENCES

[1] Anyfantis, K. N., “Design of Crash Worthy Impact Attenuator for Racing Automotive Applications: Explicit Nonlinear FEM Formulation”, ANSYS Conference 2008 , Darmstadt, Germany

[2] Belingardi G, Obradovic J, “Design of the Impact Attenuator for a Formula Student Racing Car: Numerical Simulation of the Impact Crash Test”, Journal of the Serbian Society for Computational Mechanics / Vol. 4 / 2010 / pp. 52-65.

[3] Kumar. D, Kumar. S, Singh. G, Khanna. N, “Drop Test Analysis of Impact Attenuator for Formula SAE Car”, International Journal of Scientific and Research Publications, Volume 2, Issue 10, 2012.

[4] M.T.J.Fonteyn, Dr. Ir. Witteman, “*Formula Student Racing Team Eindhoven- Crash Safety”*, MT06.10, Eindhoven, 2006.

[5] Jovan Obradovic, Simonetta Boria , Giovanni Belingardi, *“Lightweight design and crash analysis of composite frontal impact energy absorbing structures”,* Composite Structures, Vol. 94, 2012, pp. 423-430.

[6] SAE International, “Fomula SAE Rule book”, http://students.sae.org/competitions/formulaseries/rules/2013fsaerules

AUTHORS

First Author –Mayank Jain , B.Tech, MAIT, GGSIP University, jainmayu1991@gmail.com

Second Author –Aman Ved Kalia, B.Tech, MAIT, GGSIP University, amanved.kalia@gmail.com

Correspondence Author –Mayank jain, jainmayu1991@gmail.com, jainmayu@yahoo.com , +91-7503994554