DESIGN OF FRONT CRASH SAFETY DEVICE FOR CARS

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Abstract:*Road Accidents are prevailing nowadays. Necessarily, from the safety point of view, we as engineers need to build such a system which has the potential to absorb theimpact and crash energy that is generated due to the collisions at the time of accidents,which is disastrous. Though Cars have crumpled zones for absorbing impact energy but these zones additionally require systems to absorb this energy more efficiently, thus saving the passengers. Our research is based on the design of such device known as impact attenuator, which is designed for frontal collisions in cars. It is therefore necessary to install a device which is capable of protecting from such frontal collisions at high speed by absorbing all the huge energy generated at the time of impact. Suitable economical material has been selected based on all design specifications. We have successfully built such a system in terms of CAD- modeling in Solid Works and have obtained positive simulation results in ANSYS.*

Keywords: Impact, Crash Energy, Frontal collision, crumpled zone, attenuator

Introduction

According to the Report on "Road accidents in India 2015", about 1,374 accidents and 400 deaths are taking place every day on Indian roads. This further exemplifies by seeing each state statistics and on an average about 57 accidents is happening and there is a loss of 17 lives every hour in our country [4-6]. According to W.H.O statistics for 2012, out of about 11.8 lakh road accident deaths across the world 84,674 deaths were reported from INDIA alone. In the year 2013, the number of road accidents deaths in India increased to 92,618. A person dies every 4 minutes in our country due to road accidents. Many accidents are caused due to Frontal collisions. According to WHO statistics for 2012, out of about 11.8 lakh road accident deaths across the world 84,674 deaths were reported from INDIA alone. In the year 2013, the number of road accidents deaths in India increased to 92,618. A person dies every 4 minutes in our country due to road accidents.

Considering the Newtonian frame of reference, Newton laws of motion and mechanics laws states that any moving object when impacts with a rigid body, experiences a force that is equal to the rate of change of momentum of the object. When a high speed car impacts with another car, the car experiences a huge amount of force that is capable of breaking the shoulder bones and neck bone of the driver. Therefore there is a need of such a good energy absorbing device that can absorb the forces during the impact and save the driver's life. The impact force experienced during collision is being governed by the newton's second law of motion which states that "The net force on a body is equal to the product of the body's mass and its acceleration". The momentum carried by a high speed moving car is appreciable and when it impacts to either a fast moving object opposite to its direction or any stationary object, it would experience an impact force due to its dead weight, weight of the passengers and its high velocity. Hence we would require a shock force absorbing system to be installed in cars which absorbs this impact force.The system made up of an appropriate material and having a definite property of shock absorption [6-9].

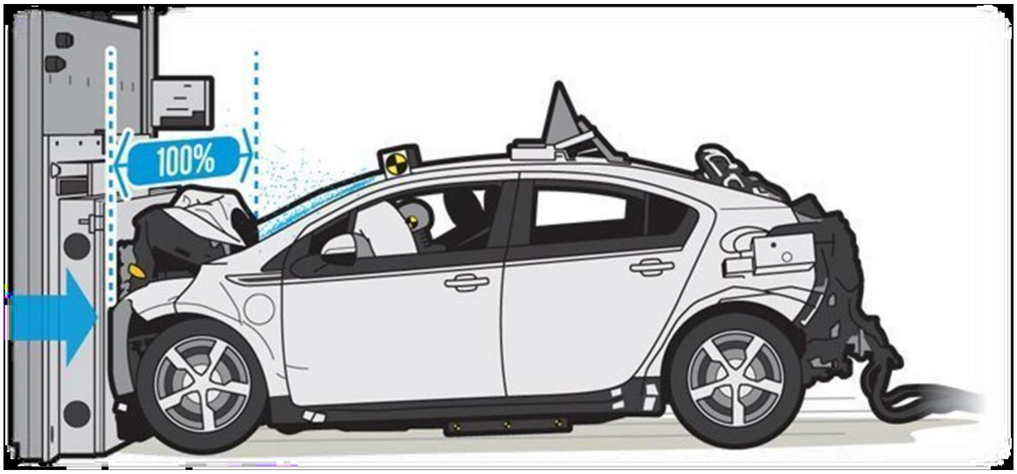

Figure (1) Impact force experienced by the car

Materials and Methods

As per the FSAE Rulebook, the following dimensions were taken. For the sake of simplicity in the manufacturing process, we are choosing Cuboidal shape of the structure. [2]
Length -270 mm (>=200mm)
Breadth -900mm (>=200mm)
Height -300mm (>=100mm)

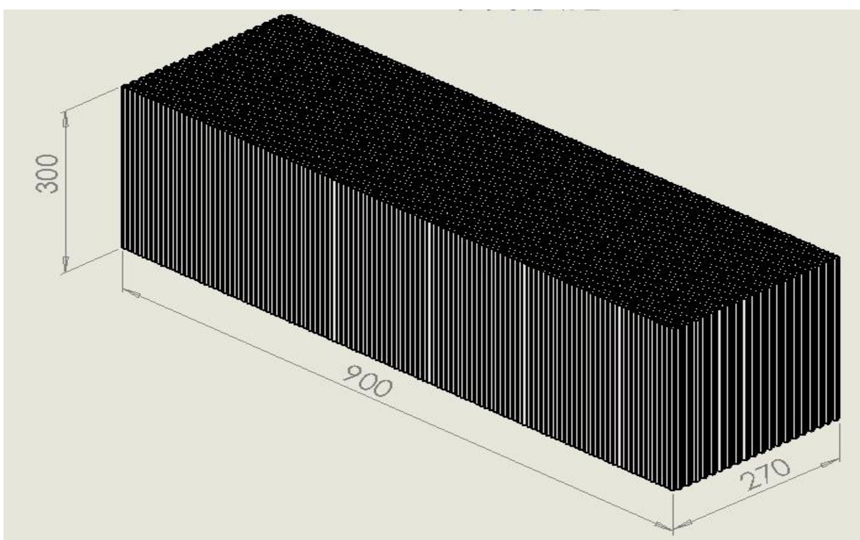

Figure (2) Isometric View of the Impact Attenuator

Impact attenuator is a device which could be able to absorb energy during frontal head-on collision by deformation progressively debilitating effect of force and retardation or deceleration transmitted to passengers. The major part of impact energy is this plastic deformation. Impact Attenuator requires a safe material which could withstand the impact force and stress developed and thus could absorb a large amount of energy. For all these requirements, the material should have more toughness than the other existing materials in the market[1].Hence the material should be chosen based on the properties like Hardness, Strength, Fracture Toughness, Formability, Plasticity, Heat Treatability and specifically Weight, Cost, Reliability and Availability. After evaluating on the above factors we get the following results, [3]

DESIGN CONCEPT	WEIGHT	COST	SAFETY	RELIABILITY	FEASIBILITY	MARKING
WEIGHTING FACTOR	0.25	0.35	0.15	0.20	0.30	
FOAM	8.0	7.0	8.0	7.0	8.0	9.5
CRIMPED METAL LATTICE	6.0	6.0	5.0	5.0	6.0	7.2
HONEYCOMB*	**8.0**	**8.0**	**8.0**	**9.0**	**8.0**	**10.2**
AIRBAG	9.0	1.0	6.0	8.0	3.0	6.0
RUBBER BUMPER	7.0	7.0	7.0	6.0	7.0	8.6

Honeycomb Design: The use of a honeycomb structure was then checked. Its scores were the highest of all. The material is appealing because of its light weight and low price. It can be created relatively cheap and also it can easily be replaced. The Honeycomb structure also scored high in safety and reliability. Its ability to reduce impact will not change to a great deal due to design and construction variance.

Figure (3) Aluminum 3003 H-18 Honeycomb Structure

Honeycomb scores were the highest in the decision matrix chart. It has great energy absorbing properties and also its cost effective and light weight. It could be manipulated into many combinations and shapes in order to fit the requirements. The geometry of the impact attenuator is also very much important in the energy analysis of design. While researching for the many types of honeycomb products available, we got a product namely Aluminum Honeycomb 3003 H-18. Our group felt this type of honeycomb may be the best choice for our application. This product is constructed from 3003 aluminum alloy foils which make it very lightweight for its size and strength. The honeycomb cells shape is what gives this material its strength. This 3003 aluminum foil material is not very strong in itself. A flat sheet of it can be easily bent and twisted by the average person. When it is arranged in a honeycomb lattice, the strength properties of the material vastly increase due to the support of the hexagonal cells. This strength gives the stopping power of the honeycomb structure. The lattice stops and resists a good amount of the impact forces that are applied to it. The honeycomb structure possesses ideal energy absorption because it is made from foil. The ductility of the foil plays an important role in absorbing the rest of the impact energy once the yield strength is breached. Therefore this would be the best probable selection for our application. [3]

Properties[10]

BASE METAL PRICE	16% rel
BRINELL HARDNESS	55
DENSITY	2.8 g/cm^3
FRACTURE TOUGHNESS	69 MPa- $m^{1/2}$
ELASTIC (YOUNG'S,TENSILE) MODULUS	69 GPa
POISSON'S RATIO	0.33
TENSILE STRENGTH:ULTIMATE(UTS)	210 MPa
TENSILE STRENGTH:YIELD(PROOF)	190 MPa

Alloy Composition[10]

METAL	% COMPOSITION
Aluminum (Al)	96.8 to 99 %
Manganese (Mn)	1.0 to 1.5 %
Iron (Fe)	0 to 0.7 %
Silicon (Si)	0 to 0.6 %
Copper (Cu)	0.050 to 0.2 %
Residuals	0 to 0.15 %
Zinc (Zn)	0 to 0.1 %

Calculation

Newton's Second Law of Motion states that, the force acting onan object is equal to the mass of that object times its acceleration. In mathematicalform it is written as:-

F= m x a
Where'F' is force, 'm'is mass and 'a' is acceleration.
When a constant force acts on a largebody, it causes it to accelerate, i.e., it changes its velocity, at a constant rate. In thesimplest case, a force applied to an object at rest causes it to accelerate in the directionof the application of force. The force can be a single force or it can be thecombination of more than one force. In this case, we would write the equation as:-

$\Sigma F = ma$--(i)

Σ represents the vector sum of all the forces acting on the body. [11]

For analyzingthe forces, we have considered the following assumptions:-

1. The speed of the impact to be 50 meter per second. (relative velocity)
2. After impact vehicle is brought down to zero velocity.
3. Time of impact is 0.07 sec.
4. Mass of vehicle = 3300kg

The rate of change of momentum of an object is directly proportional to the resultantforce applied and is in the direction of the resultant force.The resultant force is equal to the rate of change of momentum.

$F=\frac{\Delta(m\ v)}{\Delta t}$---(ii)

For a collision occurring between object A and object B in a secluded system, thetotal momentum of the two objects before the collision is equal to the total momentumof the two objects after the collision. That is, the momentum lost by object A is equalto the momentum gained by object B. Hence, total amount of momentum is a constantor unchanging value.[12]

Rate of change of momentum= mass x $\frac{\text{Change of Velocity}}{\text{Time of Impact}}$ (from eq. 2)

= 3300 x $\frac{50-0}{0.07}$

= 2.357 MN---(*)

This much amount of force will generate stresses in the frontal area of the device.

Frontal Area= Breadth x Height

= 900 mm x 300 mm

= 0.27 m^2--(**)

Stress can be defined as the internal resistance, or the counterforce, of a material generated due to the distorting effects of an external force or load. These counter-forces tend to return the atoms to their normal positions. The total resistance developed is equal to the external load. This resistance is known as *Stress*. Mathematically stress for Impact Loading can be represented as:-

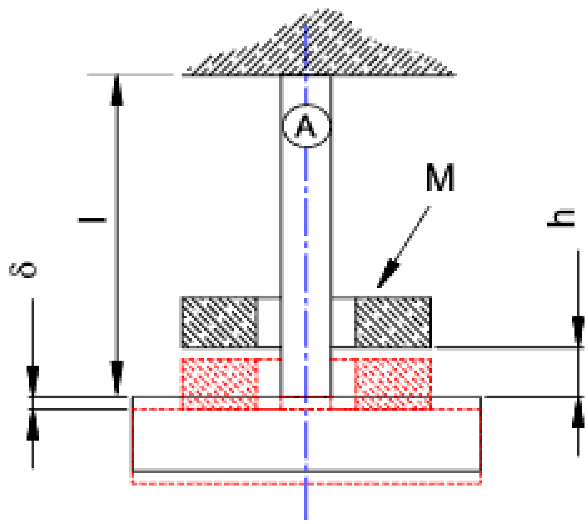

Figure (4) Impact Loading

Since, External work done on bar = Energy stored in bar

= mg(h+ δl_i) = $\frac{1}{2}\sigma_i$---(iii)

= mgh + mg [$\frac{\sigma_i l}{E}$] = $\frac{1}{2}\sigma_i A * \frac{\sigma_i l}{E}$ [$since\ \delta l_i = \frac{\sigma_i l}{E}$]

= $\frac{1}{2}$mv^2 + mg($\frac{\sigma_i l}{E}$) = $\frac{\sigma_i^2 Al}{2E}$

= $\frac{1}{2}mv^2 = \frac{\sigma_i^2 Al}{2E} - mg(\frac{\sigma_i l}{E})$

= $\frac{1}{2}mv^2 = \frac{\sigma_i^2 Al - 2mg\,\sigma_i l}{2E}$

= Ev^2 = $\sigma_i^2 Al - 2mg\sigma_i l$

= $\sigma_i^2 Al - 2mg\sigma_i l - Emv^2 = 0$

Putting $\sigma_i = x$

= $x^2 Al - 2mgxl - Emv^2 = 0$

= $x^2(0.27)(0.27) - 2(3300)(9.81)(0.27)x - (69\ \text{x}10^9)(3300)(50)^2 = 0$

= $x^2(0.0729) - x(17481.42) - (5.692\ \text{x}10^{17}) = 0$

$$x = +2794391919$$

$= -2794152119$

'or'

$\sigma_i = 2.794 \times 10^9\ Pa$-----------------------------------(***)

Results and Discussion

The above calculated stress value is for a solid cuboid, whereas our device consists of hollow hexagonal cells arranged in rows and column form. We have used ANSYS simulation software where we have done the analysis of EXPLICIT DYNAMICS of the device and then we got the value of stress which comes to be within material's tensile yield strength. This value of equivalent stress given by the software results proves that by using hexagonal cells we are able to achieve a much stable device which is capable of absorbing much higher impact energy.

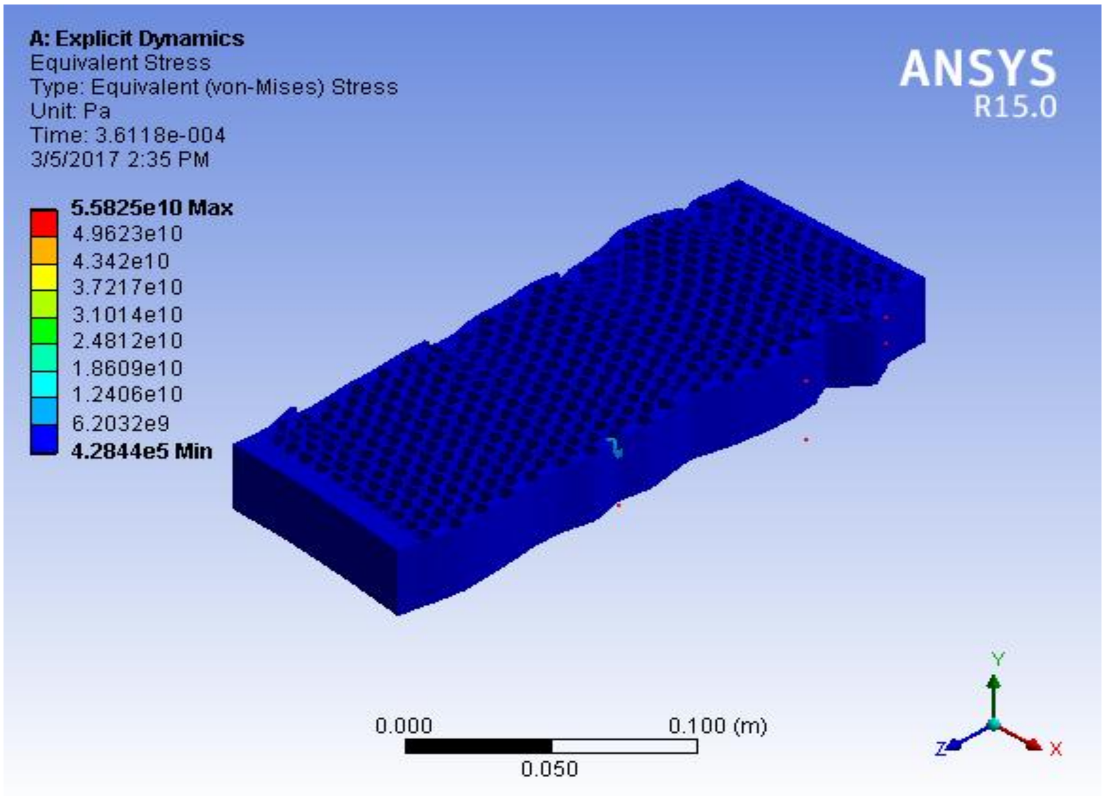

Figure (5) Equivalent stress results obtained in ANSYS

Conclusion

The behavior of an Impact Attenuator has been described with detailed material selection, and design Methodology. After doing the stress analysis, we have obtained the maximum amount of stress that the material can withstand. From our investigation, we have concluded that Aluminum 3003 H-18 Honeycomb structure is the best energy absorbing material and economical amongthe materials taken for study. We have taken the Honeycomb structure as itpossesses ideal energy absorption. In a honeycomb lattice, the strength properties ofthe material vastly increase due to the support of the hexagonal cells. Thus we havechosen the shape of the cells of the material to be hexagonal, as it is the most stable shape with no voids. As per the FSAE Rulebook, we have decided the dimensions of the device, according to our requirement. For the sake of simplicity in the manufacturing process, we arechoosing Cuboidal shape of the device. The exact behavior of the Impact Attenuator can be known by effective detailed testing procedure.

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