INNOVATION IN THE IMPACT STRUCTURE DESIGN OF A FOUR WHEEL AUTOMOBILE

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Abstract - *Accidents in an average developing country cause 130,000 deaths annually and 1-3% of total G.D.P. decline of the country[1]. The stated statistics can be the outcome of many reasons like a lethargic attitude of the driver and even the pedestrian and many of the times availability and quality of the safety instruments. Most of the accidents are due to the collision of vehicles. The first part which is affected due to collision is impacted structure; the impact structure is part of the body design of vehicle whose basic purpose is to prevent the passengers and driver from direct impulse caused due to the collision. The design of the impact structure is finalized after checking the analysis report obtained from Finite Element Analysis (FEA) done on the fairly popular software ANSYS, basis CAD design is made generally in CATIA or CREO. The impact structure generally is designed with the help of standards provided by the respective country.*

Keywords: Safety, impact structure, finite element analysis, front impact, side impact, impulse-momentum relation, validation setup.

1. INTRODUCTION

An impact structure is a structure integrated or adhered to the chassis of a four-wheeler, whose main purpose is to absorb minor collisions, basically, minimizing repair costs. Many times it's confused that its purpose is to attenuate the intensity of injury, but in reality, it's not. Its main purpose is to reduce or abate the possible physical damage to the vehicle and its parts in a minor collision. Impact structure prevents the hood, grill, trunk, fuel, exhaust and cooling system from minor collisions[2].

The term 'minor collision' is highlighted repeatedly because, during a high-speed crash, the emergency brakes are engaged. This basically lowers the height of the vehicle, because when emergency brakes are engaged at high speed, there is compression of the front suspensions. Hence, the vehicle lowers in height, which exposes the hood and bonnet to the collision. Hence, during a high-speed crash, bonnet and hood are the parts which are the most affected. While, in the case of race cars or supercars, the ground clearance is already very low, hence there is complete exposure of the impact structure to crash. In this case, even the high-speed crash does not affect the vehicle, since the crash occurs at impact structure.

The main aim of the project is to optimize the design of the impact structure, to reduce the damage to the vehicle, hence repair cost and in case of the supercar, death rate as well.

Factors considered while designing Impact Structure:

Impact structure is the component of the vehicle which annihilates itself while collision before the impulse might reach the vehicle.

As stated above, the main objective of the journal is to elucidate the optimization possible in the impact structure. The design of the impact structure, currently being used is absolute hollow rectangular piping section.

As explained earlier, the advancement which can be implemented in the design of impact structure is that the triangulation can be extruded in between the absolute hollow rectangular structures [3].

The advancement brought in the impact structures directly affects the crashworthiness, occupant safety and damage that can be caused to the vehicle.

There were various factors which were considered while designing impact structure. Some of those are:

- Design
- Material
- Analysis and Observations

1. Design:

Design of the impact structure is created such that it can withstand a humongous impact during a crash or an accident. Basically, it attenuates collision impulse. The design basically consists of the triangulation, which is one of the most efficient structures in case of impact and collision. In general, hexagonal structures and triangular structures are the most optimum and efficient shapes when it comes to attenuating and withstanding a great impact[4]. Fig1.1 and Fig1.2 elaborate the cross section and wireframe view of the impact structures (front as well as side).
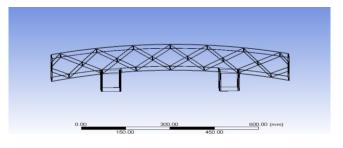

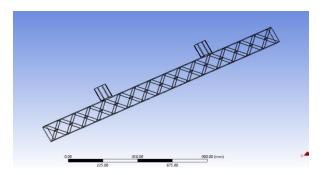**Fig1.1:** Wireframe view of front impact structure

Fig1.2: Wireframe view of side impact structure

2. Material:

The material is one of the most vital parts of the designing any product in the world. Material selection is the part where the project may either reach its zenith or fail. Hence, material selection is done while taking care of some key factors like elastic modulus, shear strength, compressive strength, thermal conductivity and most importantly price involved. Some of the materials with high compressive and shear strength were altercated, on the basis of the key factors and hence compared with each other to find the most implementable and optimum that can be used.

Some of the reviewed materials are:

Aluminium Alloy:

  AL6063 Series
- Magnesium Alloy:
  AZ91E Series
- Titanium Alloy:
  Ti6Al4V
- Grey Cast Iron

2.1 Aluminium Alloy:

Al6063 Series: The alloy has modulus of elasticity of 69MPa and density of 2690kg/m^3, making it as heavy as Al6061, just like Al6061 got high shear strength and BHN as 152MPa and 78 respectively. The alloy Al6063 is identical twin of Al6061[5], in case of properties they bear; only difference is found in chemical composition.

2.2 Magnesium Alloy:

AZ91 Series: Magnesium alloy made of the chemical composition is Mg (88.51-91.22%)+Al (8.1-9.3%)+Zn (0.4-1%)+Si (<0.20%)+Mn (0.17+0.35%)+Cu (<0.015%)+Ni (<0.001%)+Fe (<0. 005%).Making its compound composition to be Mg17(Al, Zn)12[17]. Being a magnesium alloy, it contains a high amount of magnesium, nomenclature is done on the basis of the first letter of the next major constituents. AZ91E possesses the density of 1810kg/m3 and is highly resistant to corrosion. According to the application, the crushing strength was obtained and found to be 360MPa and fatigue strength was found to be 83MPa, while Brinell Hardness Number (BHN) being 75. To attain such high valued properties, the raw material must go

through numerous hardening and strengthening processes, hence the costing of the product elevates, making it quite inappropriate for mass production [6].

2.3 Titanium Alloy:

Ti6Al4V: Titanium alloy abides with some of the culminating properties amongst all the alloys, like better machinability, low weight ratio and high strength. The chemical composition of Ti6Al4V is Ti(89.707%), Al(6%), V(4%), C(0.03%), Fe(0.1%), O(0.15%), N(0.01%), H(0.003%). Being an alloy of titanium, there are some sumptuous properties inherited from titanium elements like high corrosion resistance, low weight ratio and weldability. After heat treatment at 920℃, the alloy can easily be used for fatigue loaded components. The alloy can be machined in very abrupt and extreme environments like low cutting speed, high feed rate, rigid setup etc. [7]. Welding is possible by specific type like TIG, MIG. Because of lots of the key features, it has numerous applications in every field of engineering and even medical like surgery tools and robotic arms for operations [8].

Property	Value	Unit
Density	4419	Kg/m^3
Young's modulus	96000	MPa
Poisson's ratio	0.36	-
Bulk modulus	114290	MPa
Shear modulus	35294	MPa
Tensile yield strength	930	MPa
Compressive yield strength	930	MPa
Tensile ultimate strength	1070	MPa

2. Analysis and Observations:

Analysis of any materialistic component is nowadays with the help of Finite Element Method (F.E.M). The analysis report is the report which manifests the condition of the material or component after certain effect, the effect might be related to tensile stress, compressive stress, thermal extremity, cryogenics etc. Hence, the design of the impact structure must go under some serious stresses for crash test analysis. The final and directional deformation after the analysis, states whether the structure can be implied or not.

The analysis report provides the strength and stiffness of the component, signifying the practical life usage and durability of the impact structure.
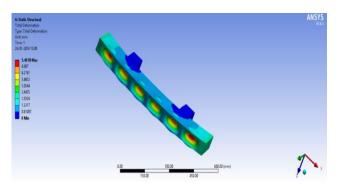
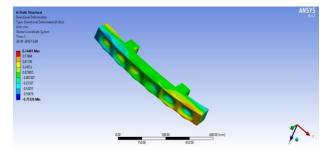**Fig3.1:** Total deformation for Ti alloy on front impact

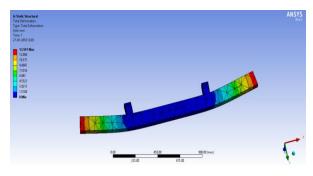**Fig3.2:** Directional deformation for Ti alloy on front impact

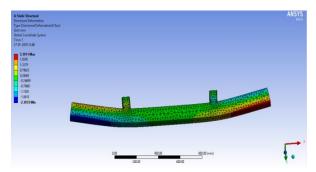**Fig3.3:** Total deformation for Ti alloy on side impact

Fig3.4: Directional deformation for Ti alloy on side impact

Total force is calculated by impulse-momentum relation[9], whilst the velocity is considered 200km/hrs. (average velocity of a supercar) for full wrap frontal collision, and 100km/hrs. for full wrap side collision test.

The overall observation consists of cost involved in material and fabrication and implemantability of the product in practical life. Let's take an example for cost: Cost factor directly affects the implimentability of the material, if the material is too expensive then it's quite difficult to use the material. The pricing of the most optimum material Titanium alloy is 25.64-27$/lb[10], whilst the pricing of the aluminium alloy is 3000-5000$/ton[11]. This creates a great difference in the decision and usage of the material. One cannot just undermine the significance of this factor, since it can affect the total cost required and ultimately, it won't be possible to use it further. Hence one definitely cannot use such expensive material for mass production and industrial use. This completely changes the scenario of the production and usage of material, when needed in large quantity.

Let's consider crashworthiness: crashworthiness refers to the ability of a structure and any of its components to protect the occupants in survivable crashes[12].it connotes a measure of the vehicle's structural ability to plastically deform and yet maintain a sufficient survival space for its occupants in crashes involving reasonable decelerations loads[13].

3. CONCLUSIONS

The impact structure not only shields the occupants from sudden impulse but also prevents the possible expensive repair costs after the collision[14]. Impact structure, in the recent future, will prove to be propitious and pertinent in a situation of a crash. The concept may not decrease the actual number of accidents, but losses of the crash definitely can be reduced. The fabrication of the impact structure of titanium or aluminium alloy for mass production can be beneficial even for industries[15]. Hence it can be concluded that impact structure can attenuate the losses caused during the accident, whether it may be related to life or economy.

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