Design and Analysis of a Monocoque for a Prototype Vehicle

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Abstract - *The rising awareness against the crude oil consumption to power a vehicle often leads us to focus on alternatives for it. Until the infrastructure for these alternatives can be established, our main aim should be to focus on achieving fuel efficiency. The project aims to design and analyze a prototype vehicle focusing on achieving fuel efficiency by the means of implementing a monocoque structure with different core material properties. A Monocoque is a type of construction in which the outer skin carries all or a major part of the stresses. Materials play a vital role in all major industries, mechatronics being one of them. Having a lighter, sturdy structure not only helps in making a machine effective but also makes it cost-efficient to produce it on a larger scale. As fuel efficiency is directly proportional to the amount of load applied, decreasing the weight of the vehicle will immensely effect in reduction in fuel consumption.*

Key Words: **Monocoque, Composite material, Prototype vehicle**

1. INTRODUCTION

To minimize the equivalent consumption of fuel for a vehicle, expressed by the kilometres with a litre equivalent of fuel (calculated by Shell with the hydrogen heating power), the most important key factors are weight, aerodynamics resistance, friction of the wheels and of the bearings, and at last but not least power-train efficiency. The aim, for the chassis and the body, is to reach the lowest weight without compromising on the structural resistance. The weight of the monocoque is assumed to be approximately about 4 kilograms. The objective is also to ensure that the structure of the vehicle should not deform permanently or show ruptures during the application of the weight.

For this reason, it is necessary to obtain the minimum weight to give the vehicle the most structural resistance but also to have a design with the most aerodynamic shape. A good technological solution to obtain the body is to use carbon fibre composite materials, which have excellent performance in terms of low density and mechanical properties if compared to traditional materials used for mechanical constructions, like aluminium and steel. Usually in the automotive field carbon fibres are used for high level applications, where there is the need for high performance and low weights while cost is not an issue. A typical manufacturing technology used to make carbon fibre components for automotive applications, is the use of prepregs. These are fabric composite materials already littered with resin. The prepregs are shaped manually in moulds and then polymerized in an autoclave, using vacuum bag around the mould. Unidirectional or multi directional carbon fibre fabrics can be used, with a specific ply lay-up to balance the stress due to pressure and temperature variation, which occurs during the cure cycle in autoclave. With this process it is possible to obtain components with high uniformity and high performance.

1.1 Objective

The objective of this paper is to build an efficient structure to support a vehicle to make it light in weight without compromising the structural strength of the vehicle. The project aims to design and analyze the structure of a prototype vehicle which can then on a larger scale be implemented on our day-to-day vehicles.

Building a lightweight structure having the same strength as its heavier counterparts can be used in a variety of fields. These fields include Aerospace industry, Aeronautical Industry, Automobile Industry amongst others.

The technological developments in most fields are moving towards a sustainable development, focused more towards reducing the carbon emissions to nearly 0. In a study published in the journal Environmental Research on Tuesday, researchers from Harvard University, in collaboration with the University of Birmingham, the University of Leicester and University College London, found that exposure to particulate matter from fossil fuel emissions accounted for 18% of total global deaths -- almost one in five -- in 2018. Even when the automobile industry is moving towards an all-electric future, the electric vehicles today consume about **150 watt-hours per kilometer**. If the average distance per day is 50 km, then it would be 18,250 kilometers per year. For this calculated consumption, electric vehicles would need to generate 2.75 MWh/year. One of the leading factors that affect this efficiency is the weight of the vehicle. The project therefore aims to design and analyze the structure of a prototype vehicle which can then on a larger scale be implemented on our day-to-day vehicles.

1.2 Existing Solution

Space Frame or Ladder Chassis- A space frame is a rigid truss like structure constructed from struts in a pattern. Like the truss, a space frame is strong because of the inherent rigidity of the triangle; flexing loads (bending moments) are transmitted as tension and compression loads along the length of each strut.

Major Drawbacks:

- The main drawback of such structure is that they add weight to the vehicle
- Results in reduction of fuel efficiency

2. Proposed Solution

Our solution consists of complete monocoque structure.

Advantages:

1. Reduces the weight of the vehicle compared to a conventional roll cage structure.
2. The major advantage that we get here is that the structural strength of the vehicle is not compromised.

3. Selected Solution

The main area of focus for this project was to create a fuel-efficient vehicle. To create a fuel-efficient vehicle, weight playing a major role the solutions taken into consideration were keeping this primary objective and design constraints in mind. The design constraints were taken from the Shell Eco-Marathon Rulebook. The solutions were determined according to the maximum load applied on the vehicle. The tools used to carry out this project were Solidworks and Ansys.

Keeping the following objectives in mind the solution was selected:

1. To create a lightweight yet sturdy structure
2. To choose an appropriate material thickness
3. To select the most efficient load bearing areas

4. Design

4.1) Design Constraints

a) The vehicle maximum height must be less than 1000 mm.

b) The vehicle track width must be at least 500 mm, measured between the midpoints where the tyres of the outermost wheels touch the ground.

c) The ratio of height divided by track width must be less than 1.25.

d) The vehicle wheelbase must be at least 1000 mm.

e) The maximum total vehicle width must not exceed 1300 mm.

f) The maximum total length must not exceed 3500 mm.

g) The maximum vehicle weight, without the Driver is 140 kg

4.2) Modelling

The design of the monocoque is done using Solidworks. We used surface modelling as a tool in Solidworks to design the shell of the vehicle.

Further, we made use of the Solidworks body tools to create the monocoque structure for the vehicle.

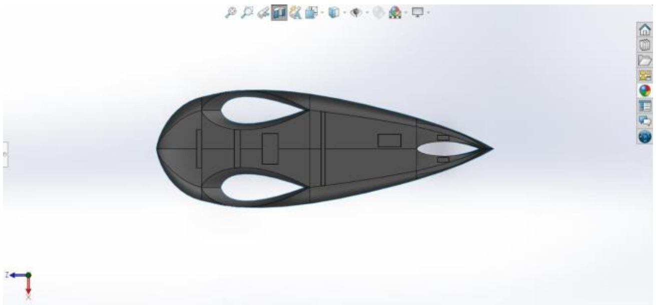

Fig-1: Monocoque structure

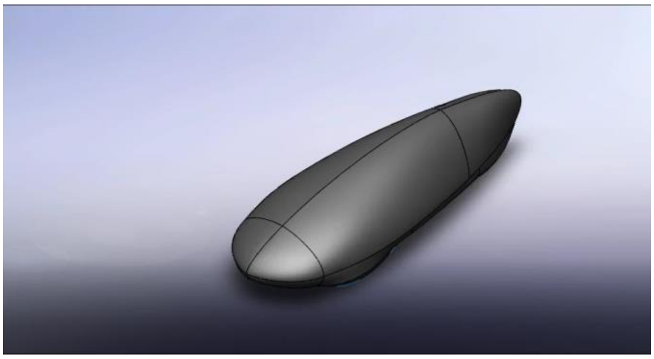

Fig-2: Shell of the vehicle

The design of the monocoque was done keeping into consideration of the design constraints as mentioned earlier. Keeping that and the aerodynamics of the vehicle in mind a shell was designed. Further the monocoque was designed keeping in mind the maximum load constraints that act upon the vehicle.

The main idea of this project was to conduct an analysis of a monocoque structure with Balsa as the core material with Carbon Fibre on either side. The tool used to conduct this analysis was ACP.

4.3) Model:

The mesh was taken for the complete geometry. The Element size was taken to be 21.2mm (default). The element order was taken as linear.

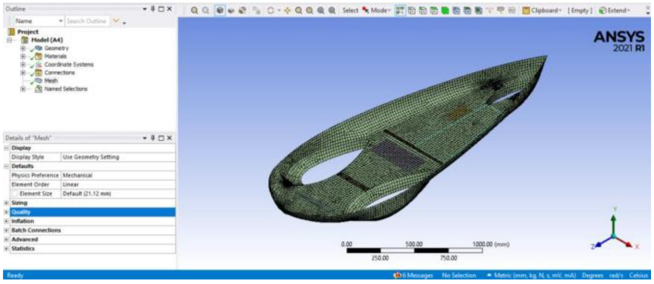

Fig-3

4.4) Material Data:

The material selected for this Analysis were Epoxy carbon woven (230gpa) wet, and end-grain balsa (0.095). Then fabrics named, Carbon Fibre and Balsa were created. Further a stack up was defined with Carbon fibre of 1mm on either side with Balsa (20mm) as the core material.

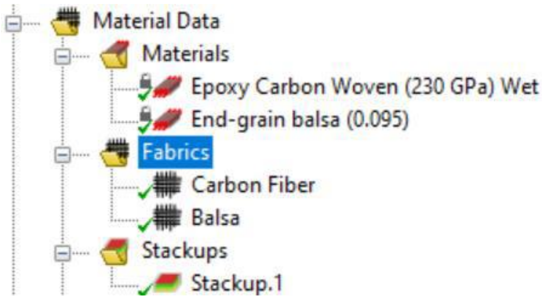

Fig-4

4.5) Element Data and Rosettes:

The base was defined as the element. The Rosette in was taken on the middle of the base.

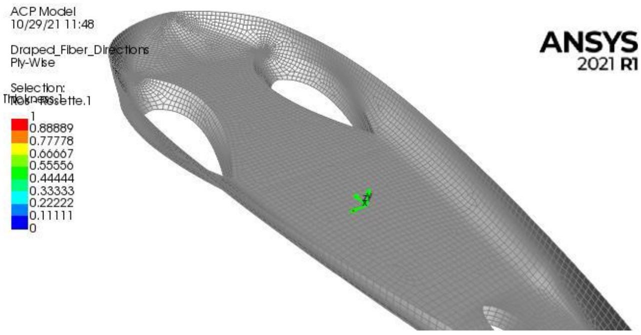

Fig-5

4.6) Oriented Selection set and Modelling Ply:

The predefined rosette was taken to define the Oriented Selection Set. Further a Modelling ply was defined using the Stack Up that was created earlier.

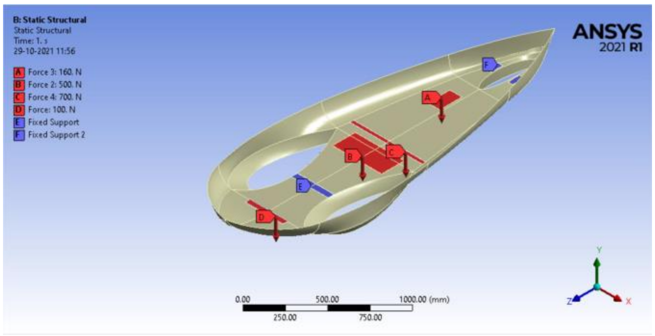

Fig-6: Load Bearing Areas

The Load bearing area was defined considering the maximum amount of load that would act on the vehicle in static condition. The two-wheel mounting areas were considered as fixed support.

5. Results:

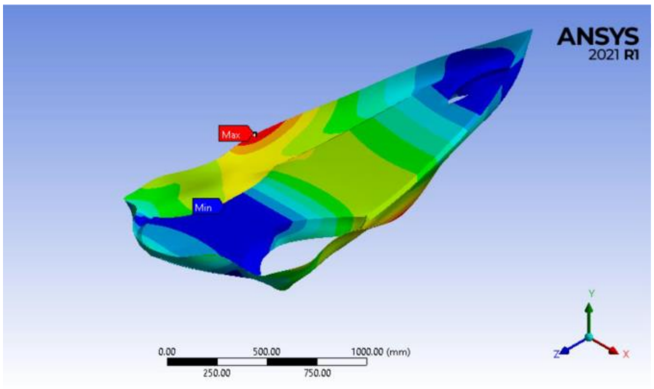

Fig-6: Stress Distribution

The total deformation on the vehicle was as follows. The maximum deformation was on the edge of the vehicle of about 13mm. The maximum strain on the vehicle was at the rear wheel mounts.

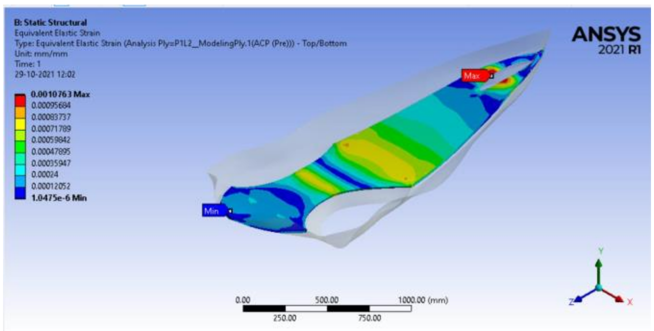

Fig-7: Deformation

The maximum weight of the monocoque was calculated to be about 3.6kgs.

Properties	
Volume	2.5367e+006 mm^3
Mass	3.6808 kg
2D Tolerance	Default (1.e-005)

Fig-8

6. Conclusion

Even though plenty of factors are not taken into consideration such as engine vibrations etc. the results do represent the maximum stress that the vehicle would observe and hence the maximum deformation was calculated. The focus now will be on decreasing this deformation and increasing the strength without compromising the weight of the vehicle.

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