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Design and Manufacturing of Aerodynamic devices for Formula Student Car

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Abstract – *Aerodynamic devices are utilized in higher levels of motorsport such as Formula-1 to increase the traction of the tires by generating down force. This increase in traction increases the performance envelope of the race car since cornering can be performed at higher speeds without a loss of control. However, the aerodynamic device that provides the down force also increases drag. The additional drag is especially detrimental on straight sections of the track. To decrease the drag adjustable wings are used. This paper describes the initial design and development of the front and the rear wing of a Formula Student car. The front and rear wings are designed to generate maximum negative lift (downforce) within the stated acceptable limits of increased drag and reduced top speed. CFD analysis of front and the rear wing and manufacturing are also covered in this paper.*

Key Words: Aerodynamics, Downforce, Drag, Formula student, Wings, CFD.

1. INTRODUCTION

Aerodynamics is the science of how air flows around and inside objects. More generally, it can be labeled "Fluid Dynamics" because air is really just a very thin type of fluid. Above slow speeds, the air flow around and through a vehicle begins to have a more pronounced effect on the acceleration, top speed, fuel efficiency and handling. Therefore, to build the most efficient possible race car it is needed to understand and optimize how the air flows around and through the body, its openings and its aerodynamic devices. It is now established that aerodynamics has a key role in the performance even when it is moving at low speeds on the track. A well aerodynamically designed car is able to utilize the airflow around it in order to produce as much negative vertical force and drag. In this way, the grip and thus the performance of the tires increases and the car is able to achieve higher cornering speeds while at the same time there is better fuel consumption due to the reduced air resistance. Aerodynamics have been a major subject in racing for the past 40 years with the purpose of increasing the normal load on the tires for increased grip without the corresponding addition of mass. The amount of grip available in the tires along with aerodynamic drag and engine power set the theoretical limits for the vehicle's velocity around the track, especially in cornering, and it is thus of particular interest when designing a vehicle to increase this grip while keeping drag to a minimum.

Fig -1: Formula Student car with Aerodynamic devices

2. Problem Definition

2.1 Problem Statement

Light weight vehicles have limited cornering ability because of weight over the wheels is lesser which causes the vehicle to roll about its roll axis. The magnitude of lateral force is directly proportion to the velocity of vehicle. There is necessity of developing a system which will be able to provide variable downforce with minimum amount of drag.

2.2 Project Objectives

- To increase the downforce.
- To maintain traction on the wheels during Highspeed cornering.
- To reduce the drag force.

3. Design and Analysis of Wing

The primary intention of race car aerodynamics is to generate a desired intensity of downforce for the least possible amount of drag. The modeling was performed using CATIA V5 and the analysis was done both analytically and by means of computational fluid dynamics (CFD) using a flow simulation integrated with CATIA V5.

3.1 Theoretical calculation

1. Dimension Calculation
Front Wing Span=1383.2 mm=1.3832 m
Rear Wing Span=858.2 mm= 0.858 m
Mean Span = 1.121 m
Assume, Aspect Ratio= 1.5

- Aspect Ratio= $(Span)^2$/ Area
- Total Wing Area = 0.837 m^2

Front Wing Area= 0.3350 m^2…………..(Taken As 30% Front)
Rear Wing Area= 0.5852 m^2……………(Taken As 70 % Rear)
Area = Span * Chord

- Front Chord=0.242 m
- Rear Chord= 0.3511 m

2. Downforce Calculation

$F= 0.5C_L\rho AV^2$

Here, F= Down Force
C_L= Coefficient of Lift = 1.12
ρ = Density of Air= 1.125 kg/m^3
A= Total Area of Wings
V= Velocity of Vehicle= 80 km/h= 22.22 m^2/s

$F= 0.5C_L\rho AV^2$
$F=0.5*1.12*1.125*0.837*22.22^2$
F= 260.348 N

Hence downforce get by the theoretical calculation is 260.348N.

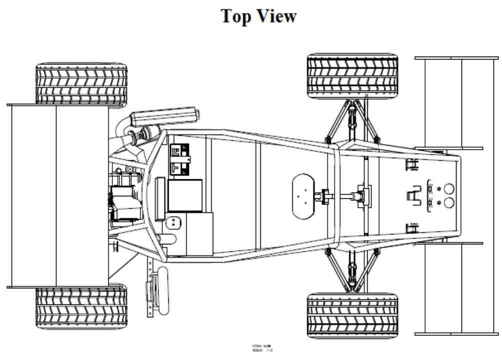

Fig -2: Top view of front and rear wing

3.2 Selection of Aerofoil

As we want to increase Downforce of car for maintain the traction, this required downforce can be generated by using different aerofoil. We have Selected Under–camber Aerofoil S1223. Values defining the airfoil are mentioned in the table 1 below.

Table –1: S1223 Aerofoil data

Description	Value
Aerofoil	S1223
Thickness	12.13%
Max. thickness position	20.21%
Max. camber	8.67%
Max. camber position	49.50%
Number of panels	81

3.3 Angle of Attack

A number of airfoils were analyzed using the XFLR5 tool to determine a suitable candidate for the wing. Eventually it was decided to use Selig S1223 airfoil due to its high lift at low Reynolds number characteristic. The coefficient of lift Cl is 1.258 and coefficient of drag is 0.113 at α=5º. A is Angle of attack for wing.

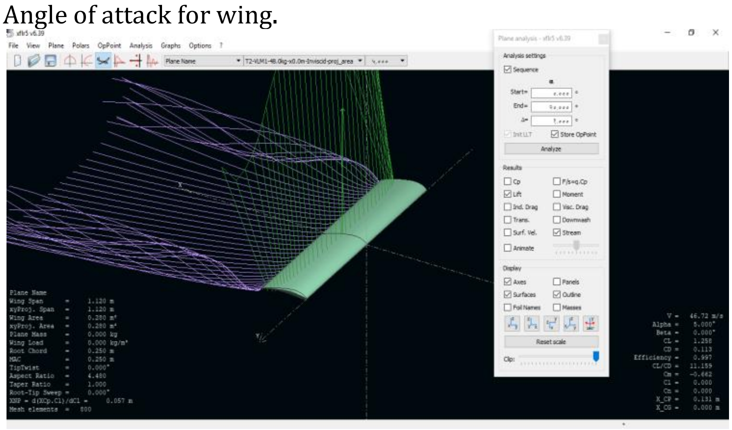

Fig -3: Aerofoil simulation using XFLR5

3.4 Modelling

As per the dimensions, shape of aerofoils, angle of attack, design a wing in CATIA V5.

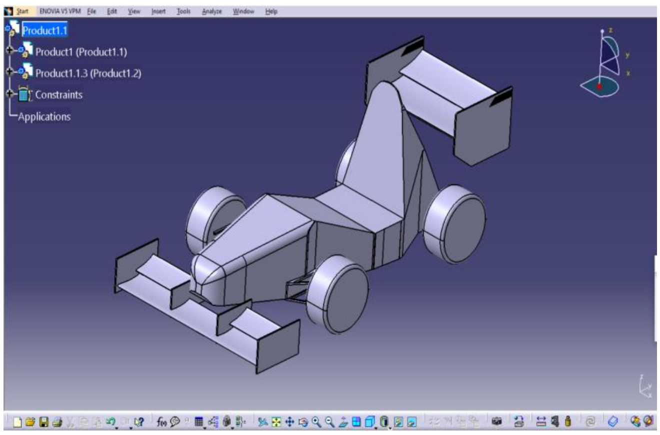

Fig -4: CAD model of vehicle with front and rear wings.

3.5 Analysis of vehicle in CFD

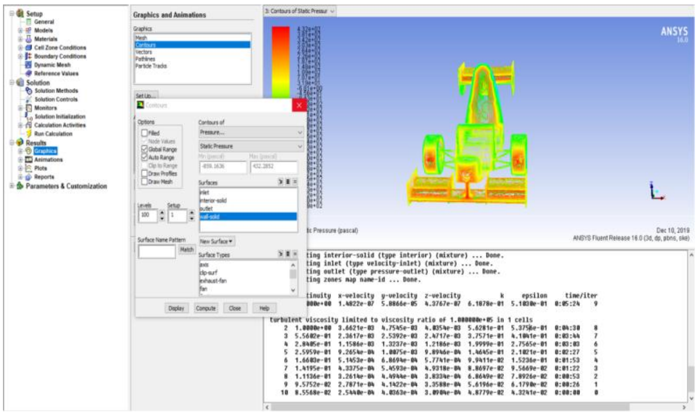

Fig -5: Analysis of vehicle with wings in CFD

In CFD analysis first import 3D model then enclosed it in a box, then mesh it. After meshing gives input values like velocity of vehicle, density of air. Then add forces in it then click to solution. After solving we get downforce value -194.05N. Negative sign indicates the force is in downward direction. In CFD can get different values like drag force, path line, air flow, pressure values etc.

4. Manufacturing

Our consideration for material selection were ease of manufacturing, cost efficient and light in weight. For this we compared best available materials which are high density foam and thermocol and we found thermocol to be best suitable material for our job. In addition to give strength two materials were compared namely Carbon Fibre and Glass fibre reinforced plastic. From which glass fibre reinforced plastic is selected to cover the aerofoil shape. Thermocol is used as base material of the manufacturing of aerofoil. The thermocol is cut by using wire cut machine in the same shape of aerofoil. For our design the aerofoil should be able to sustain minimum 20kg of load hence we decided to covered the aerofoil shape with Glass Fibre Reinforced Plastic. One layer of FRP is added, which can sustain 20kg load easily. While applying FRP thermocol melts so before applying FRP, cover thermocol with aluminum foil so it will not melt due to heat of FRP.

Fig -6: Cut themocol into Aerofoil shape by wire cutting.

Fig -7: Apply layer of Fibre reinforced plastic.

Fig -8: Side view of vehicle with wings

Fig -9: Wings mounted on vehicle.

5. CONCLUSION

The purpose of the project was to design an active aerodynamic front package in an effort to increase the performance of race car. The proposed aerodynamic design consists of a wing arrangement, which allows adapting the angle of attack. As selected aerofoil and its angle of attack gives high downforce and less drag. Effective wings can be made with thermocol and FRP without increasing weight of vehicle. Wings showing better performance while cornering as well as on straight patch. High speed cornering is achieved without losing traction. Cost has been kept to a minimum to ensure economic feasibility of the proposed design is an essential part of the project.

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