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Design, Analysis and Manufacturing of Aerodynamic System of a Formula Student car

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Abstract-

This paper describes the process of designing, optimization and manufacturing of an Aerodynamic system of a Formula student car using Computational Fluid Dynamics. The adoption of CFD for simulation could provide flexibility of design and permit optimization at reduced cost .The main objective of this project is to use this CFD tool for design and optimization of an efficient aerodynamic system so as to reduce the drag and provide maximum downforce which would enable stability while cornering.

Keywords— *Computational Fluid Dynamics, Aerofoil, Flaps, Undertray, Diffuser, Aerodynamic drag, Downforce*

I. INTRODUCTION

The Aerodynamic system forms a key element for conception of any automobile. This paper focuses on design of aerodynamic system for a Formula student Car. Formula Student is a engineering design competition held internationally among countries of the world at a student level where students build an open wheeled race car Design an aerodynamic package for a formula student car has two primary objectives - Reducing drag and producing maximum amount of downforce by iterating through various parameters. This paper provides in depth knowledge of designing process of various parts of the Aerodynamic system of a Formula student car with the specifications as shown in table I

Technical Specifications	
Weight with65 kg Driver (kg)	294
Weight Distribution (F:R)	40 : 60
Wheelbase (mm)	1545
Trackwidth (mm)	1200
Tires	16*6*10
Tire Compound	R25B
Power Unit	Triumph Daytona 675R

Table 1

II. OBJECTIVES

a) Select Proper Airfoil considering optimum Coefficient of Drag and downforce
b) Reduce Aerodynamic drag for the vehicle
c) Select the angle of attack for Airfoil

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d) Perform CFD analysis for all the components
e) Selection of material and manufacturing process for the components
f) Ensure that all the aerodynamic system is built in accordance of Formula student rules

III. DESIGN PROCEDURE

a)By iterating various weight distributions, downforce distributions & roll stiffness distributions front to rear of the vehicle, a target downforce was obtained. The Iterations were performed for obtaining the target values of downforce for the Formula student vehicle which were using tire data of Hoosier 16.0 x 6.0-10 R25B tire in MS Excel. A total of five variables were iterated in all their possible and valid permutations which were - Tire pressure, Camber angle, and Weight distribution of the vehicle, Downforce distribution of the aerodynamic package and roll stiffness distribution of the vehicle. After performing various iterations the peak value of required downforce was obtained

b)The maximum value of Drag was obtained by limiting the maximum speed of the vehicle in Autocross/Endurance using the maximum power offered by our engine. For determining maximum speed of vehicle, peak velocity of 80 Km/hr was selected

c)After obtaining the input parameters, the design of the following components of Aerodynamic system were carried out –
i) Front wing
ii) Rear wing
iii) Undertray
The primary designing of the components was carried out in Solidworks software. For optimization of the designed components, Ansys Fluent software was used as it provided high accuracy and a variety of tools for analyzing result. Ansys Fluent software uses Finite Volume Method and cell centered formulation for solving Fluid flow equation.

IV. DESIGN FINALISATION

A.*Front and Rear wing*:

Airfoil Selection:
The Airfoils are selected for Front wing and Rear wing. The airfoil for both front and rear wing is divided into two parts – Main Airfoil and Flap. Selection of Main airfoils will be done by comparing Cl vs Alpha for main airfoils as the angle of attack of main airfoils is very less leading to less increase in frontal .Selection of Airfoil for Flaps is done by comparing Cl/Cd vs Alpha graphssince the angle of attack of flaps is quite higher with respect to horizontal they contribute significantly to the frontal area of the whole vehicle.Thus the Coefficient of Drag was also considered as important as the Coefficient of Lift and the Ratio of Coefficient of Lift to Coefficient of Drag with respect to angle of attack was taken for consideration. The airfoil with the maximum Cl/Cd ratio was desired.

1) *Front wing*

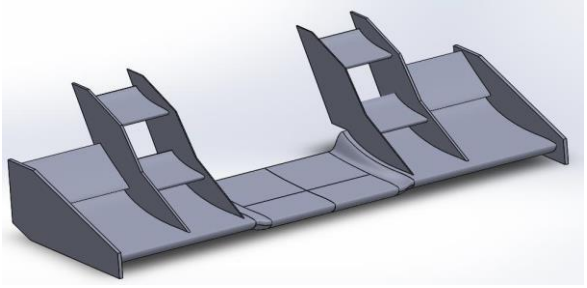

Fig 1. Front Wing CAD

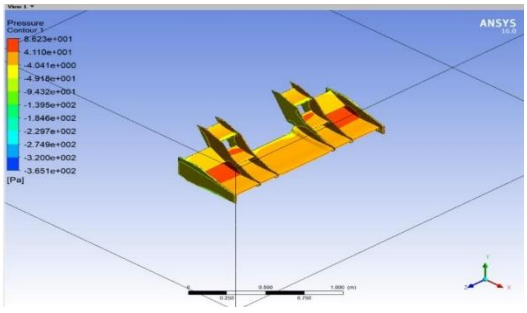

Fig 2. Front Wing Ans

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Main Airfoil S1223:

The main airfoil was selected by comparing Cl vs alpha graphs. Since the angle of attack of main airfoils is very less the increase in frontal area with increase in frontal area is considered to be very less. Due to this the airfoils shortlisted for comparison were such that they had very low Coefficient of Drag and high Coefficient of Lift at low angles of attack. The airfoil with the maximum coefficient of lift was desired.

S.NO.	AIRFOILS	CL	CD
1	S 1223	HIGHEST	MODERATE
2	GOE 477	LOWEST	HIGH
3	EPPLER 1210	MODERATE	LOWEST
4	GOE 448	HIGH	HIGHEST

Table 1 Front Main Wing Airfoil Selection

Therefore, S 1223 is selected as the main airfoil, using the above procedure of comparison. The graphs of CL vs Alpha, CD vs Alpha are given below:

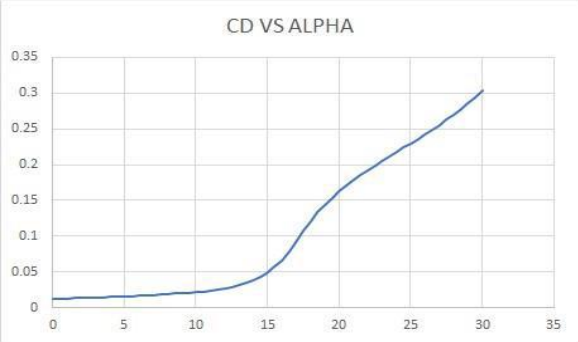

Fig 3 S1223 Cd vs Alpha plotFig 4 S1223 Cl vs Alpha plot

FLAPS - The flaps for Front wing were finalized by comparing the Cl/Cd vs Alpha graphs. Since the angle of attack of flaps is quite higher with respect to horizontal they contribute significantly to the frontal area of the whole vehicle. This is why the Coefficient of Drag was also considered as important as the Coefficient of Lift. Hence the Ratio of Coefficient of Lift to Coefficient of Drag with respect to angle of attack was taken under consideration. The airfoil with the maximum Cl/Cd ratio was desired. In case of the inboard flaps a lower angle of attack was to be used, and hence the required airfoil must perform at lower angle of attacks i.e. like a main airfoil. Hence the S 1223 already being selected as the best main airfoil in the above comparison was used.

S.NO.	Airfoil	Cl/Cd Ratio
1	NACA 6409	Highest
2	NACA 4412	Moderate
3	GOE 464	Lowest

Table 2 Front Wing Flaps Airfoil Selection

Therefore, NACA 6409 was selected as the outboard flap using the comparison mentioned above.

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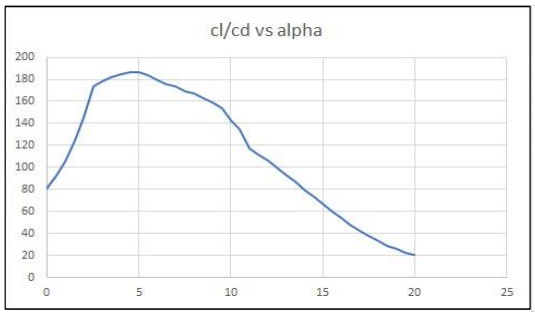

Fig 5 NACA 6409 cl/cd vs Alpha Plot

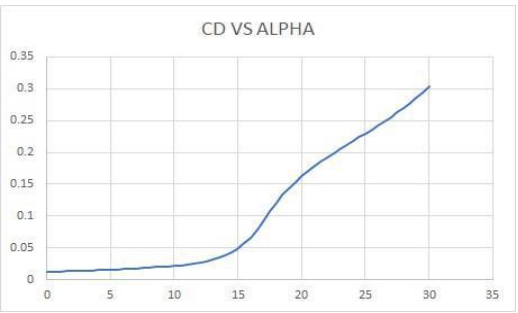

Fig 6 S 1223 CD Vs Alpha

2)*Rear Wing*

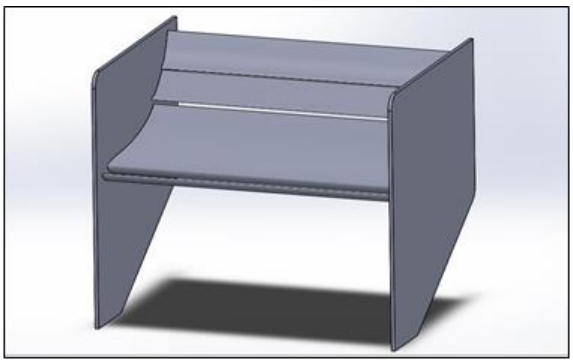

Fig 7 Rear Wing CAD Model

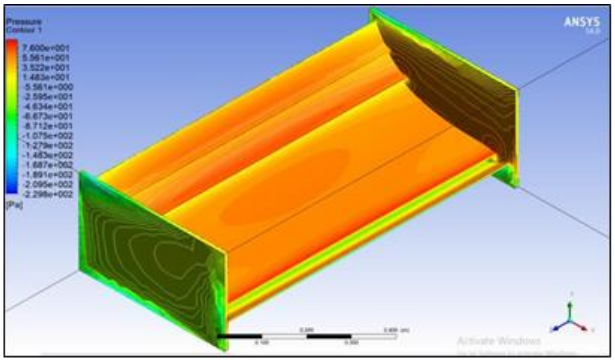

Fig 8 Rear Wing Ansys Fluent

Rear Wing is one of the most important part of the aerodynamic system and is responsible for producing downforce of 80N and drag of 20N. The Rear wing is made of Side flap, Main Airfoil and Flap and is designed so as to have Maximum plan area and minimum frontal area. The Rear wing is divided into Side flap, main wing and flap and is made in different parts. The flaps are manually adjusted so as to produce maximum downforce during skidpad event and minimum drag during the acceleration event. The selection of different airfoil is given below

Rear Main Wing Airfoil Selection

Therefore, S 1223 is selected as the main airfoil, using the above procedure of comparison. The graphs of CL vs Alpha, CD vs Alpha are given below:

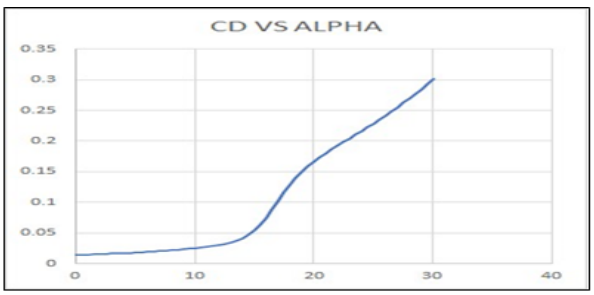

Fig 9 S1223 CD vs Alpha plot

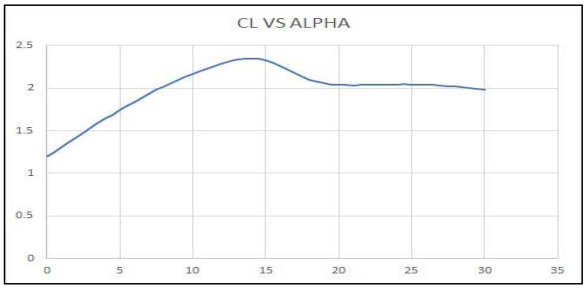

Fig 10 S1223 CL vs Alpha Plot

Rear Wing Flap Airfoil Selection

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Therefore, GOE 464 was selected as the flap using the comparison mentioned above. The graphs used for comparison are the Cl/Cd vs alpha graphs, mentioned below:

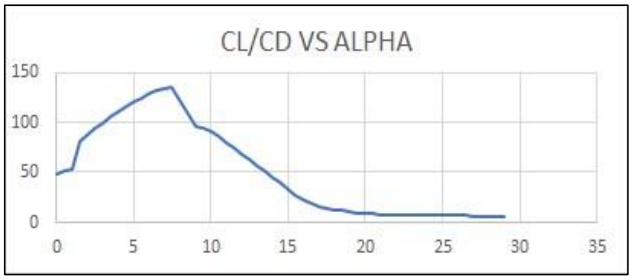

Fig 11 GOE 464 CL/CD vs Alpha

B.*Undertray*

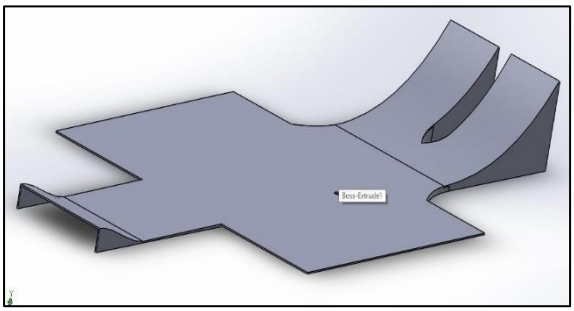

Fig 12 Undertray CAD model

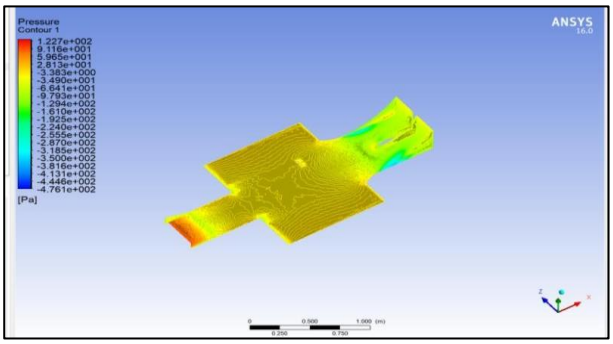

Fig 13 Undertray Ansys Solution

The undertray has been designed with an aim of maximizing the downforce by increasing the plan area as much as possible and by accelerating the air beneath the vehicle using a diffuser. It produces downforce of 66.5 N and Drag of 19.2 N. The undertray was designed as 3 parts each having a specific function, namely the undertray inlet, the flat portion and the diffuser.

1) *Undertray Inlet*:

It was designed to increase the amount of air flowing into the undertray which on getting restricted between the flat portion and the ground will accelerate and generate a drop in pressure head.

2) *Flat Portion* :

The flat portion was designed so as it maintains a constant gap between itself and the ground. The air present between it and the ground is at a lower pressure head than that of the surrounding air. This lower pressure is exerted onto the large surface area of the flat portion and in turn converted into downforce.

3)*Diffuser*:

The diffuser was designed to perform two jobs. Firstly, it generates a region of low pressure just behind the flat portion of the undertray which in turn pulls the air beneath the flat portion towards the

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rear of the vehicle and in turn increases its velocity further. This results in an even larger pressure drop.

V. MATERIAL SELECTION

Selection of material was a key element for maintaining high performance to weight ratio.For selection of material we compared the material based on the following parameters:

- Tensile Strength
- Stress by Strain
- Cost
- Density

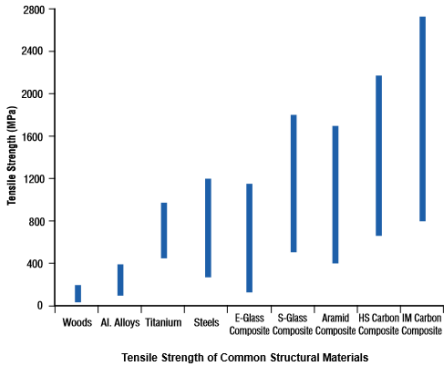

Fig 14Tensile Strength:

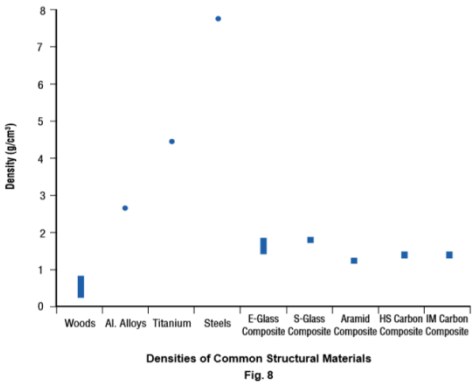

Fig 15Density:

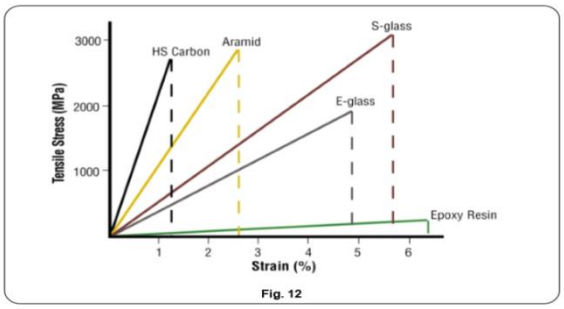

Fig 16Stress Vs Strain:

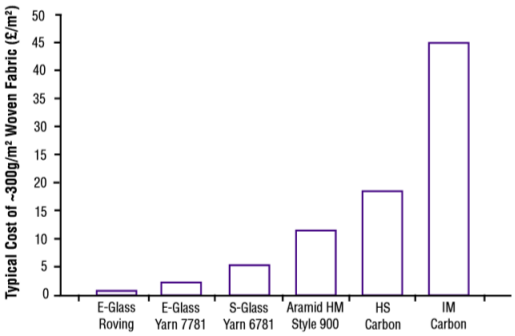

Fig 17Cost:

Based on the above results and comparing the properties we decided to use Carbon fiber for our parts.

Epoxy resin is used as a resin system to bond carbon fiber laminates. Epoxies generally out-perform most other resin types in terms of mechanical properties and resistance to environmental degradation, which leads to their almost exclusive use in aircraft components, high performance vehicles etc.

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VI. MANUFACTURING

For manufacturing the parts we used wet hand layup technique. Resin was impregnated by hand into fibres which are in the form of woven fabrics. This was accomplished by using brushes for forcing resin into the fabrics and a bath of resin. It was followed by vacuum bagging of part to ensure further resin impregnation and to consolidate laminates. Laminates were left to cure under standard atmospheric conditions at room temperature for 24 hours.

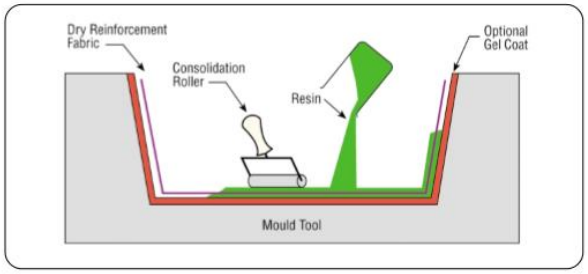

Fig 16 Wet Hand Layup

VII. RESULT

After implementation and study of the simulation on Ansys fluent software, the following results were obtained and the downforce and drag produced by each component is expressed in following table:

Table 5 Downforce and Drag values

Component	Downforce (N)	Drag (N)
Front Wing	102.9	13.7
Rear Wing	80	20
Undertray	66.5	19.2

VIII. CONCLUSION

Design, Simulation for the aerodynamic package was successfully performed. This simulation results indicated that aerodynamic system will improve cars performance in cornering and straight line speed.. The main purpose of the paper was to design a vehicle which could produce maximum downforce for stability during cornering and minimum aerodynamic drag. The vehicle further designed using this approach proved it and won the Skidpad event in Formula Bharat 2020.

REFERENCES

[1] William F. Milliken and Douglas L. Milliken 1995, “Race car Vehicle Dynamics”, Society of Automotive Engineers, Inc.

[2] Race Car Aerodynamics – JosphKartz

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[3] Anderson – Computational Fluid Dynamics

[4] Computational Methods for Fluid Dynamics – J H Ferziger&M.Peric

[5] Literature Review of accelerated CFD Simulation Methods towards Online Application" by Rebei Bel Fdhila and Md LokmanHosain

[6] Derek Seward 2014, "Race Car Design", Palgrave, Macmillan Education

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