2D ANALYSIS OF MULTI-ELEMENT AIROFOIL FOR WING

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ABSTRACT: *This paper covers a study on research, design, analysis of multi-elemental aerofoil's front wing & rear wing. The focus will be placed on reducing aerodynamic drag and increasing downforce in order to optimize and cornering of vehicle while maintaining the lowest weight possible. For this purpose we have used NACA's E423 aerofoil. We have used Solidworks for CAD modeling and simulated it on Ansys.Computational fluid dynamic analysis was used for the design of the front wing and rear wing. Optimal design gave a lift coefficient of -1.37 from the front wing & a lift coefficient of -1.48 from the rear wing. The drag coefficient of 0.104 from front wing & 0.094 from rear wing. The aerodynamic package was responsible for a significant increase in the performance of the vehicle under braking and during cornering, while the increase in the drag force had only a minimal effect on the top speed which was achieved during the event. Aerodynamics is used to develop realistic parameters for the specification of front and rear inverted aerofoils, or 'wings'. This wing package designed to produce maximum downforce within the stated acceptable limits of increased drag and reduced top speed*
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Keywords-Vehicle aerodynamics, race-car aerodynamics, wings and spoilers, drag & downforce.

1. INTRODUCTION

The Aerodynamic down-force is hugely depends on the design of the race car. The performance benefits which can be gained through the resulting increase in traction in search for increased down-force and reduced drag for formula student SAE car. It was the goal of the present research to determine areas where the aerodynamic forces are most performance enhancing by utilising CFD and then to validate the predictions using on-road measurements from the 2017/2018 of Rajendra Mane College Of Engineering And Technology, Team MH-08 Racing, Formula Student SAE race car.

The restrictions on the car frame and engine are limited so that the knowledge, creativity and imagination of the constructors is really challenged.

The car is build with a team effort over a period of about one year and are taken to the annually competition for judging and comparison with approximately 150 other vehicles from colleges and universities throughout the India.

In order to improve the properties of our car as much as possible the attention is dedicated to the chassis, to the engine, and to the aerodynamic also.

This article is focused especially to the improvements that we achieved on the account of front and rear wings. In this approach the body of the car is not considered.

1.1 Indentations and Equations

The fundamental goal of any aerodynamic race car design is to "Provide the driver the means to control and change the velocity of the vehicle at the greatest rate possible. The vehicle is the system by which artificial forces (i.e., non-human forces) are generated in order to accelerate the driver's body while he attempts to use the vehicle control systems to maintain the highest possible acceleration level, in the appropriate direction, at all times. For maximum acceleration, the force generation systems must be as powerful as possible and their mass, added to that of the driver and including the fuel necessary, as small as possible. The resultant forces which occur during the operation of a road vehicle can be split into three categories:

(i) Acceleration,
(ii) Cornering,
(iii) Braking (deceleration).

Each of these must be transferred to the surface on which the vehicle is travelling in order, for the driver to be in control of the vehicle. This transfer of the forces is via the tyres' contact surfaces.

It is useful to analyse the force at the tyre/road surface interface to see what influences it.

The maximum horizontal force which can be achieved between a tyre and the road surface is dependent on the normal force at the interface and the friction coefficient, μ_{max}.

$$F_{horizontal} = F_{vertical} \times \mu_{max}$$

$$F_{vertical} = M g$$

2. Aerofoil

An aerofoil is the shape of a wing or blade. An aerofoil shaped body moved through a fluid produces aerodynamic forces. The component of this force is perpendicular to the direction of motion is called lift. The component parallel to the direction of motion is called drag. There are two types of aerofoils symmetrical and unsymmetrical. For race car aerodynamics we are using cambered aerofoil. By using cambered aerofoil we can get required downforce by adjusting angle of attack.

2.1 Symmetrical Aerofoil

Fig.2.1

In a symmetrical aerofoil chord line joins leading edge and trailing edge. It divides aerofoil into two symmetrical parts. Its coefficient of drag is zero and coefficient of lift is zero as shown in Fig.2.1.

2.2 Cambered Aerofoil

Fig. 2.2

As shown in Fig. 2.2 cambered aerofoil chord line does not divide aerofoil into two symmetrical parts. In symmetrical camber line joining leading edge and trailing edge as shown in figure. As angle of attack increases or decreases velocity, streamline flow, pressure gradient, downforce, coefficient of lift &coefficient of drag changes respectively

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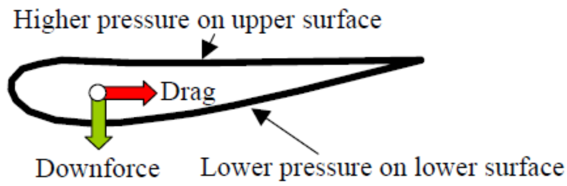

Fig. 2.3Typical cross section of wing mounted on race car

2.3 How to select and design a wing set up

First thing the designer should know that the front wings should not generate significant drag. The tests on the hill climb single sitter in the full-scale wind-tunnel demonstrated this fact [McBeath 1998], and even large changes to angle of attack did not alter the overall car drag by more than percentage pointer so. However, relatively small changes to the rear wing configuration not only altered the downforce but also made big differences to the car's drag figure. This situation is typical and representative of single sitter in general. In the continuation the eight-point plan to a first approximation of wings set up is presented:

1. Calculation the theoretical top speed without wings.

2. Decide how much you are prepared to knock off that top speed by the addition of wings.

3. Calculate the difference in power absorption figures between the top speed without wings and the top speed you are prepared to accept with wings.

4. The difference between these two power absorption figures is what you are going to donate to rear wing in the quest for downforce.

5. Calculate the maximum wing *CD* value that this represents.

6. Consult the wing catalogues to seek out first the basic configuration, then a specific profile.

7. Calculate the theoretical downforce figure that The rear wings give, then calculate the downforce required at front to balance this suitable configuration, profile, and approximate angle of attack for the front wings.

2.4 Downforce and Drag:

In Fig.2.2 below, we have a conventional aerofoil (that is, as in a airplane wing) with air moving across it from left to right as identified by the streamlines. (The streamlines represent a pictorial description of the fluid motion of the air particles in a steady-state flow.) The air travels along the upper surface and lower surface of the aerofoil. Due to the curve of aerofoil the air flow above the aerofoil gets obstructed and velocity of air decreases whereas flow below the aerofoil is not obstructed and velocity of air is also not disturbed. Due to this high-pressure area is generate above the aerofoil and low-pressure area is generated below aerofoil. Due to this pressure difference downforce is created. As we can see in the fig. Below orange region shows the area of high pressure and area below aerofoil is low pressure area.

Equation for coefficient of lift: -

$$C_L = \frac{2L}{P*V^2*A}$$

Where,
L = lift
V= speed of air
P = density of air
A= area

Equation for coefficient of drag: -

$$C_D = \frac{2D}{P*V^2*A}$$

Where,
D = drag
V = speed of air
P = density of air
A = area

2.5 Tools:

Solidworks:

Solidworks is the CAD program used. It was used to design all the geometries for the aerodynamics package before being imported and pre-processed in ANSYS Design Modeler.

ANSYS Workbench and FLUENT:

ANSYS Workbench is an engineering software suite, equipped with many different solvers and project management utilities. It was the main toolbox for this project, used to organize the modelling, meshing, solving and post-processing parts of the different optimizations and simulations.

FLUENT is the CFD solver used in this project. It is included in the Workbench suite which allows for a smoother work-on. Most of the knowledge about using this software has been acquired in a learn-by-doing approach, and the procedures used have been derived from the best practice guidelines.

3. 2D ANALYSIS OF WINGS

In our project we used “NACA E423” aerofoil for our wing designing which gives best results on streamline flow, drag, downforce. Computational fluid dynamic analysis was used for the design of the front wing and rear wing. First, we plot the coordinate points of “NACA E423” on Solidworks, then we design wing of our requirement within the SAE rules. Designing of wings is mostly depend upon the power output of your car, downforce & drag. Computational fluid dynamics is most important step of your wing design. Taken into consideration of downforce, drag & streamline flow the final design of must done.40% to 45% downforce from front wing and 60% to 55% downforce from rear wing must be optimized.

3.1 Front Wing Analysis:

For front wing we have used “NACA E423” aerofoil. We divide the wing two sections across the nose. Each part is having two elemental aerofoil. Fist element is having a span of 500 mm span,50% thickness 300 mm chord length and is set at an angle of 5 degree to the horizontal. Second element of an aerofoil is having 500 mm thickness, 50% thickness, 300 mm chord length and set at an angle of 17 degree to the horizontal .From Ansys we have calculated the values of Cd and Cl. We have got the values of Cd and Cl as 0.104 and 1.37 respectively as shown in Fig.3.2 & Fig.3.3.Both the parts of front wings are generating a downforce of 343.39 N and drag force of 12.704 N.

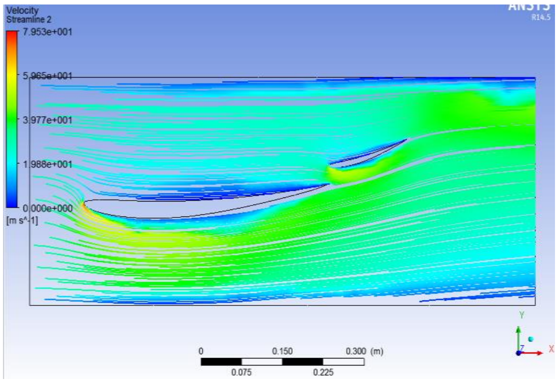

Fig3.1 Streamline flow diagram of front wing on CFD in 2D

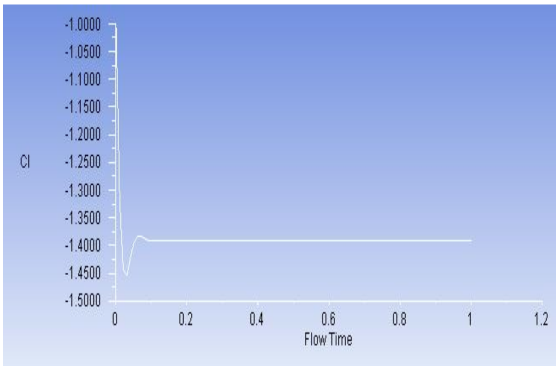

Fig3.2 Graph of C_l for front wing

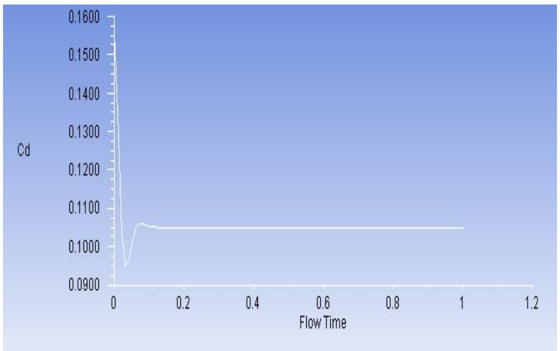

Fig. 3.3 Graph of C_d front wings

3.2 Rear Wing Analysis:

For Rear wing we have used naca E423 aerofoil. For Rear wing we have used complete aerofoil section in front. Wing having two elemental aerofoil. Fist element is having a span of 800 mm span,100% thickness 350 mm chord length and is set at an angle of 5 degree to the horizontal. Second element of an aerofoil is having 800 mm span, 50% thickness, 200 mm chord length and set at an angle of 19 degree to the horizontal. From Ansys we had calculated the values of Cd and Cl. We have got the values of Cd and Cl as 0.094 and 1.48 respectively as shown in Fig.3.5 & Fig.3.6.Rear wings are Generating a downforce of 377.39 N and drag force of 23.704 N.

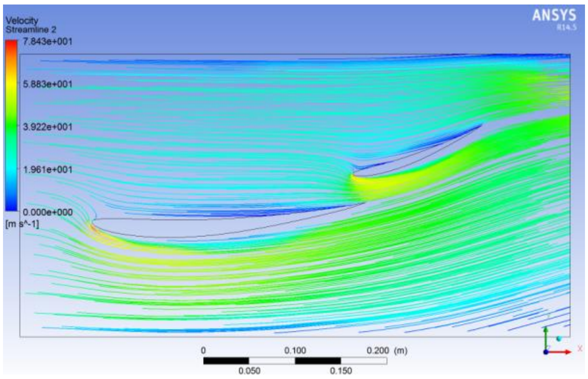

Fig. 3.4 Streamline over aerofoil in CFD

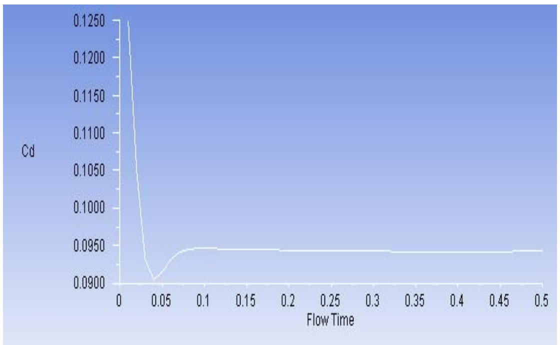

Fig.3.5 Graph of C_d for rear wings

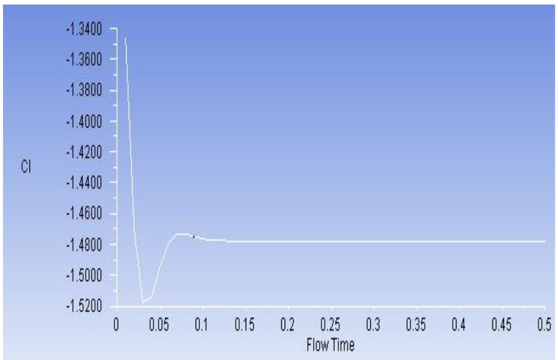

Fig. 3.2 Graph of C_l for rear wing

4. Conclusion

The generation of down force and its effect on lateral stability has a major effect on race car performance, particularly when high-speed turns are involved. In the process of designing and refining current race car shapes, all aerospace-type design tools are used. Because of effects such as flow separations, vortex flows, or boundary-layer transition, the flow over most types of race cars is not always easily predictable. Due to the competitive nature of this sport and the short design cycles, engineering decisions must rely on combined information from track, and CFD tests

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