Modeling and CFD analysis of F1 rear wing

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ABSTRACT

The paper aims to make an investigation with CFD simulation to analyze the airflow across the rear wing of F1 car with the velocity, u = 43.2871 m/s and Reynolds number of 3.2×10^6*.. The analysis is performed using the 3-D model that contains main plane along with the flap wing, attached together to create a rear wing module. Complete aerofoil is kept inside a box of 210mm height and 340mm long according to standard regulation. The chosen parameters for the present study are the chord length of the flap wing aerofoil and thickness. The simulations were performed by using ANSYS Workbench software. When cornering the wind speed is set up to 43 m/s that are the average speed of F1 car. Each cases are simulated with a gap between the aerofoil of 15mm and 45mm when the DRS is activated. Grid independence test and validation was conduct to make sure the result obtained is acceptable. The goal of this study is to investigate aerodynamic behaviour of airflow around the rear wing as well as to see how the thickness and the chord length of flap wing influence the airflow at the rear wing. The results show that increasing in thickness of the flap wing aerofoil will decreases the down force.*

Keyword : - *Modeling, CFD analysis, F1 rear wing.*

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1. INTRODUCTION

The rear wing F1 is an important element present in the F1 cars for its movement in the proper direction. Analysis of the rear wing gives a complete picture of key parameters and areas to be focused and they are to be understood w.r.t to the betterment of the performance [1]. It also encapsulates the information pertaining to the F1 for the flow movement around the rear wing. The Rear wing is a major aero-dynamic element used for altering the air-flows in and around the F1 car for reducing the drag and also it prevents the lift and further it also generates the downward force for the vehicle hassle-free movement. Coming to the designing of rear wings for F1 vehicles, the main concept emplying now a days is Computational Fluid Dynamics (CFD), it accompanies the track testing and experimental analysis with optimum design considerations. External aero-dynamics analysis and simulations made with the CFD used presently more as an entrenched tools for the development of the product and its process in the field of aerospace and automotive industries [2]. CFD and simulating process technology succor the scientists and engineers for understanding the actual physical actions and phenomena took place in and around the design that bestow a habitat for the optimization of performance along with the certain type of criteria unaccompanied with costliness and more and more number of testing of prototypes [3,4]. The main motto behind the mounting of these rear wings is to balance the down force and also to support the vehicle for its optimal performance in terms of speed and balance. It is similar to the case of conventional air planes but unlike the speeds of the air planes the F1 cars travel with lower speed. Mac number plays a significant role in both cases like sub sonic, sonic and supersonic flows [5,6]. Here in this case of F1 cars the rear wings support the vehicle movement by considering the air to be non compressible however all the aero dynamic effects that a air vehicle experiences must possesses the F1 too. Depends on the variation of the speed and angle of attack (AOA) the effects on the rear wing alter. The rear-wing is usually known to its aspect ratio, generally the AR is less for it that helps for generating large amount of down force magnitude and further it also suffers with the development of persuade drag.

1.1 Rear wing

The rear wing of the F1 vehicle is conceivably the utmost regulated aero-dynamic vehicle. There are possible no of boundaries over the variations of the aero-foil shapes, the topology and its flexibility. As discussed above the rear wing creates a quite large & powerful impact and also it emphasizes the down force in the direction from its span that is also considered as its width [7,8,9]. Next to that the embryonic angle of the rear wing will be slanted from the leading end edge to the trailing end edge, it is also considered as an angle of attack (AOA). Then after the estimation in between rear and front edges will be termed as the chord. Altering either AOA or chord will certainly influence the down ward force and also it creates the significant effect over the movement of the vehicle[10,11]. These quantities have to be used in an optimal manner for the obtainment of the maximum force required. While performing the movement it is quite important to notice and monitor the AOA and chord from time to time to stay away from the disasters.

Fig - Error! No text of specified style in document. Rear wing of an F1 car model VX220

2. MODELING OF F1 REAR WING

The rear-wing is modeled for the F1 vehicle using the ANSYS Workbench software that is further used for the analysis of CFD. The major parameter emphasized in the modeling the F1 car in relevance to the rear-wing is its span. The span of the rear wing is considered as 1.7m.

Fig 2 Aero-foil shape of the Rear-wing

The above Fig 2-1 shows the shape of the rear-wing that is been used in the F1 car vx220. It is a customary to use the aerofoil shape in the design of rear wing because of the aerodynamic friction experienced during the motion [12,13]. It will also reduces the wear and tear of the surface of the rear-wing and further the effects of the turbulent flow effects of the air along with eddies formation effects can be minimized [14]. In the Fig 2-2 it elaborates the complete rear wing of the F1 and in Fig 2-3 the mounting of the rear-wing to the F1 car and being assembled fully.

Fig- 3 3D-model of F1 Rear-wing

Fig -4 F1 car with rear-wing assembly

After the modelling part is completed the analysis of the rear wing with the velocity of 108MPH is made i.e., 48.28 mps. Before the analysis of CFD the meshing is performed then after the analysis is carried out. The pressure contours, velocity contours and angle of attack were critically analyzed for the understanding of the effects of flow conditions. Further a comparison is made based on the values of AOA and coefficient of drag and down-ward force.

3. ANALYSIS

Assumptions and conditions considered for the present work are listed below.

- Even though rear wing is a symmetrical element the complete wing is been modelled.
- The flow is assumed to be steady and disturbances free.
- The flow is an incompressible one.
- The type of flow passes is from laminar to turbulent.
- The working fluid is considered as air. The properties of it are equal to normal air
- The meshing is done with local prioritization.
- The uniformity in mesh size is required and in this case the meshing is uniform.
- The convergence of the solution is to be assessed based on the propagation and stability of the curve. In this case solution is not fully converged.

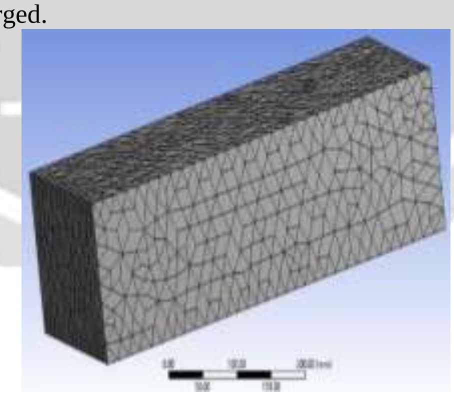

Fig -5 Meshing of F1 rear wing

The above Fig shows the meshing of the F1 rear wing in accordance with the mesh size ranging from 0.00mm to 200.00mm. As it is a pretty known fact that the size of the element influences the number of nodes. Hence in general during the analysis part it is made a condition that the meshing size differs from the part to part according to the priority being listed out.

Fig -6 Meshing of F1 rear wing with surroundings

The above Fig 3-2 shows the meshing of the controlled space in and around the F1 rear-wing in accordance the prevailing conditions. It is further considered for the investigation of the pressure and velocity contours and AOA.

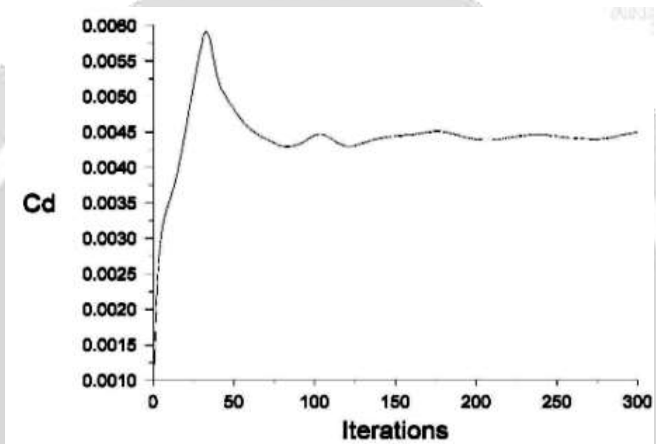

Fig -7 Graph of No of iterations vs coefficient of drag

The above Fig shows the graphical comparison of no of iterations performed vs coefficient of drag. The iterations count is observed to be 300 and the coefficient of drag ranges from 0.0010 to 0.0080. the peak value of coefficient of drag is found at the iteration value of 37, at this iteration the value of C_d is 0.0078.

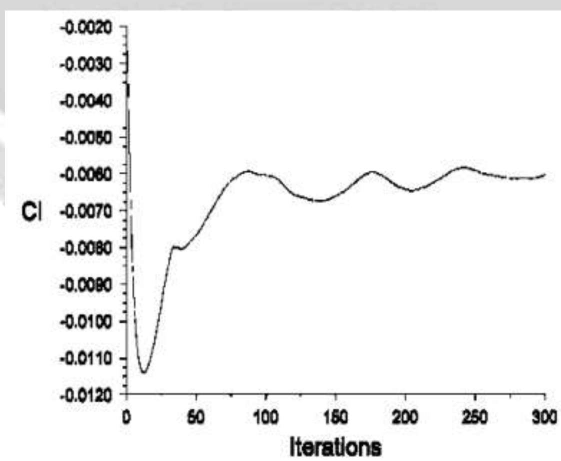

Fig -8 Graph of Number of iterations vs Coefficient of lift

The above Fig shows the graphical comparison of no of iterations performed vs coefficient of lift. The iterations count is observed to be 300 and the coefficient of drag ranges from -0.0120 to -0.0020. The least value of coefficient of lift is found at the iteration value of 18, at this iteration the value of C_l is -0.0115.

4. RESULTS

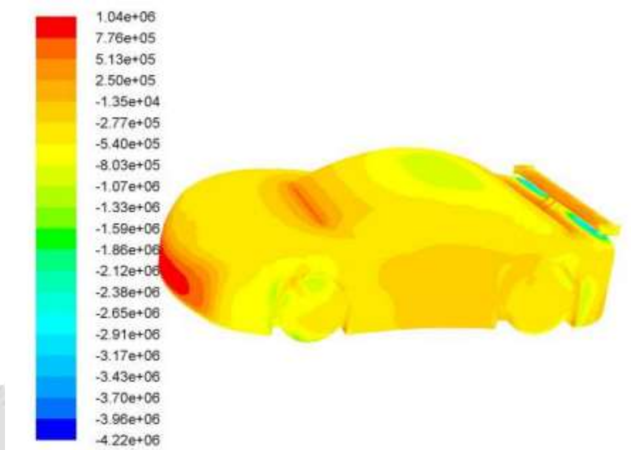

Fig - 9 Plot of pressure contour for F1 rear wing

The above Fig 4-1 shows the pressure contour plot of F1 rear wing along with the F1 car. The pressure acting over the rear wing is observed as average and above average as can be found from the numerals of analysis. The highest amount of pressure is been found at the front area of the F1 car.

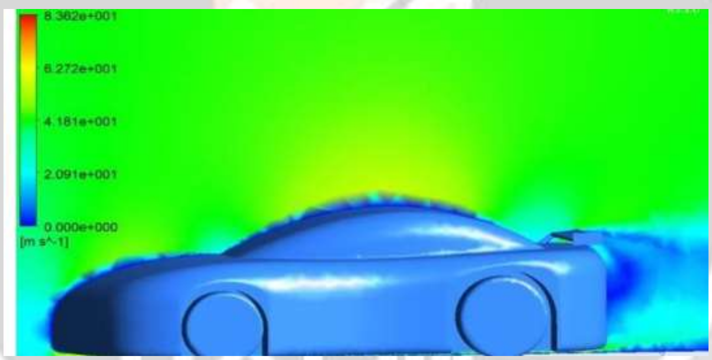

Fig -10 Velocity contour for F1 rear wing

From the above Fig 4-2 it is observed that the velocity contour has less effect over the rear-wing of F1. As it is been located at the end of the vehicle the velocity effect over it as less as compared to the front wings or front area.

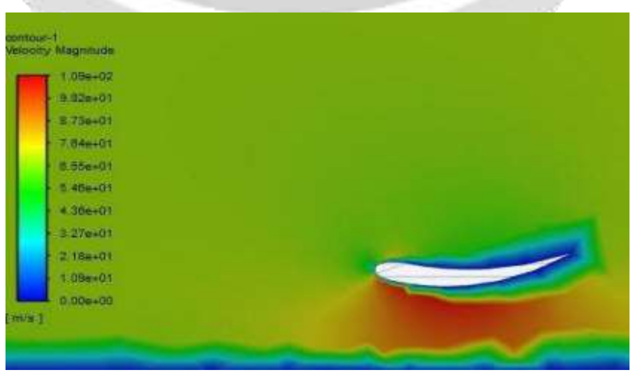

Fig -11 Velocity contour with 0^o AOA

The above Fig 4-3shows the velocity contour of the rear wing with 0^{o} angle of attack, in it the maximum velocity is found to be 1.09e+02 m/s and the minimum being 0 m/s. The maximum velocity experiences at the middle of the front frontal area and the minimum being observed at the end tip.

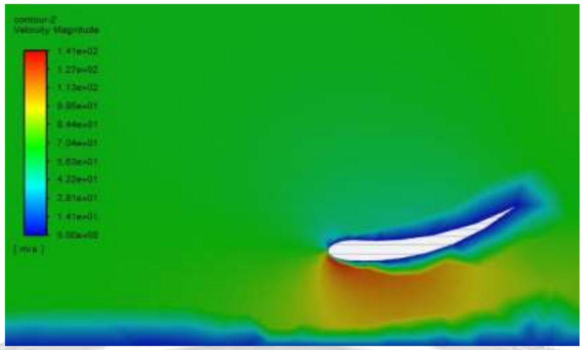

Fig -12 Velocity contour with 10^{o} AOA

The above Fig 4-4 shows the velocity contour of the rear wing with 10^{o} angle of attack, in it the maximum velocity is found to be 1.41e+02 m/s and the minimum being 0 m/s. The maximum velocity experiences at the middle of the front frontal area and the minimum being observed at the end tip.

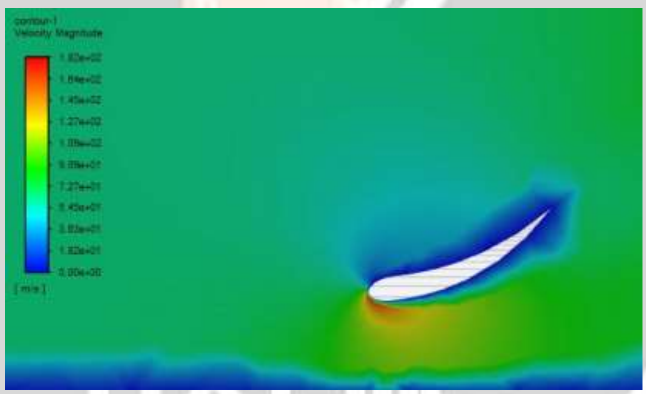

Fig -13 Velocity contour with 20^{o} AOA

The above Fig 4-5 shows the velocity contour of the rear wing with 20^{o} angle of attack, in it the maximum velocity is found to be 1.82e+02 m/s and the minimum being 0 m/s. The maximum velocity experiences at the middle of the front frontal area and the minimum being observed at the end tip.

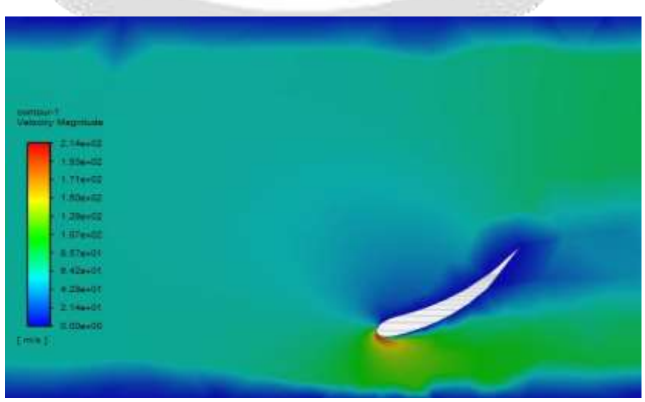

Fig -14 Velocity contour with 30^{o} AOA

The above Fig 4-6 shows the velocity contour of the rear wing with 30^o angle of attack, in it the maximum velocity is found to be 2.14e+02 m/s and the minimum being 0 m/s. The maximum velocity experiences at the middle of the front frontal area and the minimum being observed at the end tip.

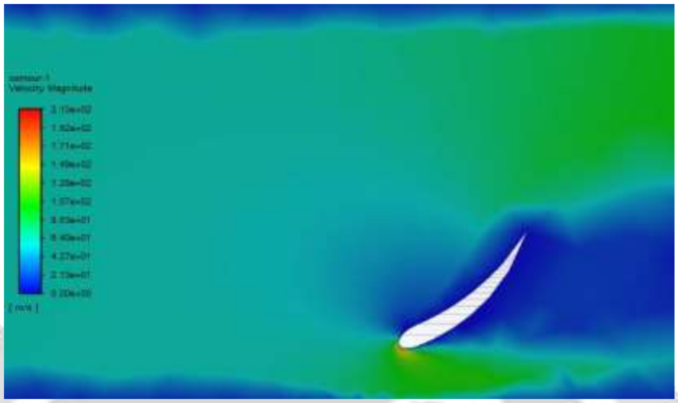

Fig -15 Velocity contour with 40^o AOA

The above Fig 4-7 shows the velocity contour of the rear wing with 10^o angle of attack, in it the maximum velocity is found to be 2.13e+02 m/s and the minimum being 0 m/s. The maximum velocity experiences at the middle of the front frontal area and the minimum being observed at the end tip.

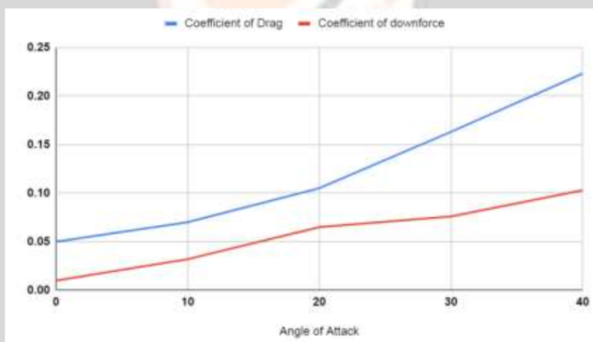

Fig - 16 Coefficient of drag and Coefficient of down force vs AOA

The above Fig shows the interrelationship in between the coefficient of drag, coefficient of down ward force and the angle of attack. It further interprets the connection of how the coefficients of drag and down ward force are changing with respect to the AOA. It is clear that up to the 20^o AOA the C_d and C_{df} are having same slope and in the positive upward direction. Once the AOA has crossed the 20^o AOA then there is a predominant change in the coefficient of drag is observed as compared with coefficient of down force.

5. CONCLUSION

From the above work it concluded that the rear wings takes part a cardinal role in the F1 vehicle. The rear-wings catch hold the adverse effects of the aero dynamic action and makes an arena for the vehicle to discharge its function well. And also it is found that the relationship among the coefficient of drag, coefficient of down force is fair enough till the angle of attack is 20^o. Further it is understood that with the application various composite materials like Kevlar or zylon based will play a better role against the dynamic functioning of the F1.

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