Design of Undertray for a Formula SAE car

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***Abstract*—For a typical FSAE vehicle, low center of gravity, low weight and low moment of inertia are the primary targets while designing and manufacturing the vehicle. Hence these cars are manufactured in a very low weight range ranging from 160kg to 240 kg. Owing to the large power to weight ratios achieved by the above mentioned goals, the vehicles tend to move at the higher speed than desired but the aerodynamic force exerts a jacking force in the opposite direction of the motion called the aerodynamic lift due to which the tyres of the moving vehicle tend to lose the grip on the track and slip off the track. So this paper focuses on the design of the aerodynamic device like an undertray to develop the force opposing the aerodynamic lift so that the traction of the tyres is not lost and proper tyre road interaction is obtained.**

***IndexTerms*—Aerodynamics, Undertray, CFD, downforce**

I. INTRODUCTION

Aerodynamic devices are defined as the devices used for optimizing the interaction of the vehicle with the air flowing around it, which further results in advantage in terms of performance of the vehicle.

The undertray is also known as diffuser and is responsible to o the overall downforce of the car.A diffuser, in an the relation to automobile , is a converging,diverging section of the underbody of the car which improves the car's aerodynamic properties by increasing the transition between the high-velocity airflow below the car and the much slower freestream flow of the ambient atmosphere. It works as space provide for the underbody airflow to lower its velocity and expand (in area, density remains constant at the speeds that cars travel) so that it does not cause excessive flow separation and drag, by providing a extensive amount of pressure recovery so that the flow separation is not caused. The diffuser itself accelerates the flow in front of it, which helps generate downforce. When a diffuser is used, the air flows from the front of the car into the underbody from the front of the car, so the velocity is increased and the pressure is reduced. There is a peak of low pressure at the transition of the flat bottom and diffuser. The diffuser slows down this high velocity air back to normal velocity and also helps fill in the area behind the car making the whole underbody a more efficient downforce producing device by reducing drag on the car and increasing downforce.

II. LITERATURE REVIEW

1. Aerodynamic design for formula sae[3]:Vehicle performance is significantly affected by the aerodynamic improvements in automotive racing. Design and implementation of aerodynamic devices such as inverted wings and undertrays have been included the to improve performance. In this work of the literature the technology used in undertray development by Global Formula Racing is mentioned. The support of CFD simulation was taken to simulate the downforce obtained form the undertay in various conditions like yaw pitch and roll. The predicted performance is then compared with the real time testing data and it is found that the there is about 31%error in measured downforce with 1% improvement in laptimes.

2. Ground effect aerodynamics of race car[6] :Low pressure on the surfaces nearest to the ground concerned with generating downforce by an effect called ground effect,parts that are most aerodynamically efficient and contribute less drag than that associated with are used as parts of an open wheeled car's aerodynamics. Downforce generation plays a greater role in lap time reduction but the drag reduction is also an important part of the research. As the aerodynamics plays an very important role in improving the performance of the vehicle the by using the ground effect so in this paper apart form the the CFD models and simulation runs to examine the motion of edge vertices the ground effect modelling is also done to confirm the ground effect performance of the car.

3. CFD Invertigations of an Open Wheeled Race car[5]:Because the aerodynamic loads, which are acting on the high-speed vehicles, play a significant part concerning the dynamic behaviour of the latter, the aerodynamics is one of the most important design considerations for cars such as Indy or Formula 1. In this study, the main goal is to investigate the influence of the boundary conditions at the level of the ground on the main aerodynamic characteristic of an open-wheel race car using the facilities offered by the ANSYS CFX, CFD code. The influence of the ground on the main aerodynamic characteristics of the car, drag and lift, is studied in two ways, commonly used in wind tunnels, respectively without ground effect (fixed wheels and no relative motion between car and road), and with the moving wall approach. The conclusions are demonstrated by the results, using the relative increment of drag, lift and pitching moment, and by the computer-graphics visualizations. There are also presented some considerations concerning the importance of the rotating wheels in aerodynamics of the road vehicle and the opportunity to simulate it in a virtual

environment.

4. Two dimensional analysis of a rotating cylinder in ground effect[10]: A study of the front wing in front of the front wheel was studied using Computational Fluid Dynamics (CFD). The result were presented representing the similar situation where a front wing is place in front of a cylinder. The comparison on what effect do these two objects have on each other are studies through CFD simulation, when operating in close proximity. The conclusion were made form the different CFD simulations. run that the aero foil generates lift instead of downforce in most of the configurations baring some of the which would give the desired results.. This may explained the reduction in the front wing span that was adopted by the after the Formula One (F1) regulation changes for the 1998 season.

III. METHODOLOGY

The undertray was selected as a perfect aerodynamic device keeping in mind the pros and cons not only in the design but also considering the manufacturing and cost factor. As the undertray provides a great amount of downforce but very less amount of drag the undertray was selected as the suitable aerodynamic device. The design process was selected in such a way that the undertray is basically a converging diverging nozzle type body which would be fitted on to the bottom of the car to generate downforce, so the determination of the inlet and the outlet angles was to be done primarily and then the width or the third dimension was to be designed. A simple trial and error approach is used in the available dimensional constraints to determine various dimensional parameters of the undertray.

The basic setup for the dimensional constraints and the analysis setup are shown below:

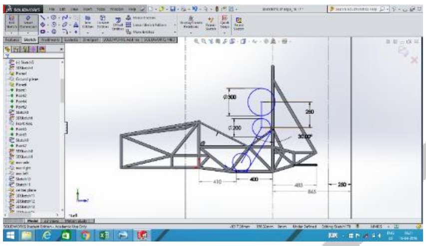
Fig 1 Dimensional constraints

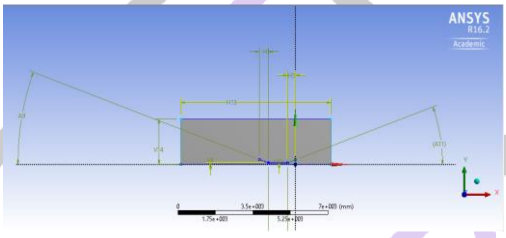

Fig 22D model with dom

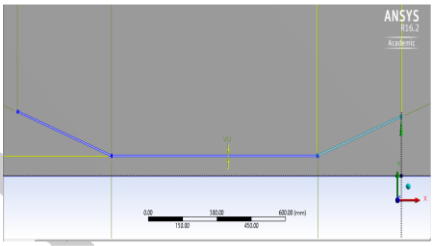

Fig 3 Closer view of 2d geometry

IV. SIMULATIONS AND RESULTS

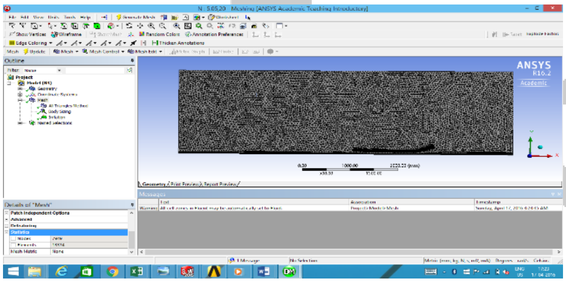
Fig 4 Meshed domain

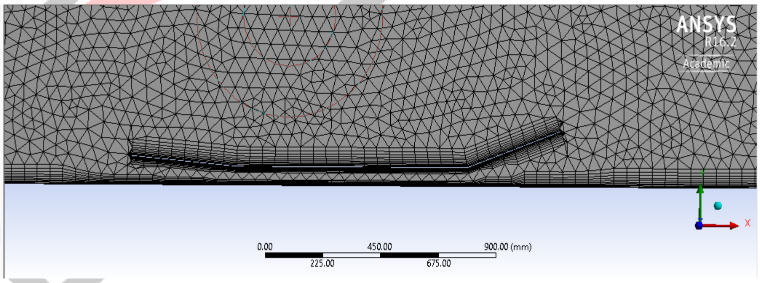

Fig 5 Inflation Applied in the mesh

The mesh was setup as shown in the above figures the meshing statistics are mentioned below:

Type: Triangular Unstructured Mesh

Element size: 50mm,

Inflation: Maximum layer = 10,

Growth rate = 1.2,

Nodes: 7949, **Elements**: 13374

The boundary conditions for the 2D simulations to be ran are as below:

Mathematical Model: K-ε model with enhanced wall treatment. **Inlet**: Velocity Inlet at 11m/s**Outlet**: Pressure outlet at 0 absolute pressure.

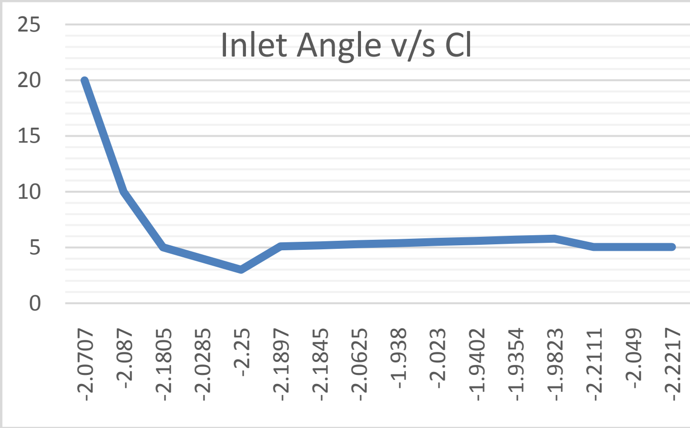

Fig 6 Graph of inlet angle v/s lift coefficient

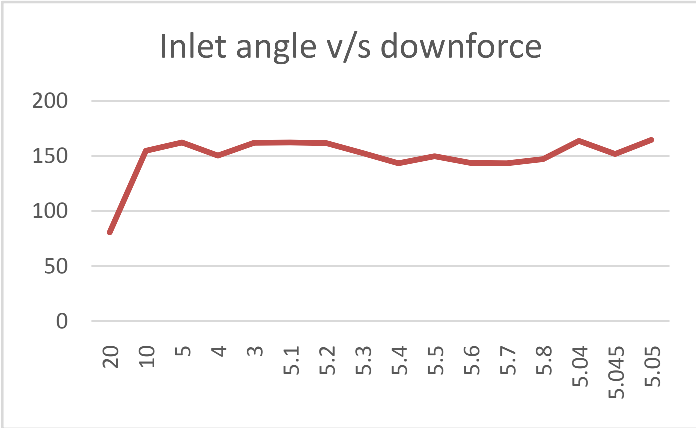

Fig 7 Graph of inlet angle v/s downforce

By setting up the 2D simulations according to the boundary conditions mentioned above the results were obtained that the maximum downforce was obtained at an inlet angle of 5.05° and the outlet angle was obtained 20°.

Similar to the 2D design process the 3D design process was followed, the width was altered and the graphs of width v/s downforce and drag are plotted.

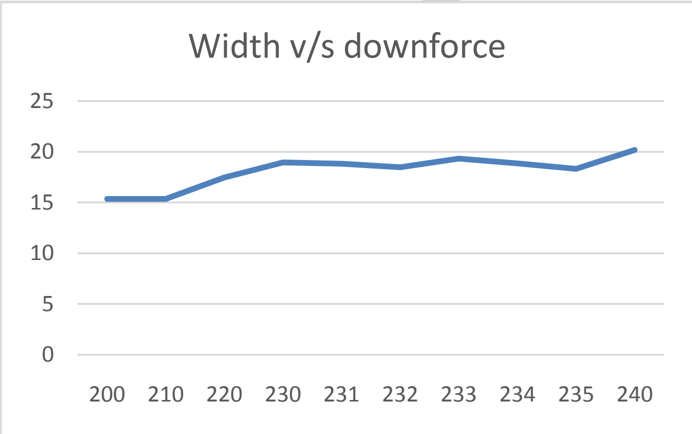

Fig 7 Graph of inlet angle v/s lift coefficient

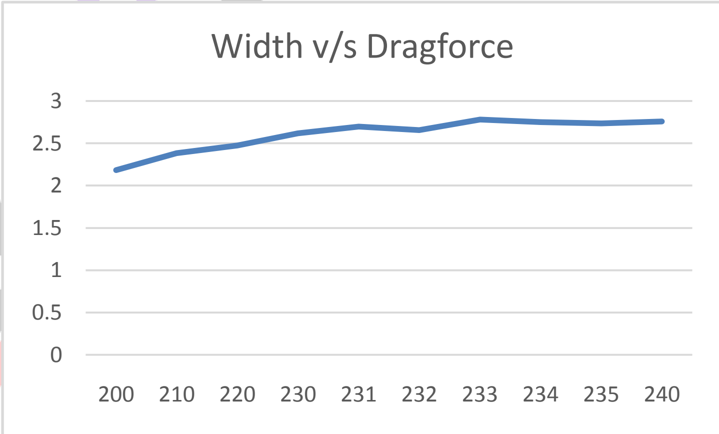

Fig 8 Graph of width v/s Dragforce

So from the above observations the it was found out that the maximum downforce was obtained at the width of 240 mm

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V. CONCLUSION

The conclusion was derived that the inlet angle which the maximum downforce was achieved is 5.05° and the width of the air dams in the diffuser for the same is 240mm

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