

## **Alterations of Formula 3 Race Car Diffuser Geometry for Optimised Downforce**

**Soumya Kanta Das<sup>1</sup>, Pavan Kumar<sup>2</sup> and Shweta Rawat<sup>3</sup>**

*VIT University, Vellore PESIT Engineering College,  
Bangalore IGDTUW, IP University, Delhi.*

### **Abstract**

This paper deals with the aerodynamic behavior and performance of a Formula-3 Race car diffuser. The effects of operating parameters such as ride height, diffuser length and ramp angle on down-force along the straights are dealt. Even one-hundredth of a second matters a lot in Motor Racing. The Diffuser being an underbody aerodynamic component plays a vital role in enabling the car to carry speed on Track. Overtaking is an important aspect of Racing, as it helps in gaining track position and ultimately the race finish order. Hence, the above mentioned parameters are taken into consideration and its set-up changes are closely examined to improve overtaking maneuverability. Steady state conditions have been considered with the analysis of flow around a bluff body configuration due to the complexity of a complete Formula 3 car. Computational Analysis performed on a bluff body subjected to 3-D axial flow is completed using ANSYS Fluent package.

**Keywords:** Formula 3, Diffuser, Overtaking, Computational Fluid Dynamics (CFD).

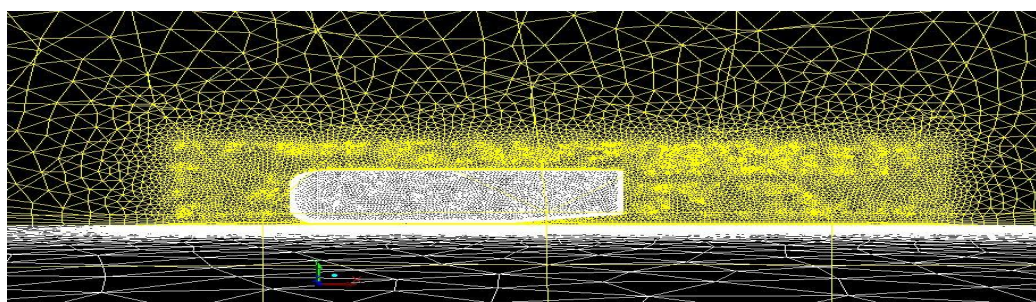
### **1. Introduction**

Aerodynamics plays a vital role in governing a Race Car's performance. Depending on circuit characteristics, the set-up can be altered to suit top speed along with minimum drag and maximum downforce. For a Racing driver the ideal set-up is normally to get the maximum amount of downforce at high speed corners and minimum drag in high speed straights, for least downforce generated. Motor Racing is highly regulated,

developed and competitive sport. Formula-3 is a class of open-wheel Formula Racing, whose technical regulations are governed by FIA. Underbody diffuser accounts to a major role in improving aerodynamic efficiency of a Formula-3 Car. The key role of a rear diffuser on a modern Race Car is to accelerate the flow under the car, creating an area of low pressure on the whole underfloor plan area. The constant density of the air at such low speeds creates a vacuum at the enlarged area of the diffuser which sucks more air from the underfloor and simultaneously slowing down the flow towards the rear during the exit in order to match it up with the ambient flow and filling the wake behind the car, also, the upward momentum is provided to the flow which further increases the downforce. The effect of varying ramp angles of diffusers on the downforce and drag coefficients is computed and pressure plots and velocity contours are plotted in CFD.

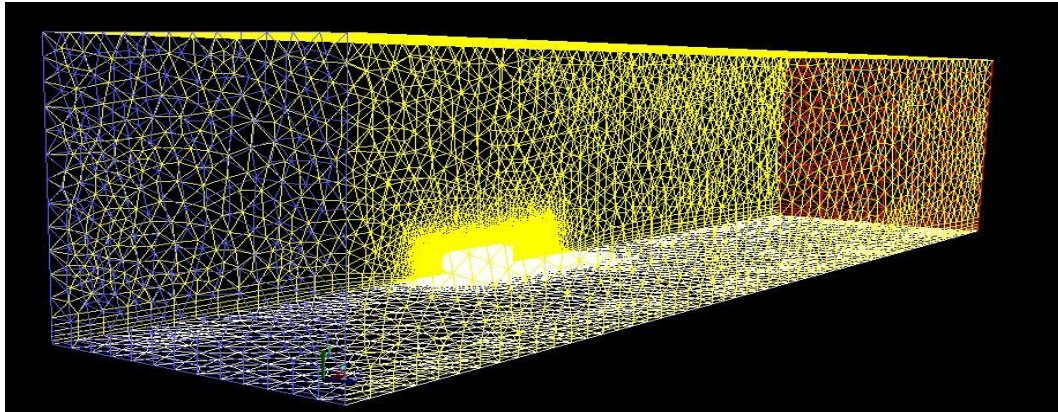
## 2. Set-Up and Meshing Tools

Diffuser characteristics are analyzed by integrating a diffuser with an Ahmed Body, whose slant angle is made zero degree and carrying out an unstructured meshing for it on CFD package. The ramp angles were continuously increased with steps of 2 degrees. The mesh sensitivity is of 413379 nodes and 1806979 elements for a bluff body of 1044 mm long, 288 mm high and 389 mm wide. As per FIA Formula-3 technical regulations on rear body work & dimensions under “Article 3” (i) overall width of the car is limited to 1850 mm. (ii) rear track width should not exceed 1540 mm. (iii) Maximum width of body work behind rear wheel center line is 900 mm. Keeping these in mind the diffuser length is set to be 350 mm according to the proportions of an actual F3 diffuser. The element size in the vicinity of the bluff body is set at 15 mm and the bluff body itself at 10 mm. A coarse meshing but a high smoothing transition is set for more precise results. K-Epsilon model is adopted for this experimentation as it's the best at speeds of 50m/s which is taken here.



**Figure 1:** Ahmed body meshing.

The computational domain which basically works as a virtual wind tunnel for the set-up is shown in figure 2.



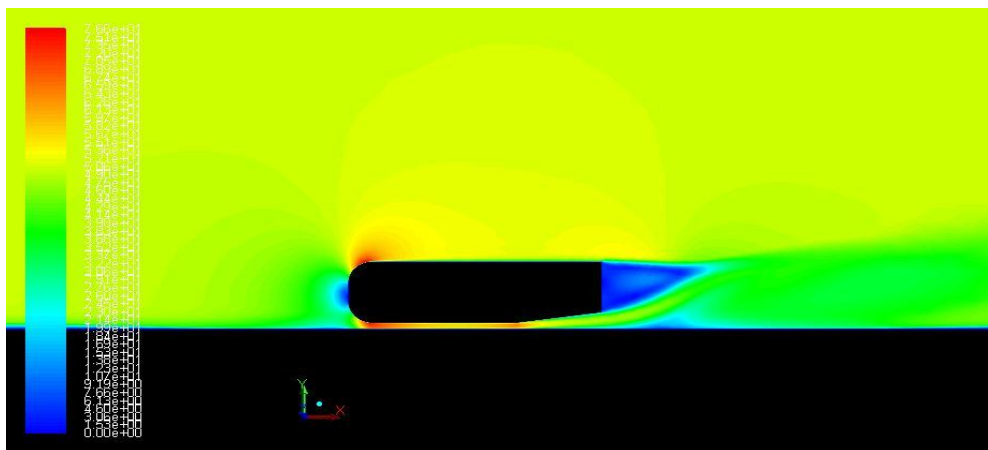
**Figure 2:** Computational Domain.

For speed equal to 50 m/s, the ramp angle for the diffuser is increased from  $2^\circ$  and the values of downforce and drag are computed for various angles till the angle of stall i.e.  $20^\circ$  is reached where maximum downforce is obtain and angles more than that, show the gradual decline of downforce.

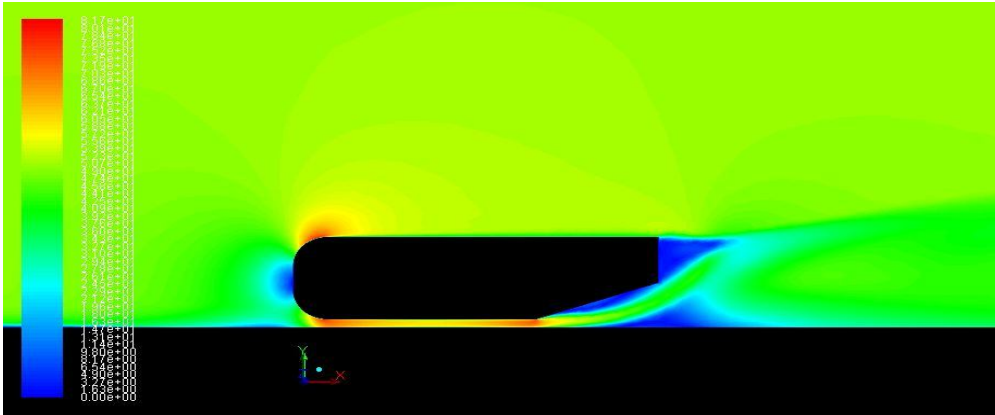
### 3. Contour Plots

#### 3.1 Velocity plots for $8^\circ$ and $20^\circ$ ramp angle

From figure 3, it can observed that the velocity of air underneath the car prior to the entrance of diffuser section has a higher value. This is primarily due to the compromise in static pressure, as per Bernoulli's theorem. As the air flows passes through diffuser, its velocity decreases to maintain constant mass flow rate.



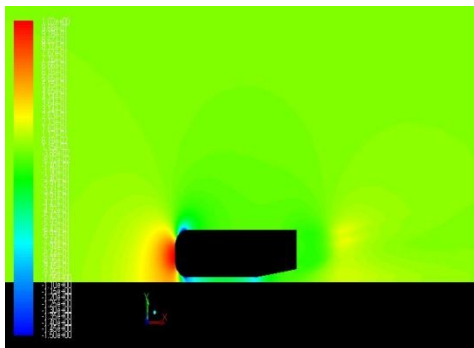
**Figure 3:** Velocity plot at 80.



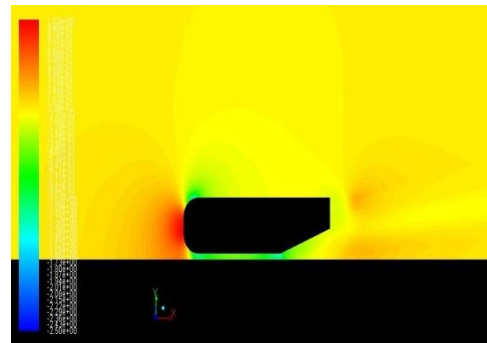
**Figure 4:** Velocity plot at 200.

There is significant reduction in the area of low velocity towards the rear of the Ahmed body with the increase in the ramp angle and we observe that the up wash of flow is with greater velocity thus, increasing the downforce manifold.

### 3.2 Pressure plots for $8^\circ$ and $20^\circ$ ramp angle



**Figure 5:** Pressure plot at  $8^\circ$



**Figure 6:** Pressure plot at  $20^\circ$

The above plots depict the pressure distribution over bluff body at two different ramp angles. In figure 6, the immense low pressure gained under the body indicates the gain in downforce as also shown in the velocity plots.

### 3.3 Static Pressure plot at $20^\circ$

The pressure contour is represented for  $20^\circ$  ramp angle, as mentioned earlier the diffuser stalls at that angle. Negative pressure underneath & high pressure over the bluff body results in pressure differential which generates down force. Carefully observing the above contour, it can be noted that the pressure inside diffuser region is below atmospheric pressure & attains the same value only at the exit [3].

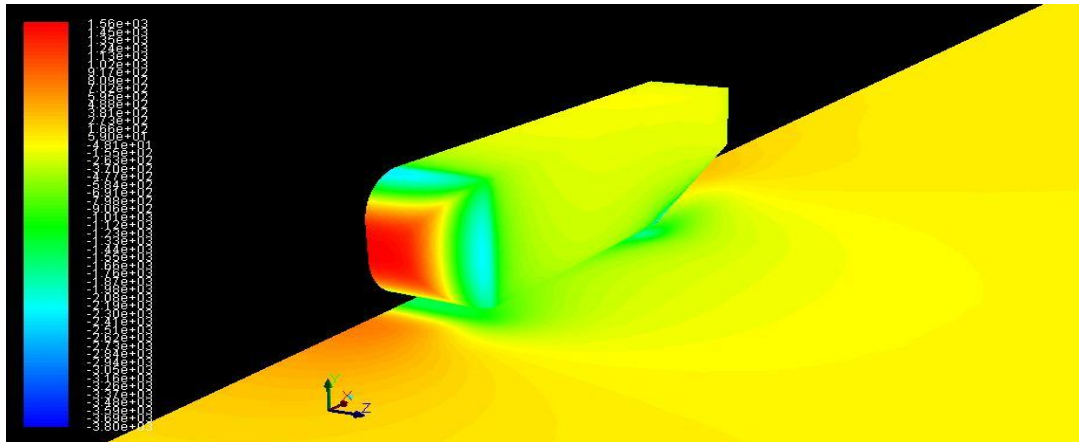


Figure 7: Static pressure plot at  $20^\circ$

### 3.4 Turbulent Kinetic Energy plots at $8^\circ$ and $20^\circ$

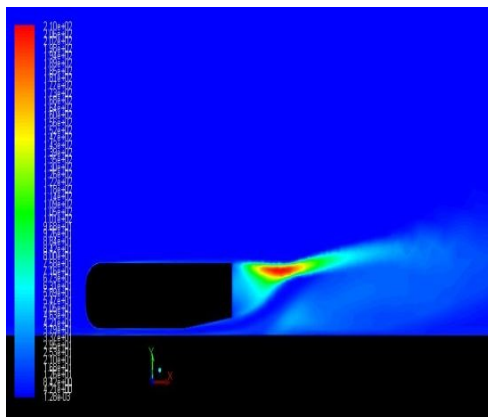


Figure 8: Turbulent kinetic energy at  $8^\circ$

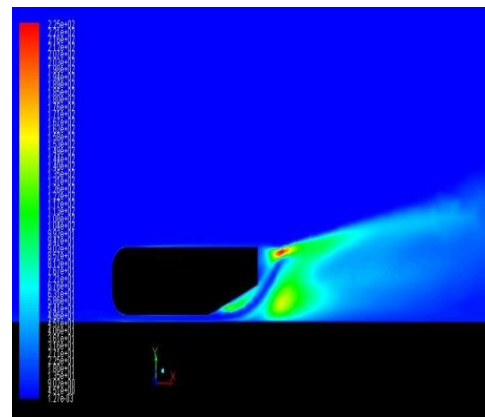


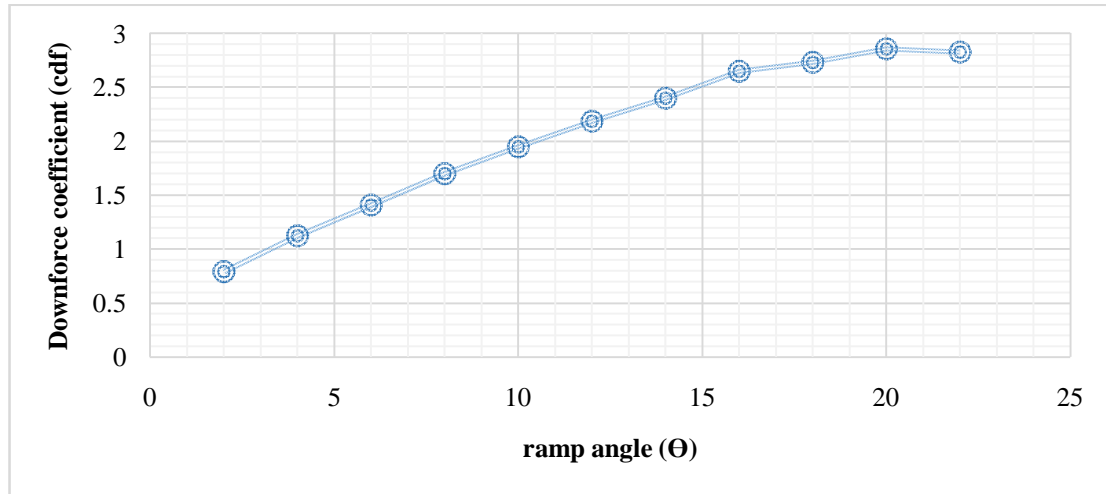
Figure 9: Turbulent kinetic energy at  $20^\circ$

The above plot highlights the mean kinetic energy per unit mass associated with eddies in turbulent flow. It can be observed that turbulence is redistributed for the  $2^{\text{nd}}$  case thus offering more drag than  $8^\circ$  ramp angle.

## 4. Results and Discussion

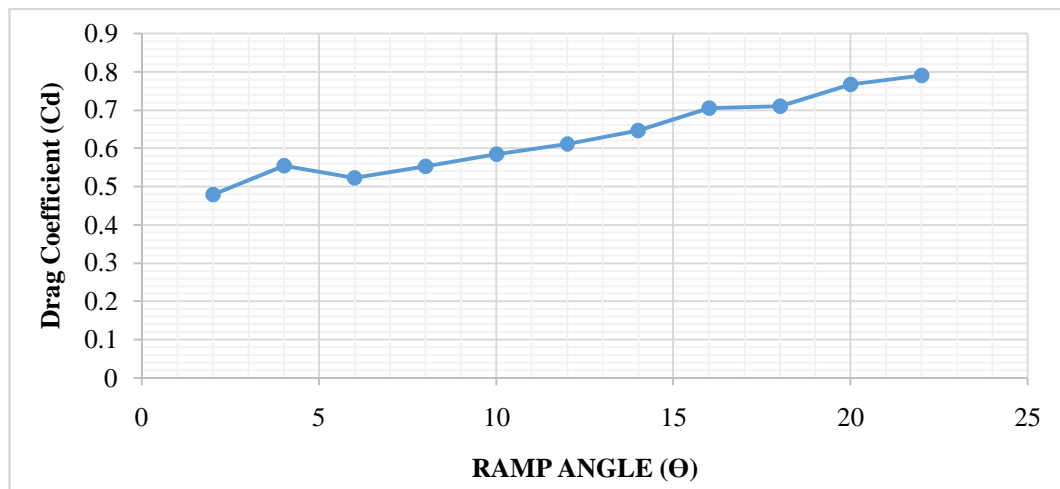
### 4.1 Graph showing Downforce Coefficient vs. ramp angle

The Graph depicts that downforce coefficient increases linearly with the increase in ramp angle and slight decrease initiating from  $16^\circ$  angle and then ultimate stall occurring after  $20^\circ$  from where the downforce drops significantly.



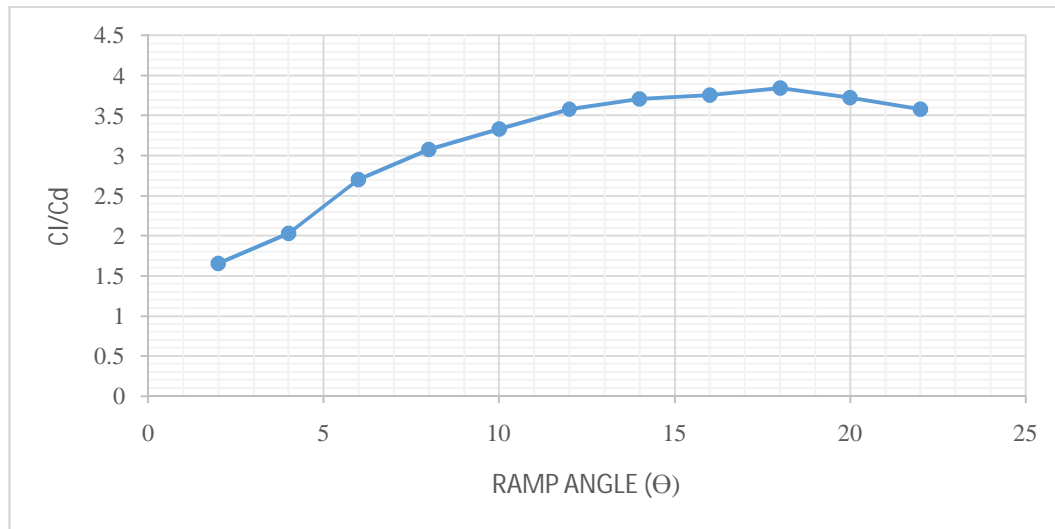
#### 4.2 Graph showing Drag Coefficient vs. ramp angle

The above graph highlights the increasing drag penalty along with the increase in downforce on increasing ramp angle. For the case of  $6^\circ$  ramp angle where minimum co-efficient of drag occurs, the pressure change that occurs underneath the bluff body is smaller compared to  $20^\circ$  case.



#### 4.3 Graph showing $C_L/C_D$ vs. ramp angle

The graph shows that  $C_L/C_D$  declines in a range between 18-20 degrees. Though the stall angle is found to be  $20^\circ$  from the  $C_{DF}$  vs. ramp angle graph, but we infer that  $C_L/C_D$  vs. ramp angle graph gives a much clearer idea about how to increase the efficiency of the diffuser. Thus, this implies that the ramp angle of  $17^\circ$ - $18^\circ$  is ideal for maximum down force since in Formula 3 diffusers, drag is compromised for down force increase.



## 5. Conclusion

A 3-D bluff body was outlined which enabled us to understand the performance of diffuser. The geometry was simulated over a range of ramp angle 0-22 degrees, keeping the ride height constant at 30mm. For optimal performance of diffuser, 18 degree ramp angle would be the best set-up. So as to achieve maximum aerodynamic efficiency & down force. This research can be further extended in analyzing the flow over two bluff bodies subjected to slip-streaming.

## References

- [1] Article: 3 – 2013 Formula 3 Technical Regulations, Federation Internationale De L' Automobile
- [2] Competition Car Aerodynamics by Simon McBeath
- [3] Kevin M.Peddie and Louis F.Gonzales -CFD study on the diffuser of a Formula 3 Race Car.

