FOSSEE, IIT Bombay
OpenFOAM Research Migration Project
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Aerodynamic analysis of Ahmed Body

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Synopsis

Ahmed body is a generic car body (a simplified car model) i.e the flow of air around the Ahmed body captures the essential flow features around an automobile. It allows us to capture characteristic features that are relevant to bodies in the automobile industry.

In this project, The airflow over the ground vehicle is analysed, and the coefficient of drag is calculated using OpenFOAM. The Ahmed body is made up of a round front part, a movable slant plane placed in the rear of the body to study the separation phenomena at various slant angles, front radii and ground clearance. These geometrical parameters are varied and their effect on drag coefficients and velocity contours are observed.

The project was migrated from the following paper.

Khan, Rehan & Umale, Sudhakar. (2014).
CFD Aerodynamic Analysis of Ahmed Body.
International Journal of Engineering Trends and Technology.
18. 301-308. 10.14445/22315381/IJETT-V18P262.

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1. Abstract

The airflow over the ground vehicle is analysed and the coefficient of drag is calculated using OpenFOAM. For this calculation, the Ahmed body (simplified car body) a ground vehicle is considered which is commonly used as a test case in the industry. The Ahmed body is made up of a round front part, a movable slant plane placed in the rear of the body to study the separation phenomena at 25°, 35° angles, and a rectangular box, which connects the front and rear slant plane. Air is used as a working fluid. The inlet velocity of fluid is 40 m/s. A Laminar model is used. Two separate cases have been solved for two different front radii of Ahmed body R80, R120 and ground clearance at 20mm, 40mm and results are compared. The results are present in the form of drag coefficient values and velocity contour plots.

2. Introduction

Ahmed body is a simplified car model created by Ahmed et in the 1980s to investigate the behaviour of newly developed turbulence models for complex geometry cases. The Ahmed body is made up of a round front part, a movable slant plane placed in the rear of the body to study the separation phenomena at different angles, and a rectangular box, which connects the front and rear slant plane as shown in the figure, Ahmed body is simplified model of a car body, but it demonstrates all the flow features involved in an actual case of a moving car.

3. Problem Statement

In this project, A 2D model of Ahmed's body is to be generated and meshed and variation of coefficient of drag is numerically investigated at conditions given below

1. Rear Slant angle at 25 degrees
2. Rear slant angle at 35 degrees
3. Front radius at 80 mm
4. Front radius at 120 mm
5. Ground clearance at 20 mm
6. Ground clearance at 40 mm

4. Geometry and Mesh

The geometrical shape of the Ahmed body (simplified car body) investigated is given below. Due to the considerable deviation of its geometry from normal vehicles, the body represents the basic aerodynamic properties of a vehicle, especially in the rear part. The rear slant angle ϕ has a strong effect on the aerodynamic drag and lift at the back.

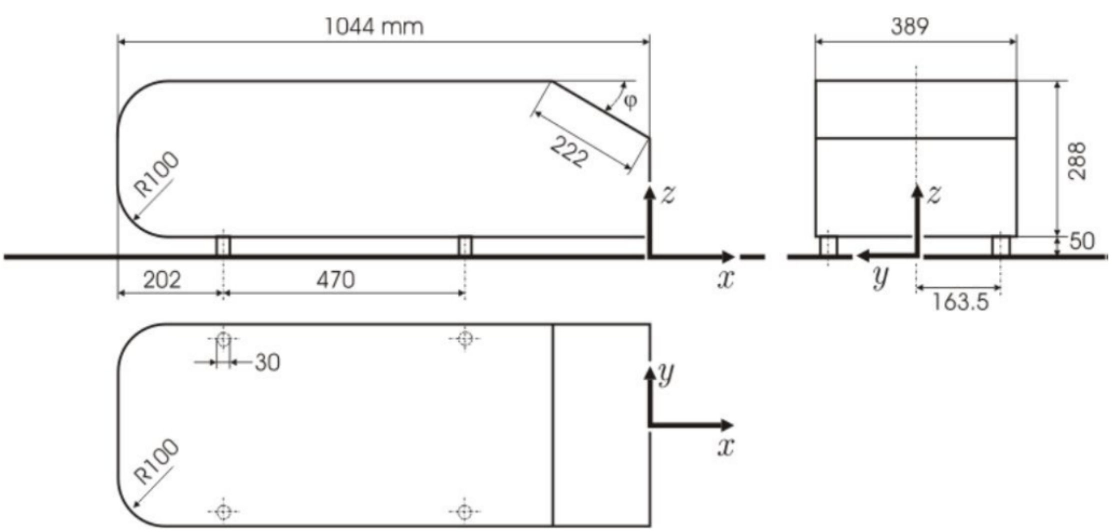


Fig. 1 Geometry of the Ahmed body [5]

Tunnel size	(2m x1.46m) ¾ open test section
Length	1.044m
Height	0.288m
Front radius	0.1m
Ground clearance	0.05m
Slant angle	25^0, 35^0
Inlet velocity	10,20,30,40 m/s
Yaw angle	$B=0^0$
Blockage ratio	3.8%
Cross-sectional area	$A=0.112m^0$

4.1 Mesh Generation

Initially a 3D mesh was considered as given below, however, there were convergence issues. The solution was diverging for most of the meshes. Hence, the original 2D geometry was chosen.

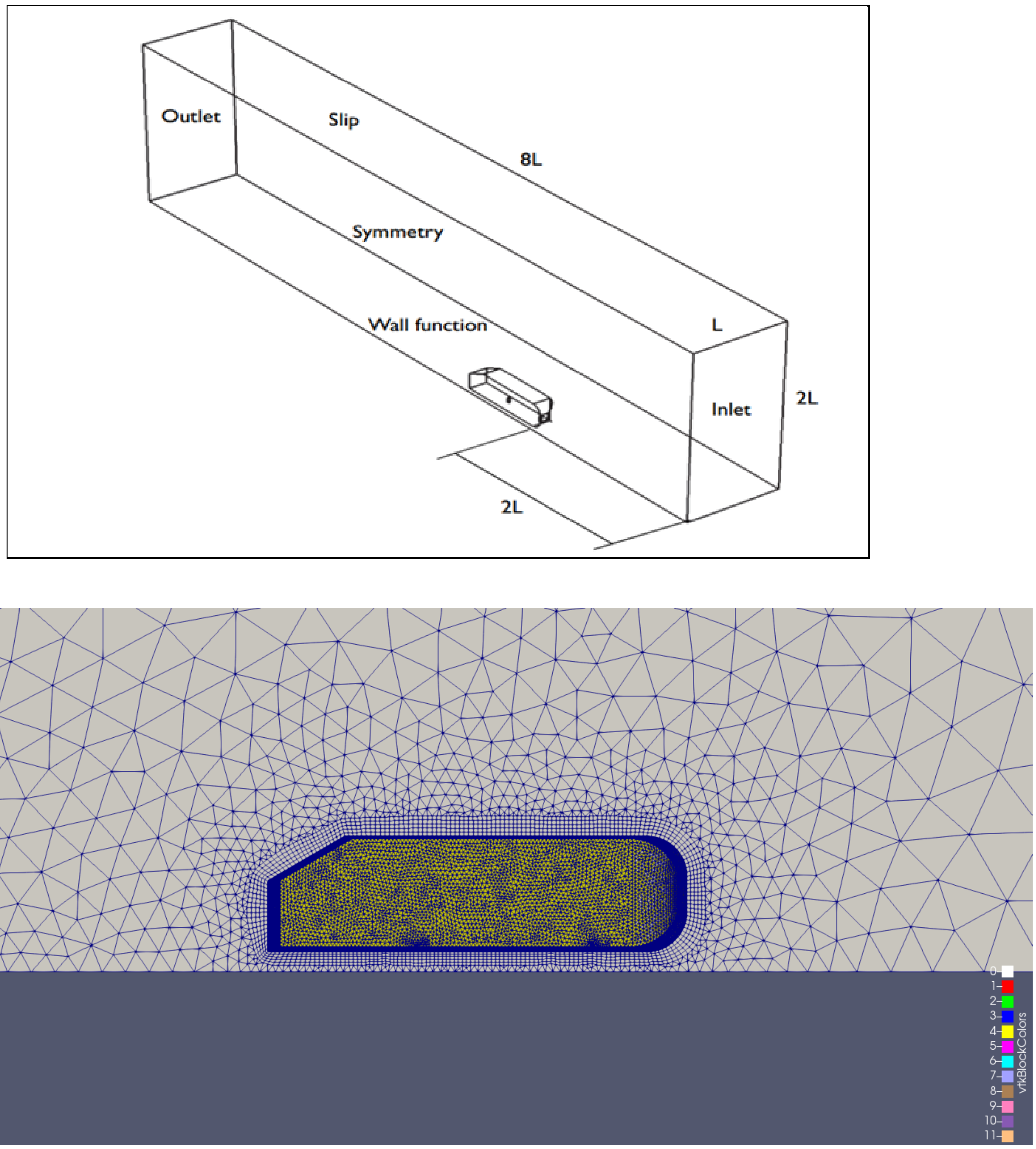
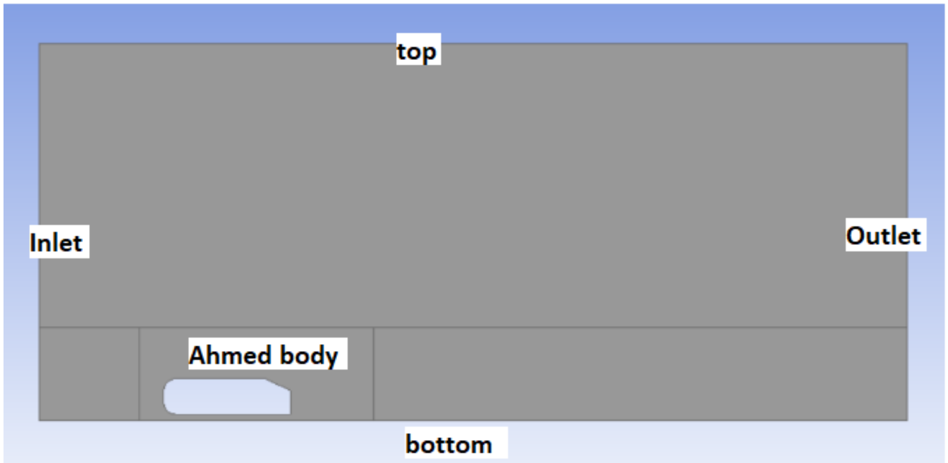
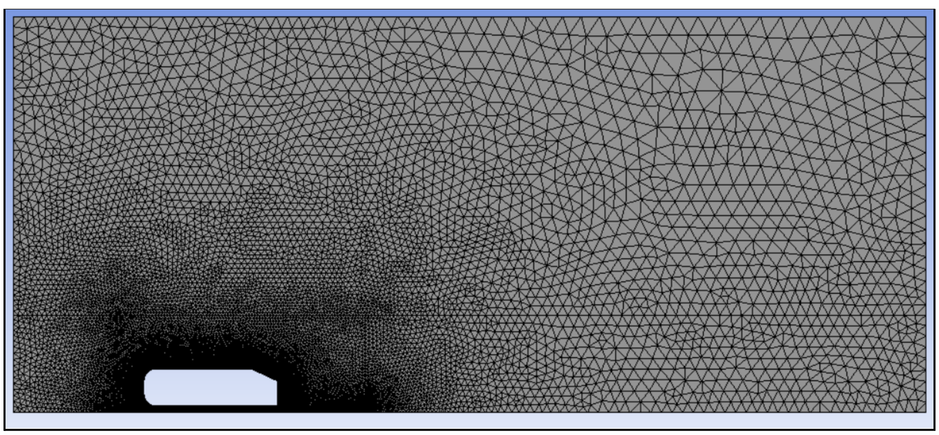


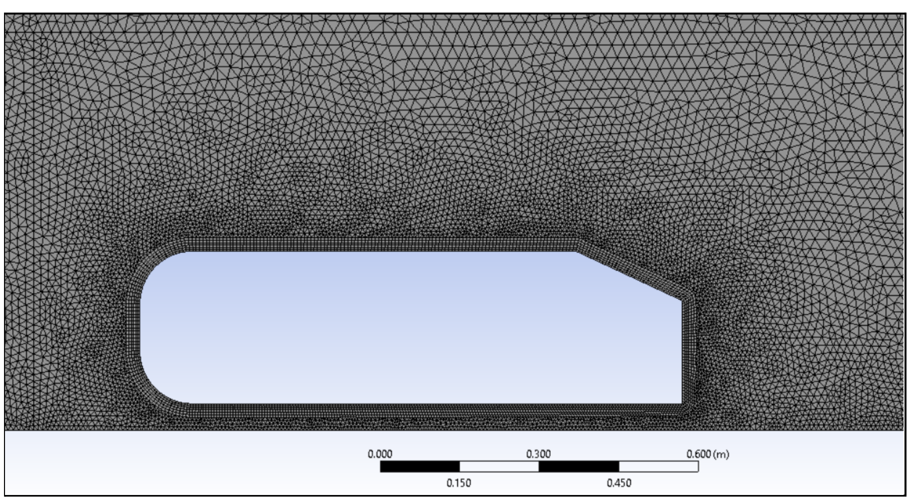
Fig: 3D Mesh

4.2 Mesh Details

2D Mesh: Domain is split into various patches to refine certain regions in the geometry, The Mesh is generated in ANSYS and imported into OpenFOAM.







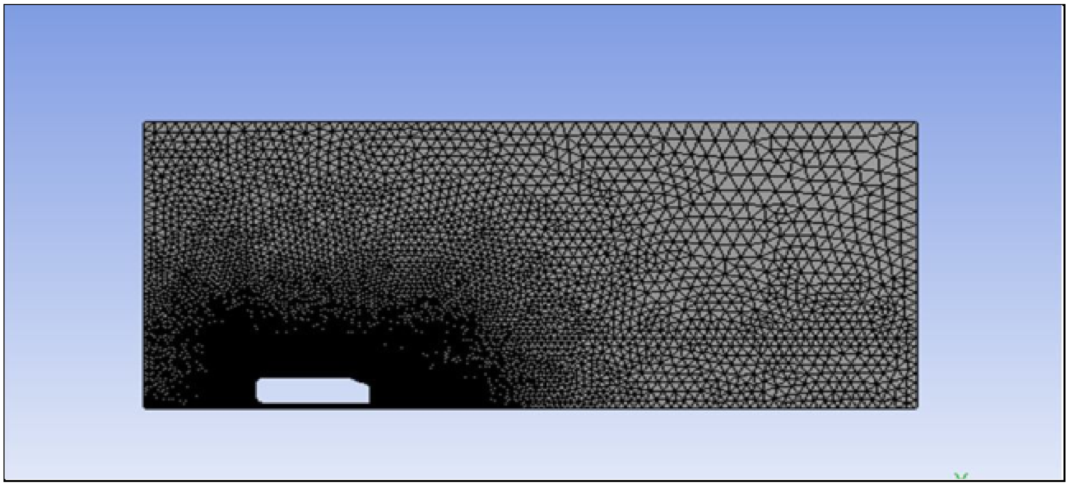


Fig: Comparison with Reference Paper Mesh.

5. Governing Equations

The governing equation consists of continuity and momentum equation in the two-dimension form without the transient term as the flow is considered to be in a steady-state. The equations are as follows

Continuity Equation

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

Momentum Equation in x-direction

$$\rho u\frac{\partial u}{\partial x} + \rho v\frac{\partial u}{\partial y} = -\frac{\partial \hat{p}}{\partial x} + \mu[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}]$$

Momentum Equation in y-direction

$$\rho u\frac{\partial v}{\partial x} + \rho v\frac{\partial v}{\partial y} = -\frac{\partial \hat{p}}{\partial y} + \mu[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}]$$

6. Boundary Conditions and Solver Setup

6.1 Velocity boundary conditions

- Inlet velocity = 40m/s
- The internal grid velocity is initialized to 40m/s
- Constant Inlet velocity
- Zero gradient boundary condition at outlet
- No-slip boundary condition at - Domain walls, Ahmed body walls, Ground

6.2 Pressure boundary conditions

- All cells are initialized to zero
- Zero gradient boundary condition at inlet
- Zero gauge pressure at the outlet
- Zero gradient Boundary condition at Domain walls, Ahmed body walls, ground.

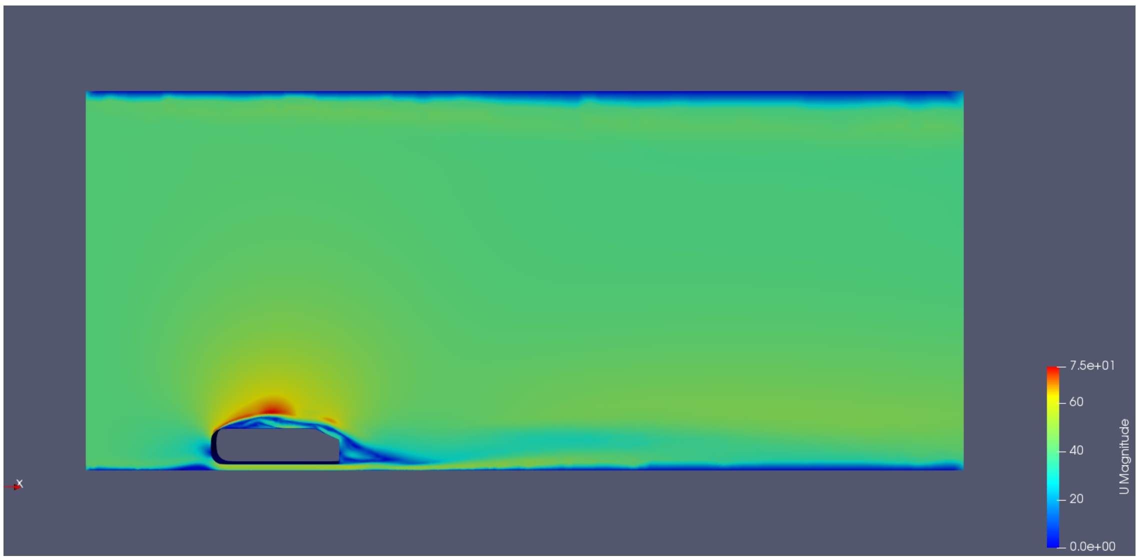
6.3 Solver Parameters

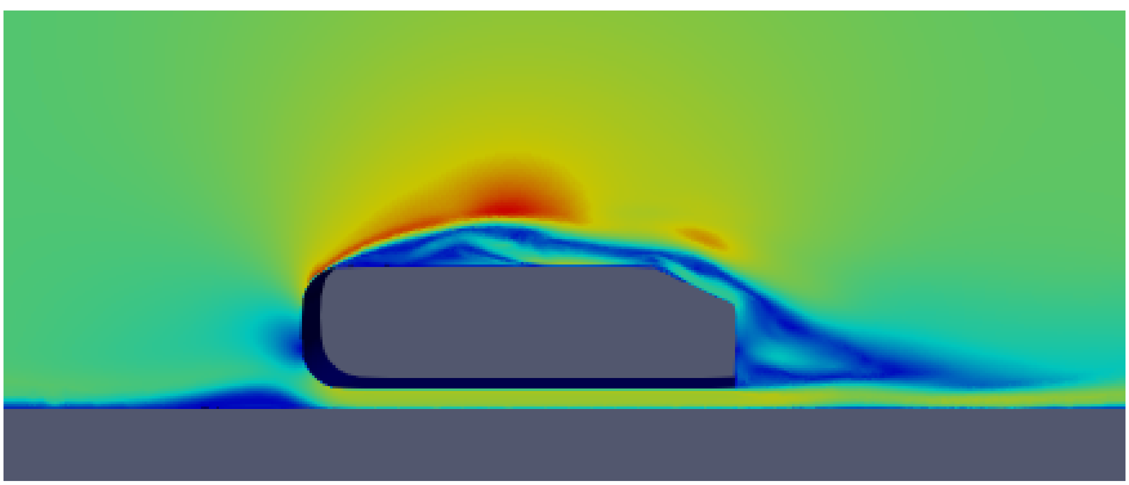
- Laminar flow assumption.
- Solver - simpleFoam
- Simulation time - 20000
- deltaT - 10s
- 5 Non-orthogonality correctors
- Force coefficient calculation using libforces library

7. Results and Discussion

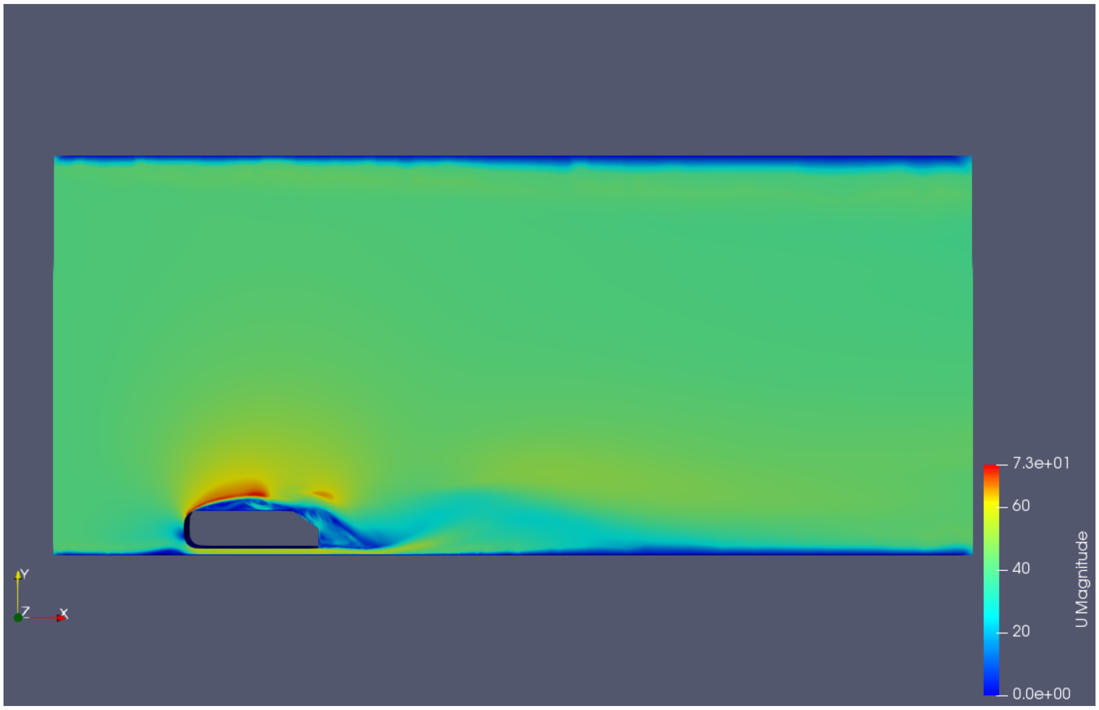
7.1 Variation in slant angle

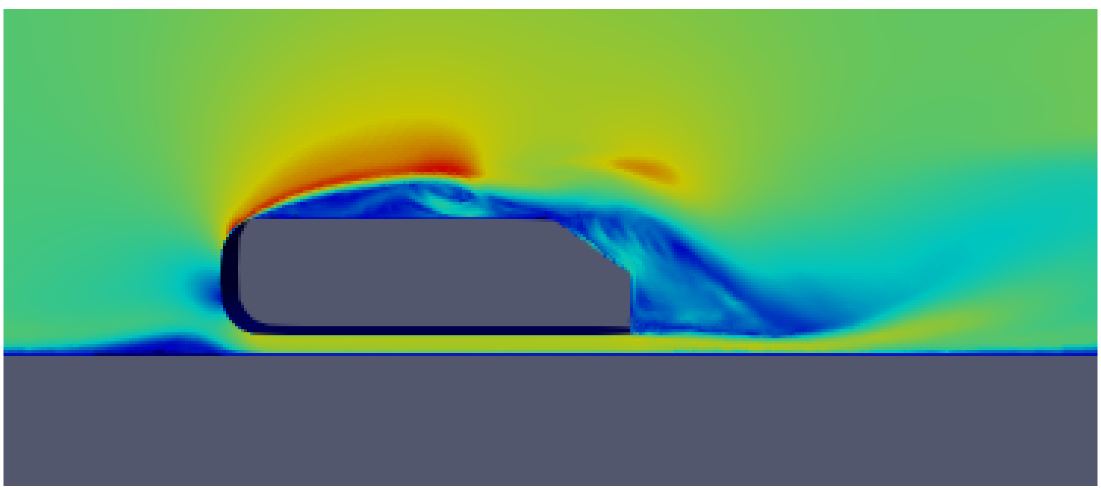
1. 25° rear slant angle





2. 35° rear slant angle



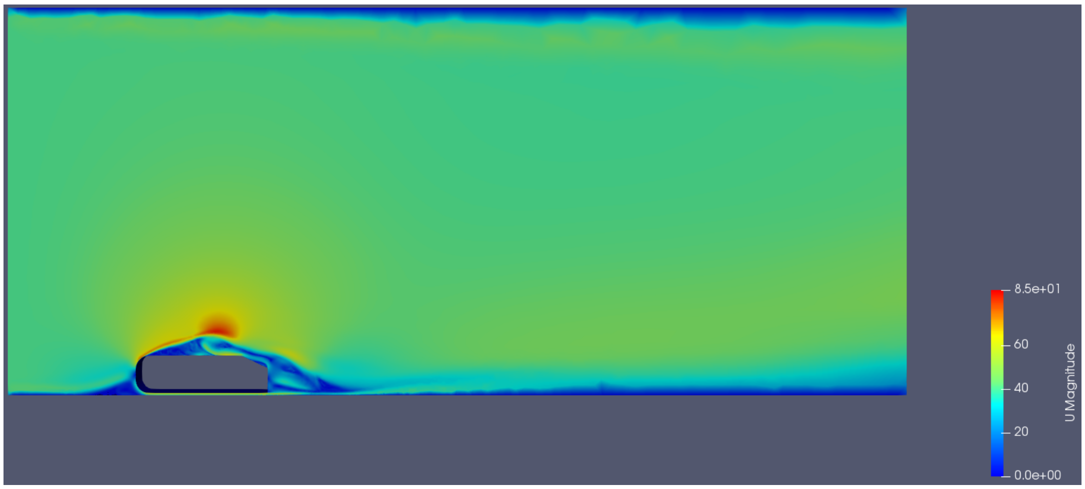


Observations

- Wake regions are similar with a few differences in max velocity regions, which might be affected by the colour scheme for the contour.
- Compared to the 25-degree case, the flow separation occurs earlier which can be seen here with a larger wake region

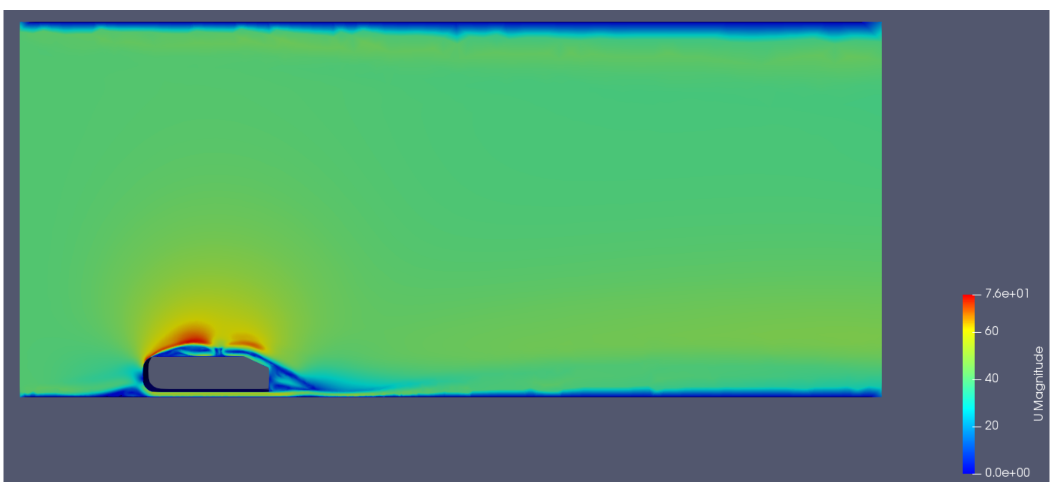
7.1 Variation in ground clearance

1. Ground clearance 20 mm



# Time	Cm	Cd	Cl	Cl(f)	Cl(r)
20000	2.199722e-20	2.884971e-01	1.830189e-21	2.291232e-20	-2.108213e-20

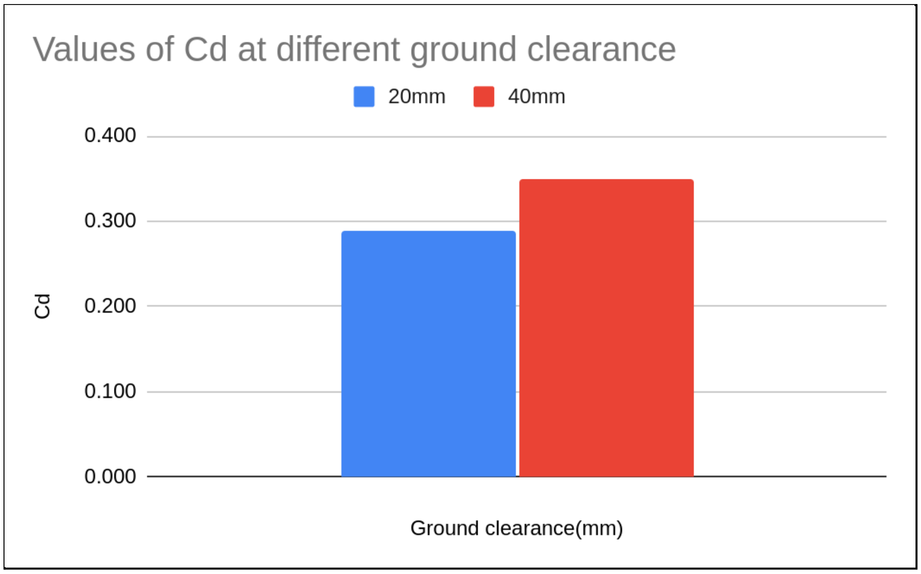
2. Ground clearance 40 mm



# Time	Cm	Cd	Cl	Cl(f)	Cl(r)
17000	2.368380e-20	3.511628e-01	2.023126e-20	3.379944e-20	-1.356817e-20

Observations

- Cd for the 20mm GC case is very similar and 40 GC is a little higher than expected. But the trend is the same when compared with the reference paper results.



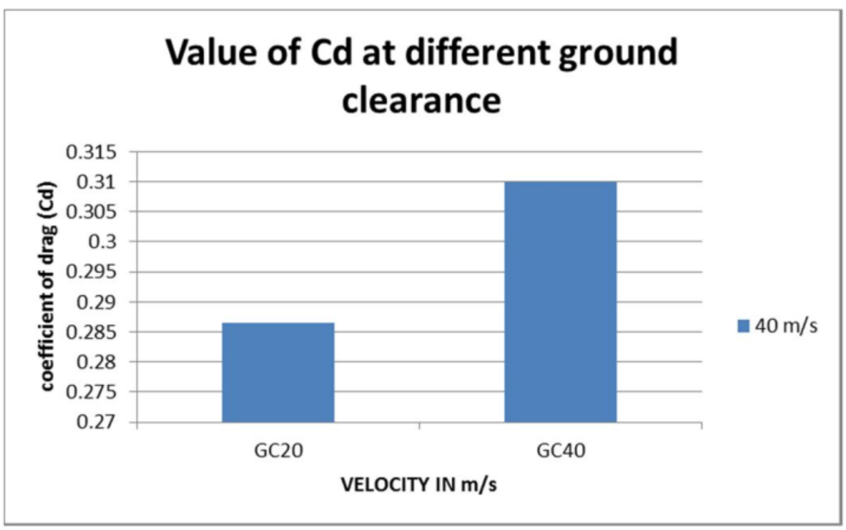
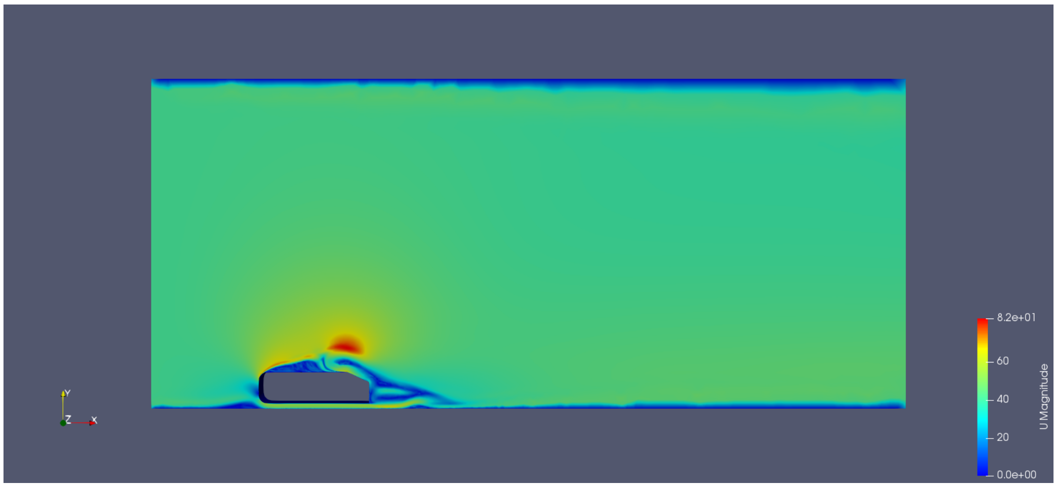


Fig. 10 Comparison of Cd values at ground clearance

Reference Paper Results

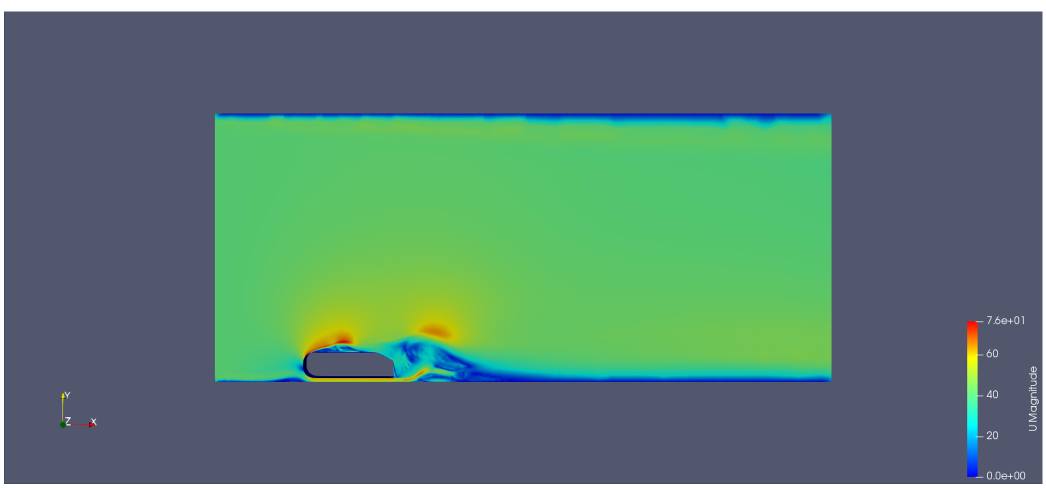
7.1 Variation in fillet radius

1) 80 mm fillet radius



# Time	Cm	Cd	Cl	Cl(f)	Cl(r)
20000	-3.690511e-21	4.231482e-01	7.512664e-21	6.582044e-23	7.446843e-21

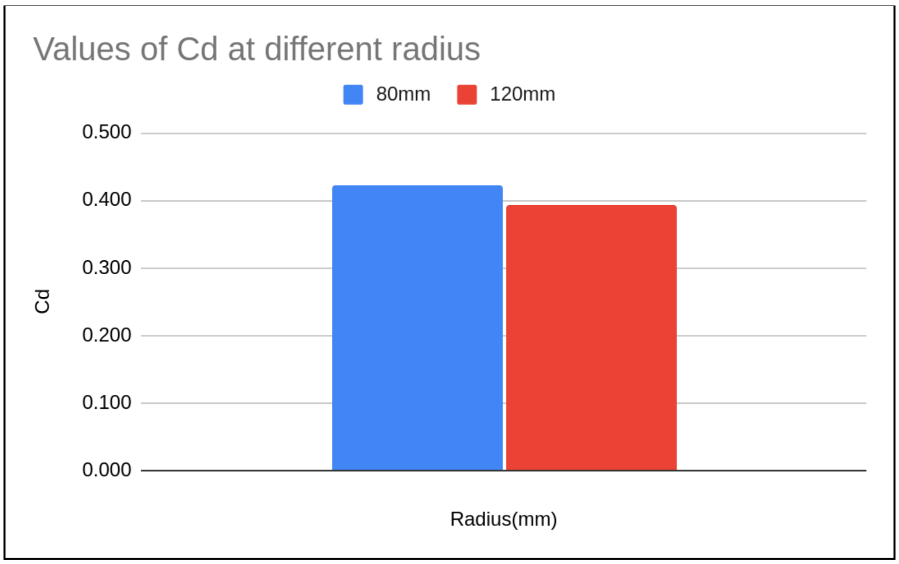
2) 120 mm fillet radius

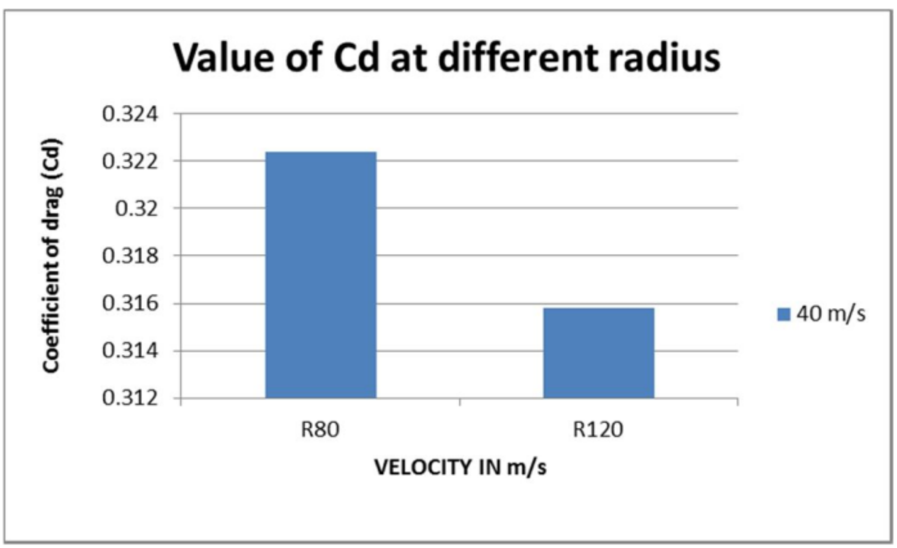


# Time	Cm	Cd	Cl	Cl(f)	Cl(r)
20000	-1.927556e-20	3.929437e-01	-2.261640e-20	-3.058376e-20	7.967361e-21

Observations

- Similar to the previous cases, the values are a little different but the trend followed is similar.

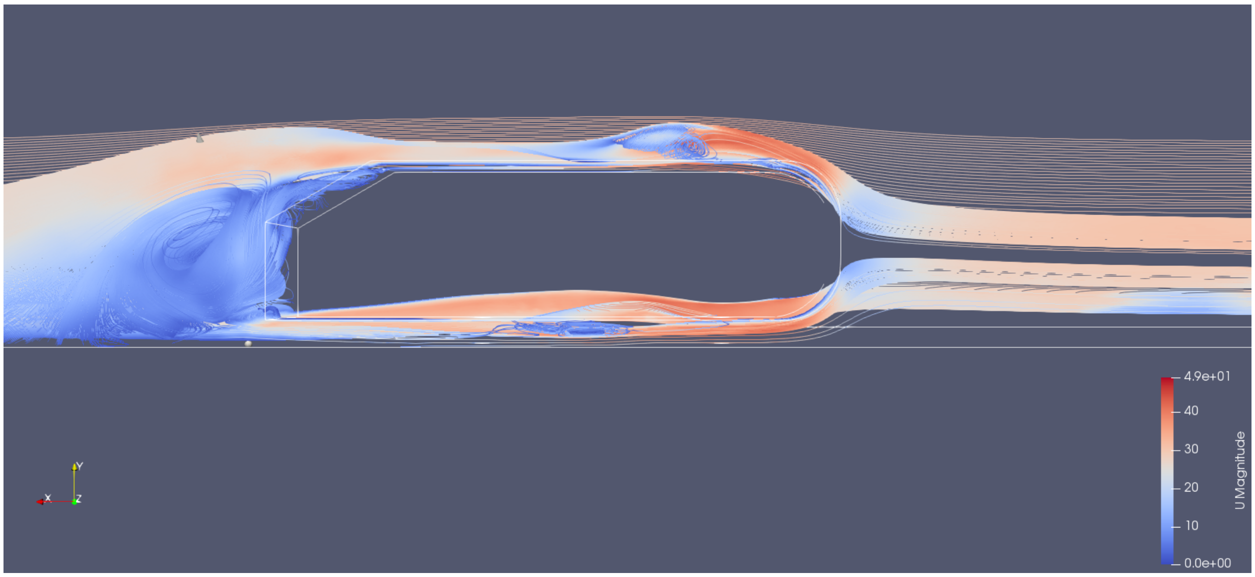


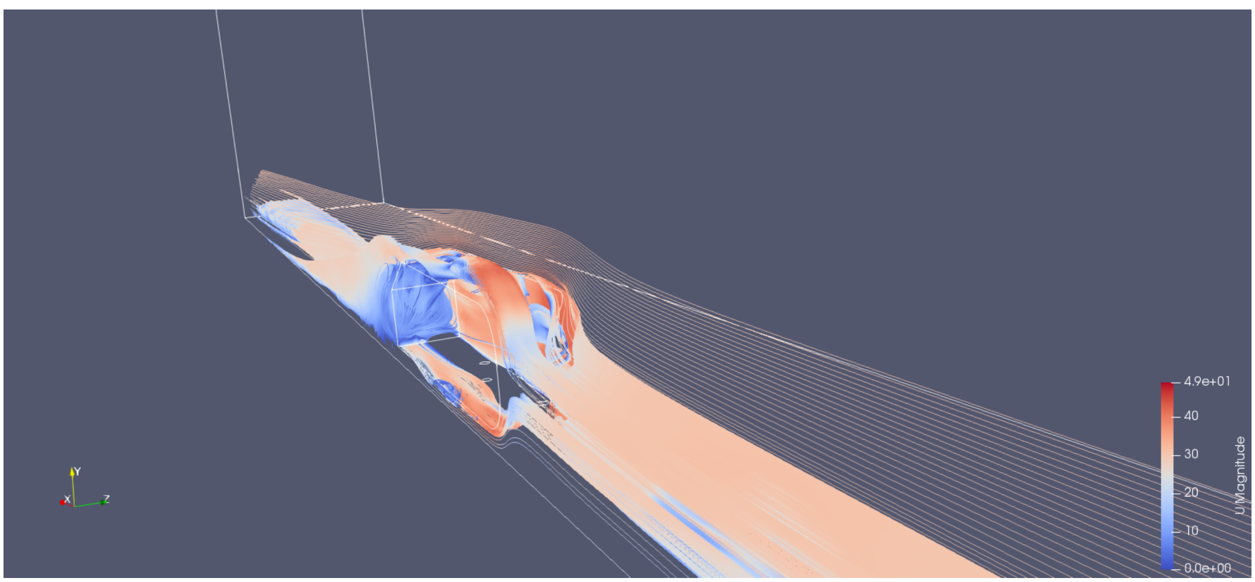


Reference Paper Results

8. 3D simulation results.

These are the results obtained from working 3D simulations, We can clearly observe the streamlines and the effect of the front fillet on the airflow.





9. Conclusion

1. The airflow around the Ahmed's body was observed and the effects on drag coefficients through variations in the geometry is successfully observed.
2. Various drag coefficients are compared with the reference paper's results to observe similar results.

10. References

1. Khan, Rehan & Umale, Sudhakar. (2014). CFD Aerodynamic Analysis of Ahmed Body. International Journal of Engineering Trends and Technology. 18. 301-308. 10.14445/22315381/IJETT-V18P262.

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