Exploring the use of vortex generators on model vehicle bodies

MECHANICAL ENGINEERING
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Introduction

The scope of this project is to explore the use of vortex generators to improve the aerodynamic efficiency of vehicles today.

Vortex generators are usually blunt shaped bodies that affect the flow of air in the control volume of interest. This project aims to optimize the use of vortex generators to control the flow separation of air over a vehicle and reduce the pressure drag of the vehicle .

Hypothesis: The vortex generators will energize the boundary flow to delay the flow separation and reduce the overall pressure drag of the vehicle body.

Figure 1: Vortex generators used on modern vehicles[1]

Project Objectives

Aim: To determine whether vortex generators reduce the drag on a model vehicle body

1. To use CFD software to study how the flow of air around a 3D model car body changes with changes in the position and number of cube shaped vortex generators on the vehicle body.
2. To analyze non-dimensional quantities of interest such as drag coefficients on particular regions of the vehicle.

Approach

A basic knowledge of parallel computing and CFD software (Openfoam) to run CFD simulations and post process data was gained with the help of colleagues and online tutorials. After this, the software and parallel computing resources were used to obtain quantities of interest . I used LES (Large-eddy simulation) models in which the large (turbulent) scales were resolved on the mesh but the subgrid-scale features were modeled geometrically, The geometric mesh used in the simulations is shown below.

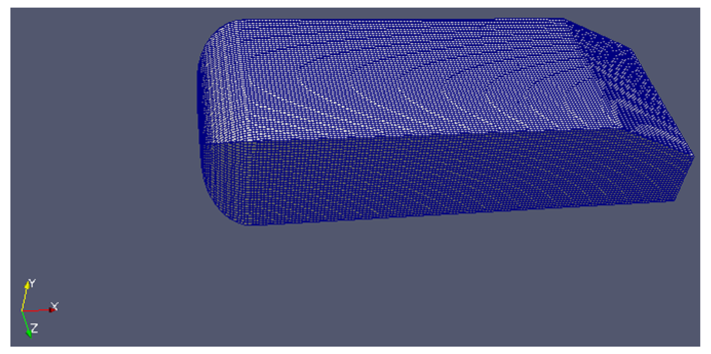

Figure 2: Model vehicle body mesh (Above)

Each simulation usually took 36hour with 22 processors.

Dimensions for this model body (Ahmed body) were obtained from the paper cited[2].

Results and Discussion

The diagram below shows how the appearance of the mesh after the cube-shaped vortex generators were added.

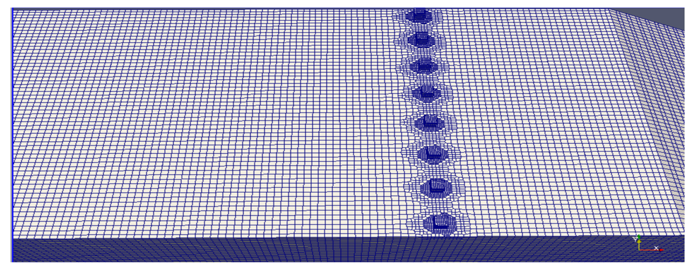

Figure 3: 8 vortex generators 9 inches upstream from the ramp edge

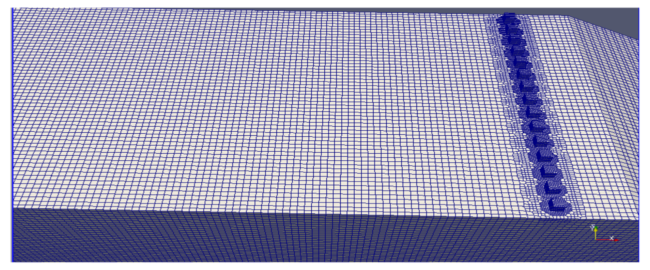

Figure 4: 15 vortex generators 3 inches upstream from the ramp edge

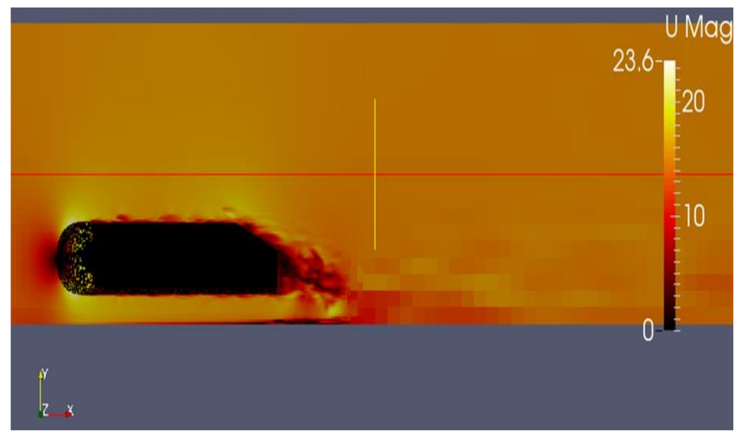

Figure 5: X direction velocity contours for case with 8 vortex generators

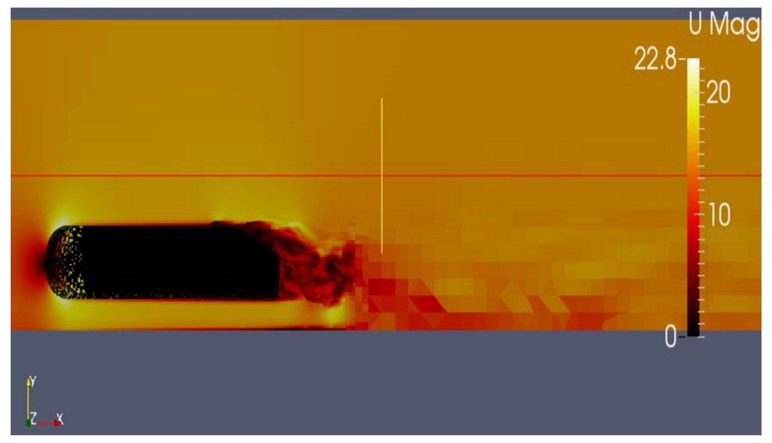

Figure 6: X direction velocity contours for case with 15 vortex generators

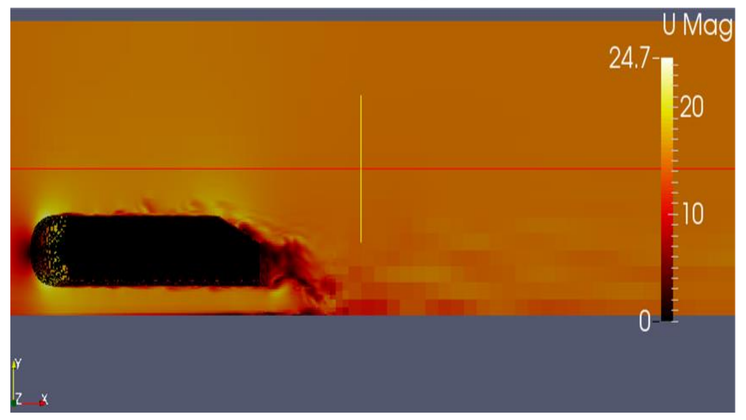

Figure 7: X direction velocity contours for case without any vortex generators (On left)

- There is a significant change in the flow when vortex generators are added.
- The flow is more turbulent at the ramp and back surfaces
- How these might affect the coefficients of drag (Cd) of specific regions and the whole body was then explored.

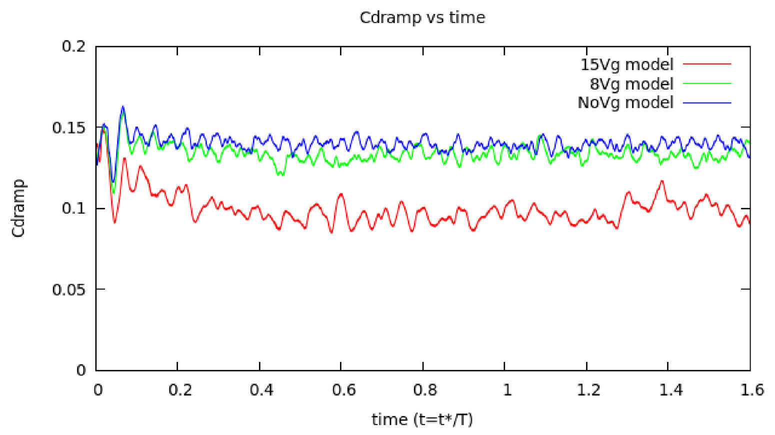

Figure 8: Cdramp (Coefficient of drag on ramp) vs time

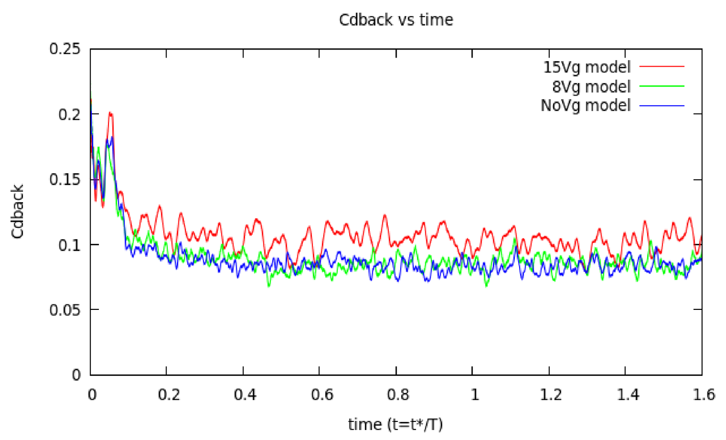

Figure 9: Cdback (Coefficient of drag on back) vs time

- With an increase in the number of vortex generators and decrease in the distance between the vortex generators and the origin, the coefficient of drag force (Cd) on the ramp decreases.
- However, the opposite is true for the back of the model vehicle body. Thus we see that these two effects might compensate for one another. The Cd of the bottom surface and the entire body was then further analyzed.

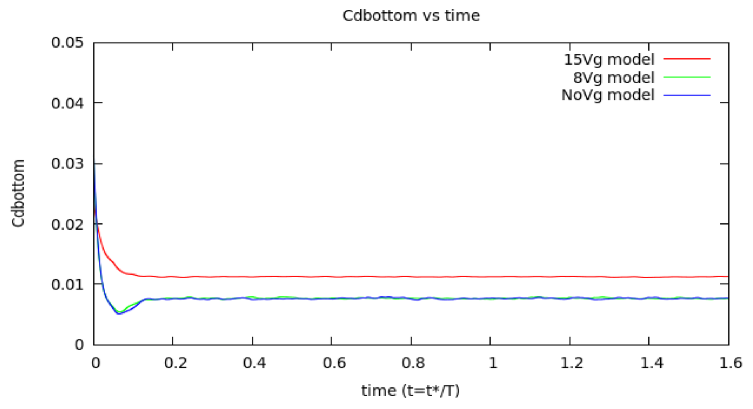

Figure 10: Cdbottom vs time

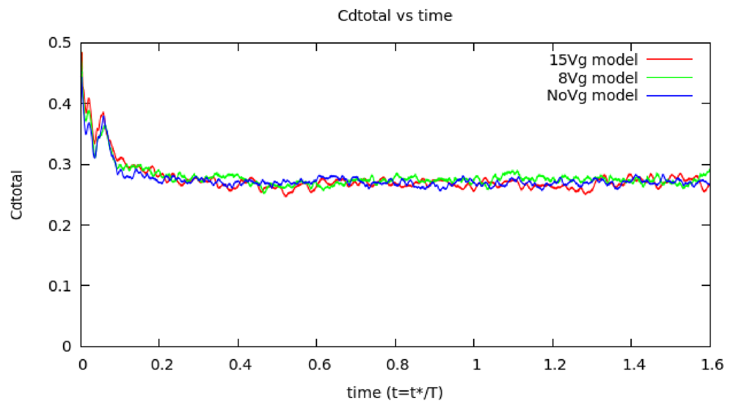

Figure 11: Cdtotal vs time

- Coefficient of drag on the bottom surface (Cdbottom) changes a little when there are many vortex generators (15) closer to the ramp.
- It barely changes in the case with 8 vortex generators.
- Vortex generators do cause a change in the coefficient of drag of the various surfaces.
- Surprisingly however, the effects of the vortex generators on the entire body is too small to show a significant improvement.

Conclusions

- The drag coefficient reduction on the ramp proved that the cube-shaped vortex generators could in fact be used to reduce the drag on particular surfaces.
- However, the drag coefficient increment on the back surface of the body compensated for that effect.
- This was confirmed by the final graph which showed the relationship between the coefficient of drag of the entire body and the time was almost unchanged.

All three cases had approximately the same coefficient of drag over the time. This is an unexpected result. However, we understand better why and how this result is being obtained. Further refinement to the mesh as well more simulations must be conducted to understand the reasons for this as well how a desirable result can be obtained if there exists one. This is an on-going project.

Acknowledgements

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References

[1]Vortex generator image. Digital image. N.p., n.d. Web. 13 Apr. 2015. <http://www.vividracing.com/catalog/wm.php/images/aprevoxvortex2.jpg>.

[2]Pujals, G., S. Depardon, and C. Cossu. "Drag Reduction of a 3D Bluff Body Using Coherent Streamwise Streaks." Experiments in Fluids 49.5 (2010): 1085-094. Web. 2 Feb. 2015