Computer-Aided Development of Aerodynamic Coefficients

Ostap Lisowitch and Dr. Byungik Chang
Tagliatela College of Engineering

Introduction

Wind tunnel testing is routinely used to study various aerodynamic phenomena and determine aerodynamic parameters of engineering structures. However, the required design aerodynamic coefficients for a complex shape may not always be available from the wind tunnel testing or standards. In the last decade, a computer-aided computational fluid dynamics code has been widely used in fluid mechanics for simulation of complex structures. Computational Fluid Dynamics (CFD) provides a quicker and virtually a free alternative to modeling complex systems in comparison to wind tunnel testing.

The primary objective of this study is to verify and develop aerodynamic coefficients for multisided cylinders, in particular, drag coefficients (C_D) using CFD (ANSYS-CFX) [1]. There are numerous numbers that describe the regime of flow, one dimensionless hydrodynamic numbers that directly describe flow past a structure is the Reynolds Number (Re). Reynolds Number is classified as a ratio of inertial forces to viscous forces which enumerates the relative importance of the forces inflicting the object or structure. Drag coefficient (C_D), indirectly related to the Reynolds Number, is a dimensionless quantity that is used to quantify the drag or resistance of an object in a fluid environment, such as air in this study.

$$C_D = \frac{F_d}{\frac{1}{2}\rho v^2 A} \qquad Re = \frac{\rho v D}{\mu}$$

The output will be able to predict buffeting loads for the fatigue design of multisided cross section slender support structures without field or wind tunnel test, which costs much more compared to computer modeling.

Methods

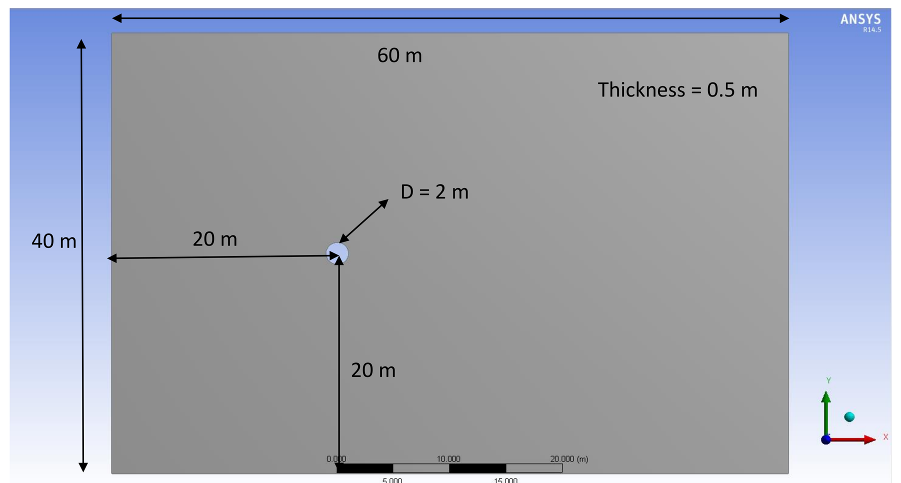


Figure 1: Geometry

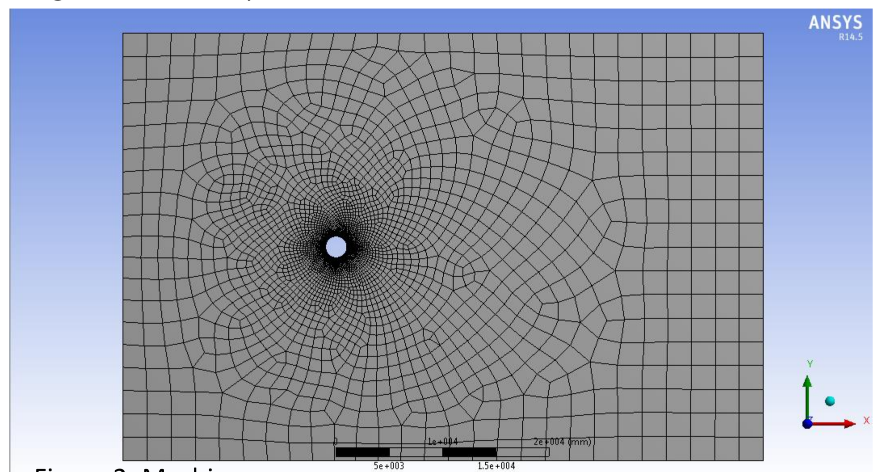


Figure 2: Meshing

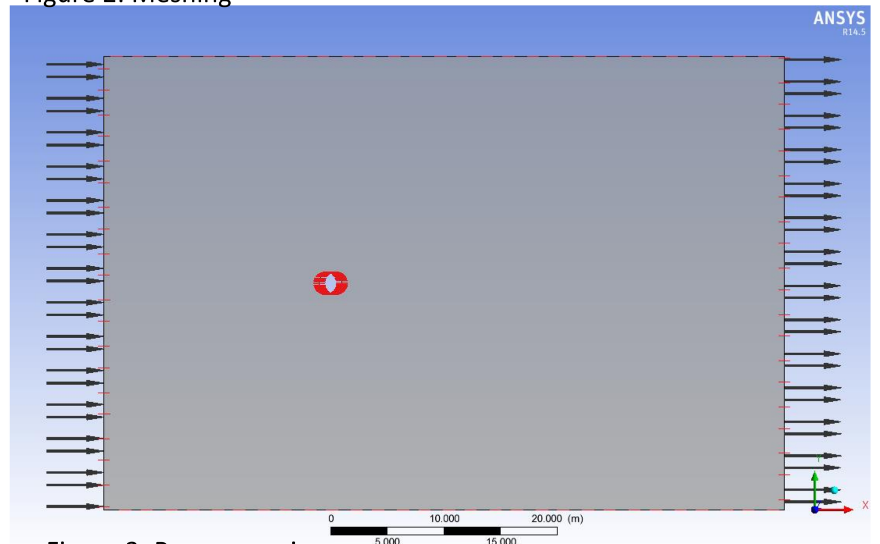


Figure 3: Pre-processing

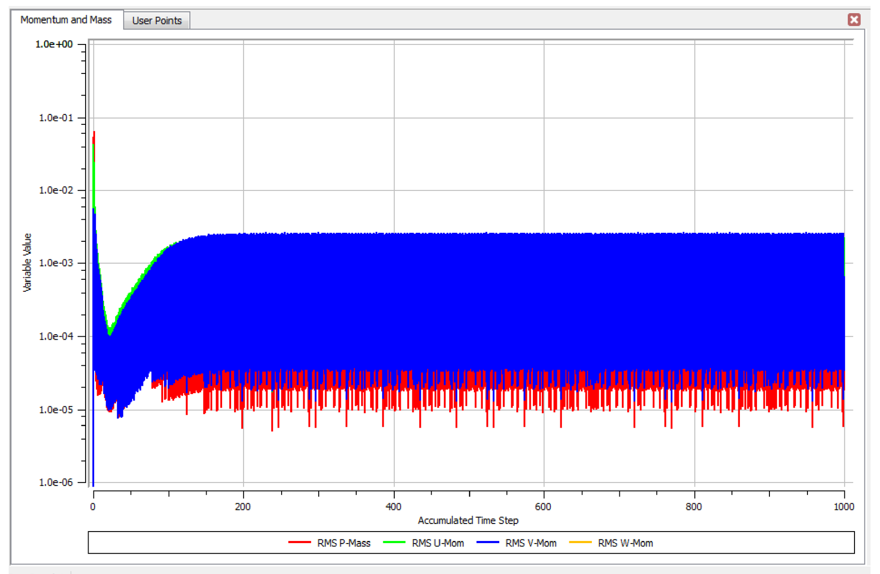


Figure 4: Solution Convergence

Results

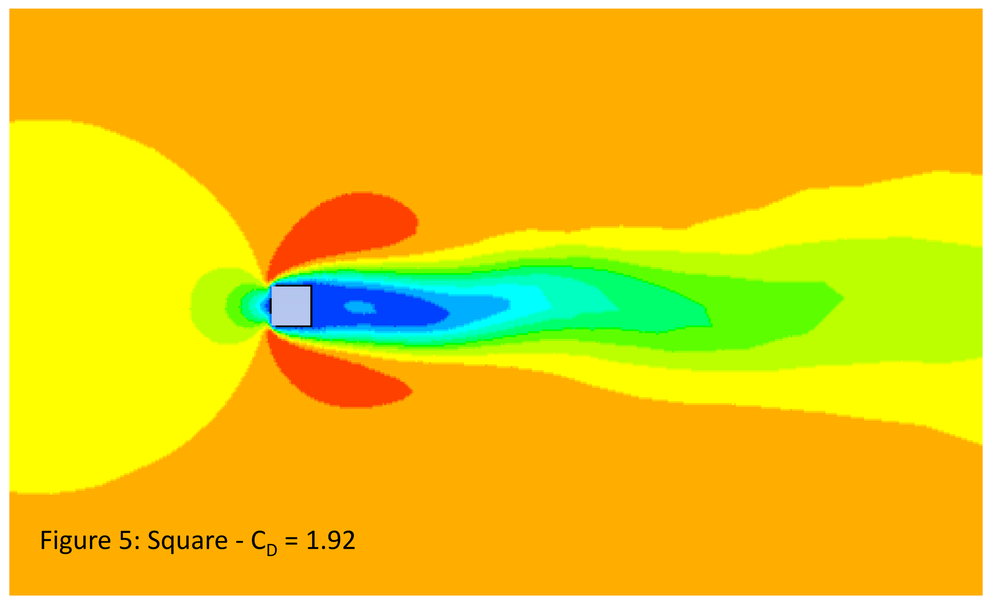


Figure 5: Square - C_D = 1.92

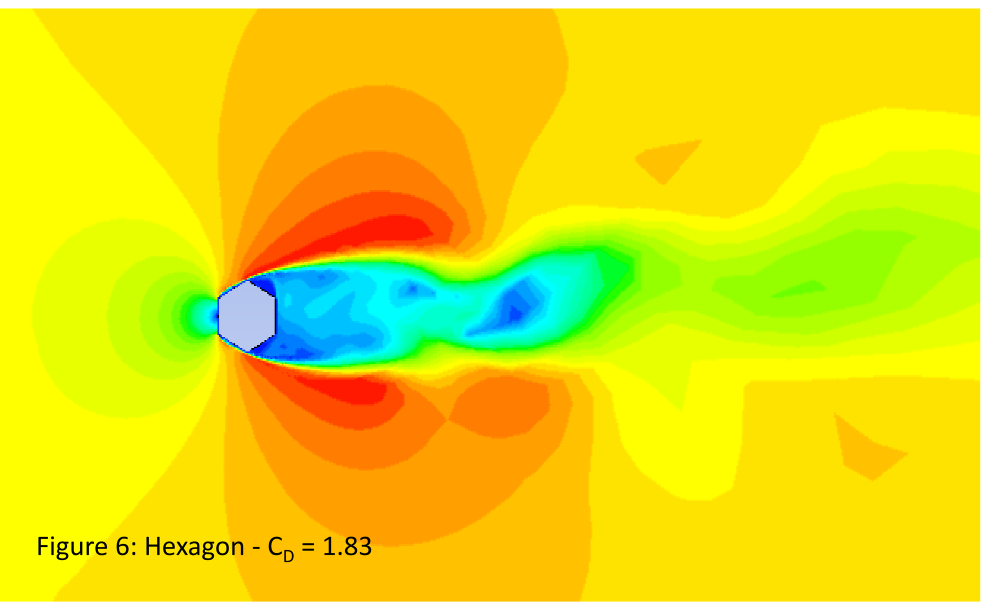


Figure 6: Hexagon - C_D = 1.83

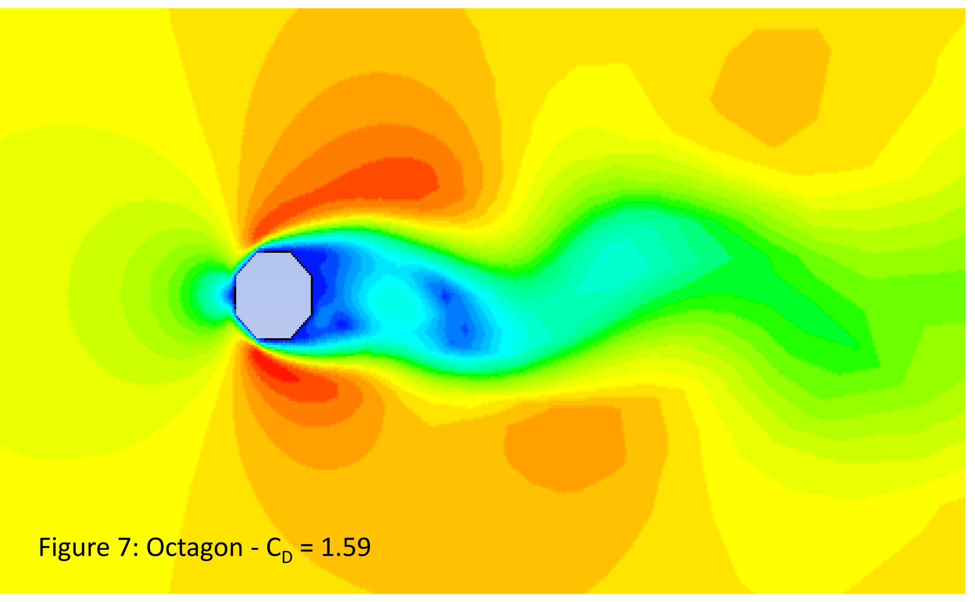


Figure 7: Octagon - C_D = 1.59

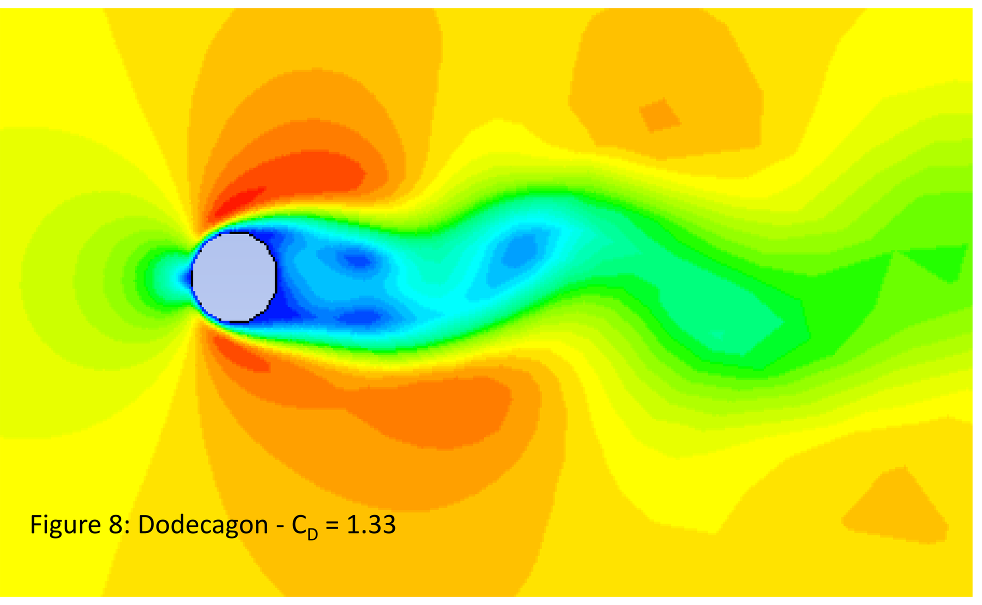


Figure 8: Dodecagon - C_D = 1.33

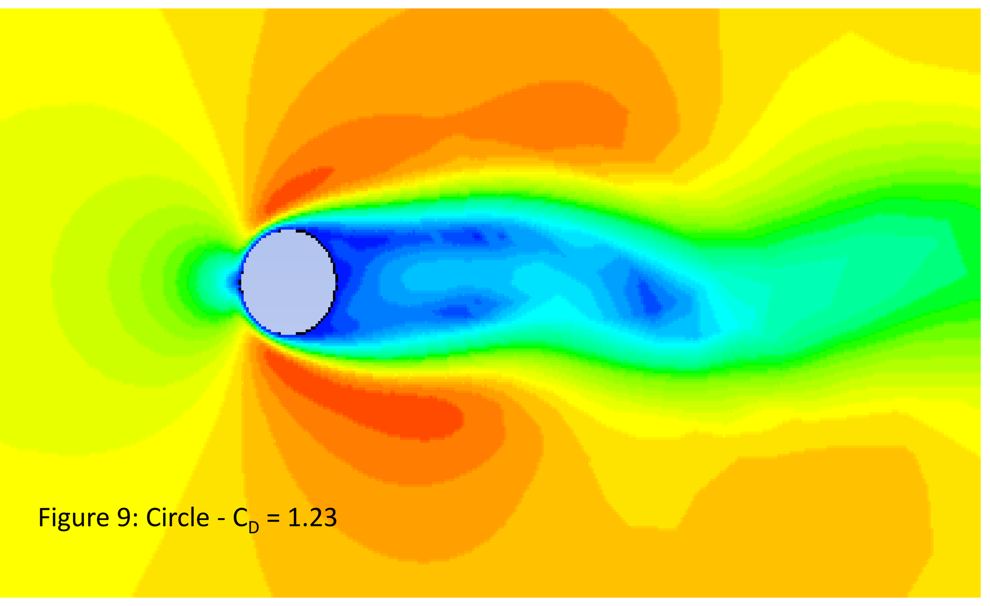
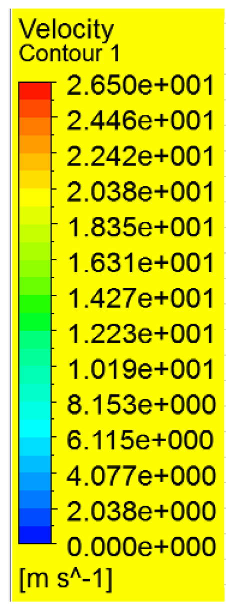


Figure 9: Circle - C_D = 1.23



	Drag Coefficients of Multisided Cylinders (Re 100)			
	Number of Sides	Wind Tunnel	Design Code [5]	ANSYS-CFX
	Square - 4	2.0 [2]	1.7	1.92
	Hexagon - 6	NA	NA	1.83
	Octagon - 8	1.0 ~ 1.6 [3]	1.2	1.59
	Dodecagon - 12	1.2 ~ 1.6 [2, 3, 4]	1.2	1.33
	Circle - 1	1.2 [2,3]	1.1	1.23

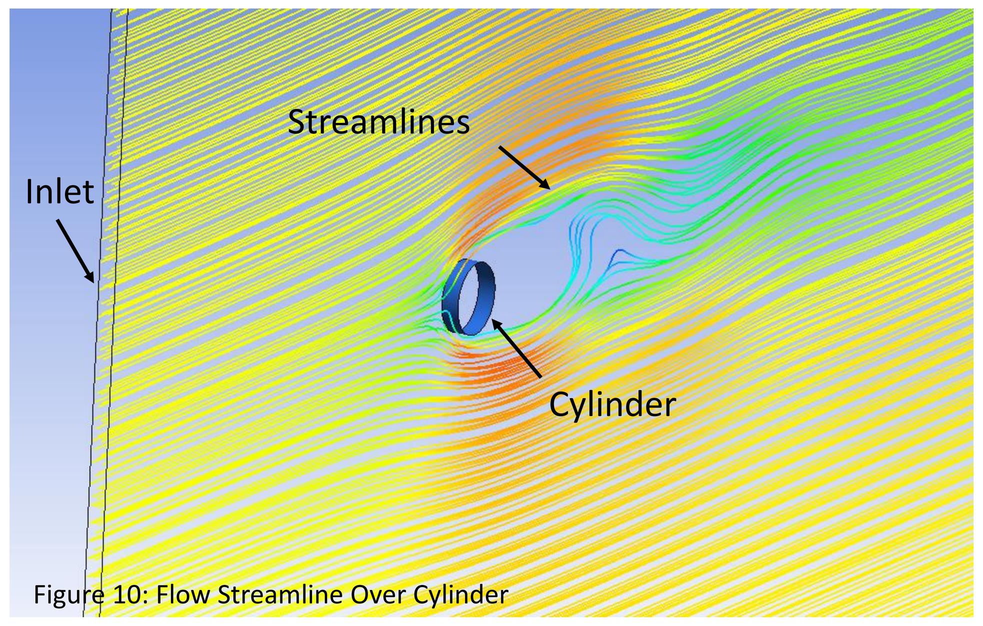


Figure 10: Flow Streamline Over Cylinder

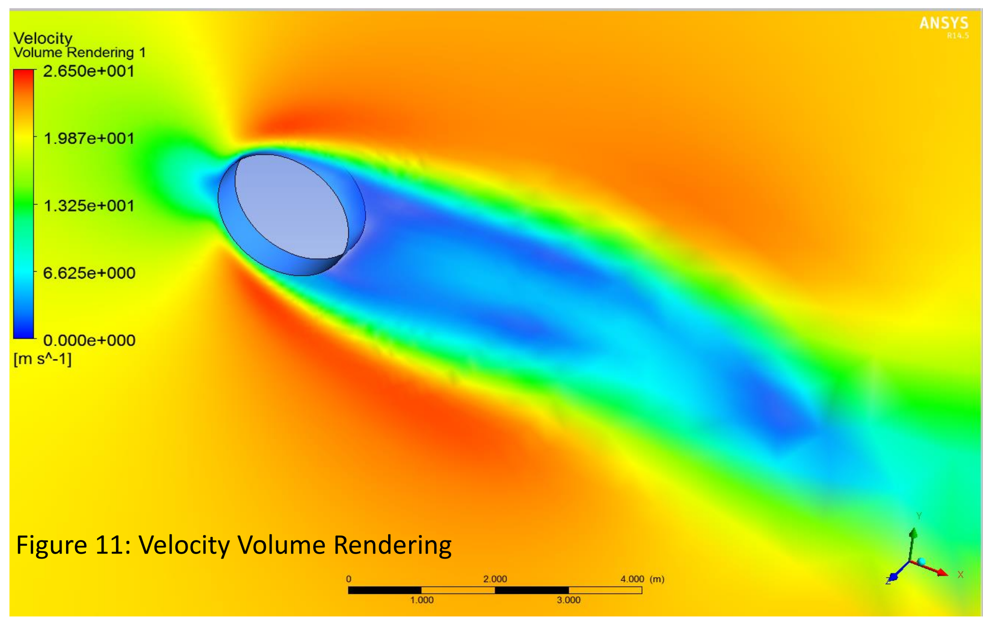


Figure 11: Velocity Volume Rendering

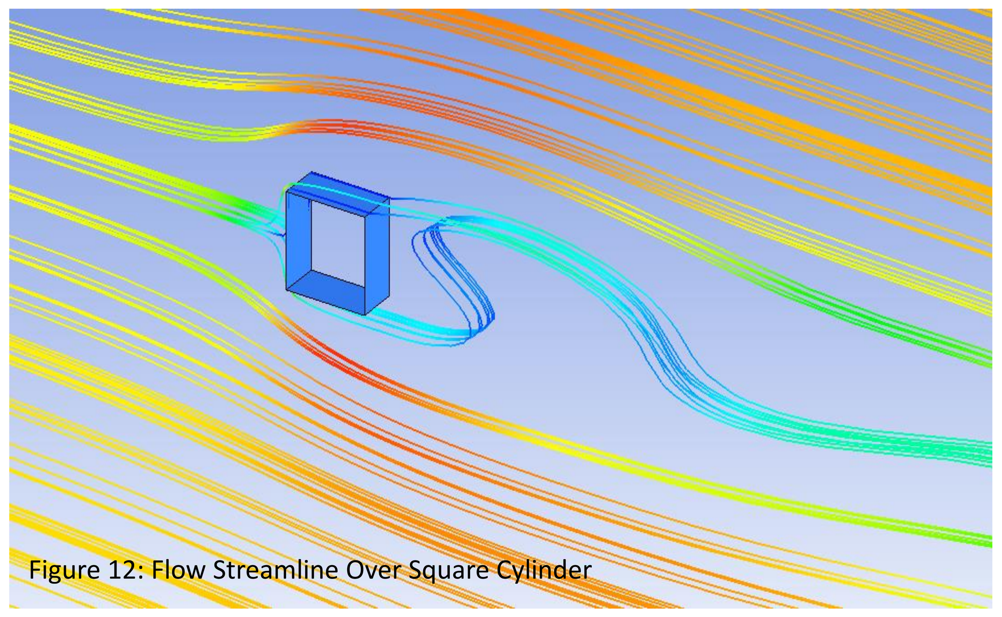


Figure 12: Flow Streamline Over Square Cylinder

Conclusion

It was determined that CFD is a fast, inexpensive, and accurate method of modeling complex fluid to structure interaction. With the resulting data aerodynamic coefficients were verified and developed, as well as, predicted vortex shedding and buffeting loads.

Future Works

In CFD, Aerodynamic coefficients were developed at a Reynolds Number of a 100. The following task is to model the various cylinders with a Reynolds Number range of $100 < Re < 1.0 \times 10^6$, which covers typical wind velocity in reality. This task involves analyzing 20 various turbulence options. Going further into the project, analyzing vibration induced vortices would become the third objective.

Acknowledgements

Special thanks to my faculty advisor Dr. Byungik Chang for guiding me in the right directions throughout my research and Dr. Daniels for ANSYS Tutorials and Lectures.

References

[1] "ANSYS - Simulation Driven Product Development." ANSYS - Simulation Driven Product Development. N.p., n.d. Web. 05 Sept. 2014.
[2] Scruton, An introduction to wind effects on structures, Engineering design guides 40, BSI&CEI, 1981.
[3] James, W.D. Effects of Reynolds number and corner radius on two-dimensional flow around octagonal, dodecagonal and hexdecagonal cylinders, PhD Dissertation, Iowa State University, 1976
[4] Chang, B. A time-domain model for predicting aerodynamic loads on a slender support structure for fatigue design cylinders, PhD Dissertation, Iowa State University, 2007
[5] American Association of State Highway and Transportation Officials, Standard Specifications for Structural Support for Highway Signs, Luminaries, and Traffic Signals. Washington, D.C., 2010.