INTRODUCTION: Using the CFD Module of COMSOL Multiphysics 5.4, we studied the flow past a circular cylinder with sinusoidal ridges (shown below), at Reynolds numbers of 20, 50, 200, and 500.

We define the cylinder in polar coordinates by

\[ r(\theta) = \frac{L}{2} + a \cdot \cos(\omega \theta), \quad 0 \leq \theta \leq 2\pi \]

Where \( L = 0.15m \) is the base cylinder diameter, \( a \) is the ridge amplitude, and \( \omega \) is the number of ridges.

COMPUTATIONAL METHODS: The computational domain is a two-dimensional plane channel with length \( 20L \) and width \( 3L \). The center of the cylinder is positioned in the center of the channel, a distance \( 2L \) from the inlet. An inlet velocity with a parabolic profile is chosen at the leftmost wall, and a zero-pressure outlet boundary condition is chosen at the rightmost wall.

We use the following dimensionless quantities:

\[ Re = \frac{\rho U_c L}{\mu}, \quad St = \frac{f L}{U_c}, \quad C_D = \frac{2F_D}{\rho U_c^2 L}, \quad C_L = \frac{2F_L}{\rho U_c^2 L} \]

Where \( U_c \) is the centerline velocity, \( f \) is the frequency of vortex shedding, and \( F_D, F_L \) are the total drag and lift forces, respectively.

Additionally, we perturb the flow with a brief vertical oscillation of the cylinder in order to trigger vortex shedding at \( Re = 200 \) and 500.

RESULTS: In the laminar flow regime, we found:

- The recirculation zone length is independent from the number of ridges
- The following relationships between the number of ridges and \( C_D \) and for \( \omega = 4 \), between the counterclockwise angle of attack \( \alpha \) and \( C_D \):

- Similar relationships were found for \( Re = 20 \).

In the periodic shedding regime, we found the following relationships:

- Values for the Strouhal number, \( St \), were also computed.

CONCLUSIONS & FURTHER RESEARCH:

- As \( \omega \) increases, the \( C_D, C_L \), and \( St \) values tend to approach that of a smooth cylinder (\( \omega = 0 \)).
- When \( \omega > \sim 13 \) in the periodic shedding regime, values for \( St, C_D, \text{mean}, \) and \( C_L, \text{pkp} \) become approximately steady. When \( \omega < \sim 13 \), results are erratic and no clear trend can be deduced.
- More research needs to be done to investigate the unique geometry of cylinders with \( 1 \leq \omega \leq 4 \).

REFERENCES:


Acknowledgements

SUNY New Paltz Summer Undergraduate Research Experience (SURE) Program for 2018