Performance Optimization of Ocean Current Turbine Blades

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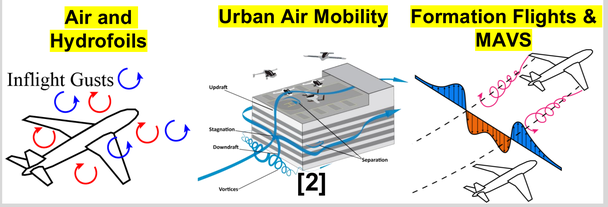
Introduction

Ocean current turbines offer a promising source of renewable energy. However, unsteady ocean currents and upstream flow disturbances can significantly affect the power output of the turbines. This project investigates how disturbances generated by an upstream cylinder influence the loads on a downstream airfoil using computational fluid dynamics (CFD) and low-order modeling.

Other engineering applications affected by flow disturbances include:



Objectives

What's the problem?

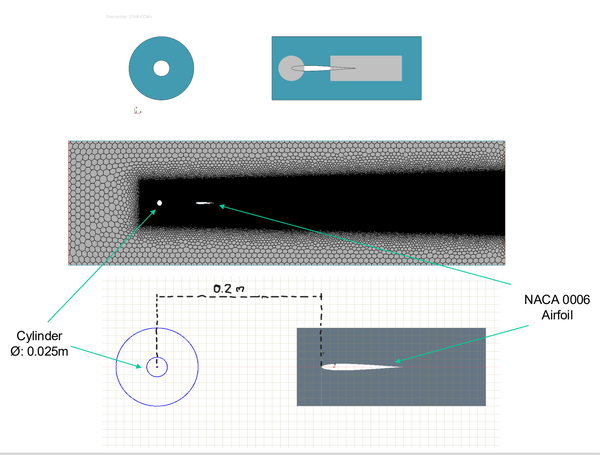
When utilizing CFD to validate the literature, the simulated lift coefficient consistently overpredicted the experimental results that were reported, of which being ±0.25.

Goals

- Learn the basics of fluid dynamics and CFD
- Identify possible causes for the overprediction
- Evaluate multiple modifications to the computational setup to reduce the overprediction

Computational Set Up

- Cylinder-airfoil based interaction with a 0.2m spacing
- 0.3m/s inflow velocity
- Unsteady Reynolds-Averaged Navier-Stokes (URANS)



Results

Baseline Simulation (Reference Case)

This configuration had the lowest lift overprediction of ±0.7625. Its main change included a coupled flow solver with a CFL constant of 1 and a timestep of 0.001s.

Mesh Independence Study

Changing the refinement value from 0.001m to 6.4E-4m produced an overprediction of ±0.7875. With this only being a 3.3% change, mesh convergence was achieved.

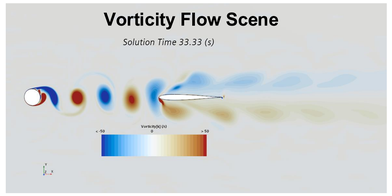
Cylinder Spacing Study

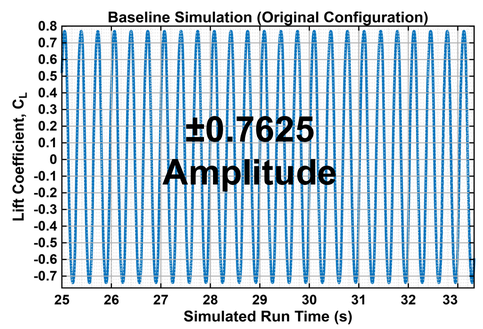
Moving the cylinder closer to the airfoil created a graph that was no longer stable, whereas moving farther away dropped the overprediction to ±0.7595. This indicated that the spacing was not the cause of the discrepancy

Methods & Collected Data

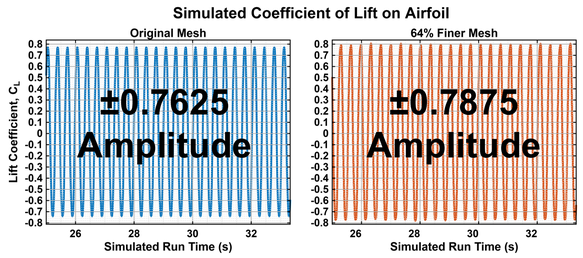
Main Areas of Investigation

- Checked various solvers and timesteps
- Make sure that the issue was mesh independent
- Investigate if the spacing between the cylinder and airfoil had any effect on the coefficient of lift

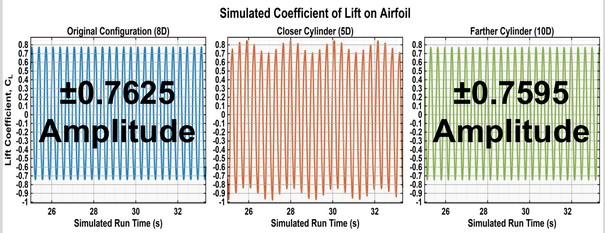




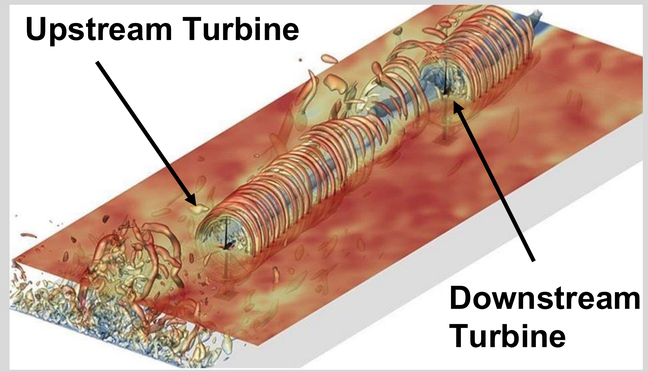
Baseline Simulation Lift Plot and Flow



Mesh Independence Study



Cylinder Spacing Study

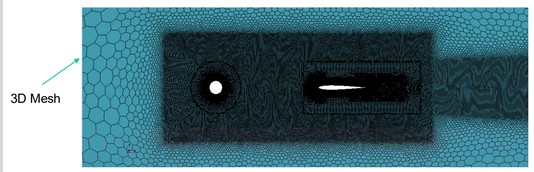


[1], Wake Interaction Between Upstream and Downstream Turbines

Conclusions

Although the target lift overprediction, of ±0.25, was not achieved, this study identified several factors that are unlikely to be the cause of the discrepancy. The mesh refinement study demonstrates that the issue is mesh independent, while modifying the spacing failed to reduce the overprediction in any meaningful way. These findings will help narrow the possible sources of error in future work.

Future work will investigate three-dimensional Large Eddy Simulations (LES) to determine if the discrepancy is caused by turbulence modeling or 3D flow effects



References

[1] Porté-Agel, F., Bastankhah, M. &Shamsoddin,. *Boundary-Layer Meteorology* (2020).
[2] Gusts Encountered by Flying Vehicles in Proximity to Buildings, A. Mohamed