# Development & Validation of an Actuator Line for Floating Wind turbines


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## 1. Project Aims

1. Development - *Modify the in-house `OpenFOAM`-based Actuator Line Code to account for platform motions.*
2. Validation - *Validate simulations results against experimental force and wake data.*
3. Application - *Apply the method to explore the interaction between ambient turbulence and platform-motion-induced coherent structures.*

## 2. Importance of Floating Offshore Wind Energy

- Access to deeper waters - estimated 80% of all practical wind energy potential found in deeper waters[4].
- Higher wind speeds - Stronger and more consistent wind speeds allow for greater yield.
- Smaller seabed footprint - Floating turbines do not require a monopile foundation.
- Increased complexity - Platform design introduces complexity and design methods have not yet converged[1].
- Additional Unsteadiness - Platform motions introduce unsteadiness into the wake.

$\Longrightarrow$ Understanding the dynamic wake system poses a major challenge in FOWT farm optimisation and requires high-fidelity yet computationally affordable models. One such candidate model is the floating actuator line method.

## 3. Experimental Validation Case

- UNAFLOW[2] & NETTUNO[3] experimental campaigns.
- 1:75 scaled 10MW version of the DTU-10MW turbine.
- 2.38m diameter rotor resulting in a (local/global) blockage of (48.7%/8.4%) in the POLIMI wind tunnel.
- Thrust, torque and wake measurements.
- Monochromatic platform motions in pitch, surge, yaw, roll, and sway.

## 4. Methodology

- Turbine - Representation via actuator line method (fig. 1).
- Turbulence - Ambient turbulence recreated via divergence free synthetic eddy method[5]. Flow field solved for using large eddy simulation with Smagorinsky model for subgrid stresses. See fig. 2.
- Blockage - Boundary layers represented via wall models ($y^+ \approx 180$).
- Solver - Discretised using the finite volume method with cell size $\Delta = D/120$. Solved using PIMPLE algorithm. Mesh contains approximately $15 \cdot 10^6$ cells.

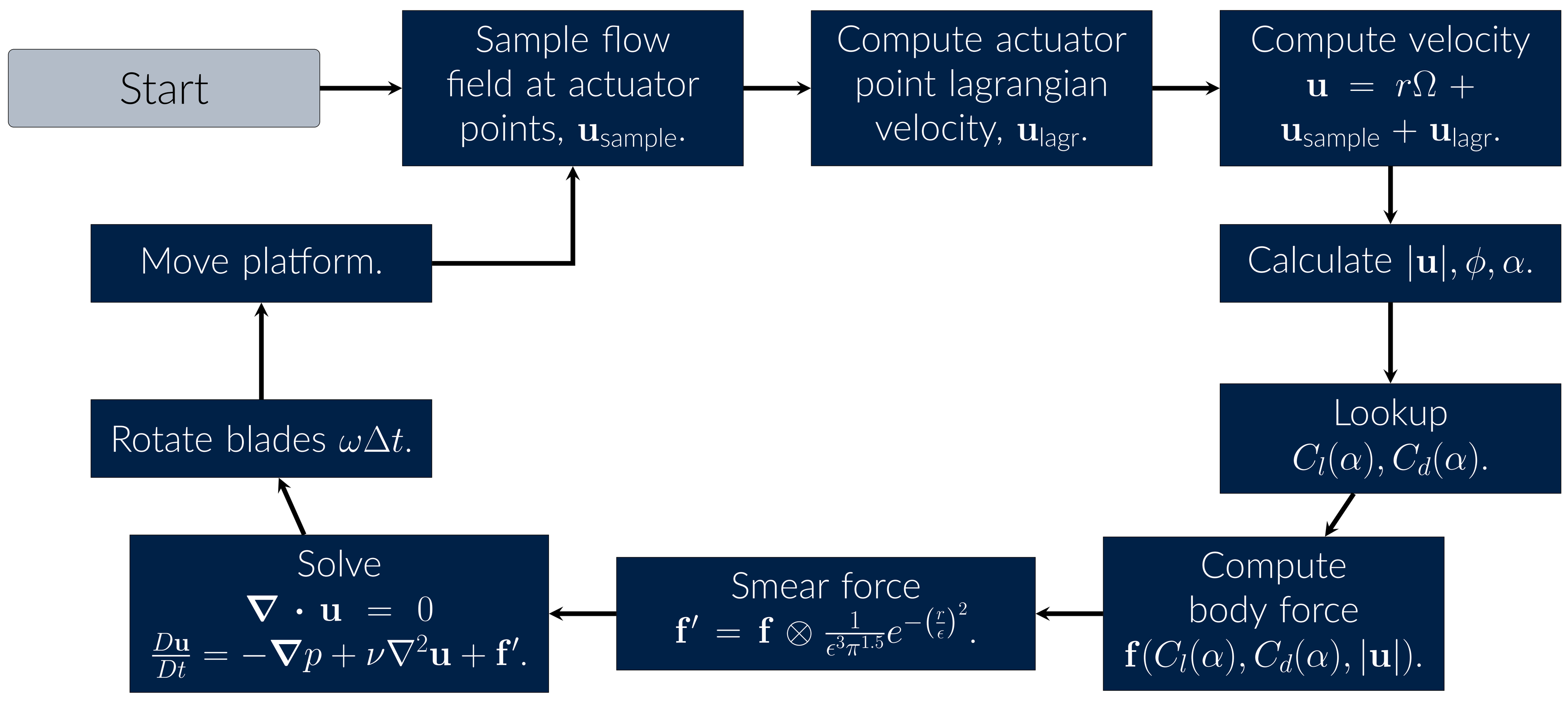


Figure 1. Modified actuator line method procedure.

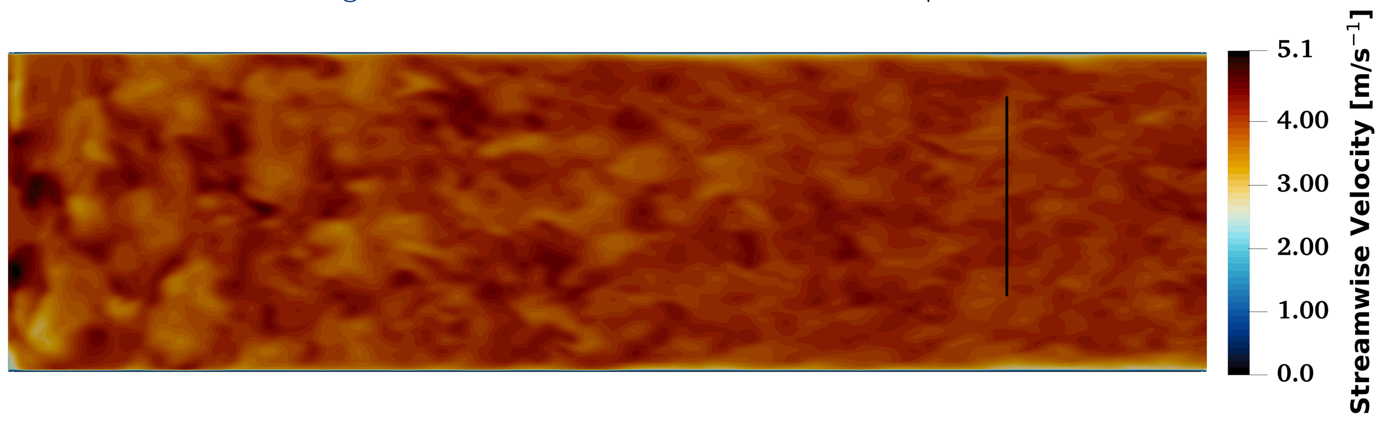


Figure 2. Inlet turbulence plotted over a streamwise-vertical plane. The rotor plane is labeled with a black line.

## 5. Results

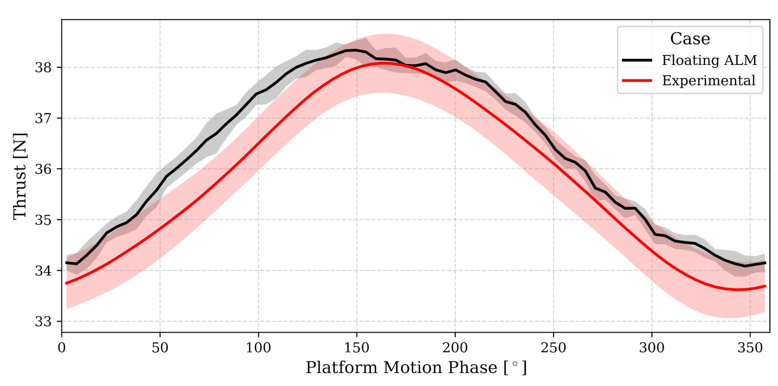


Figure 3. Phase averaged thrust variation of a pitching turbine with harmonic platform motions described by $A = 1.3°, f = 1$Hz.

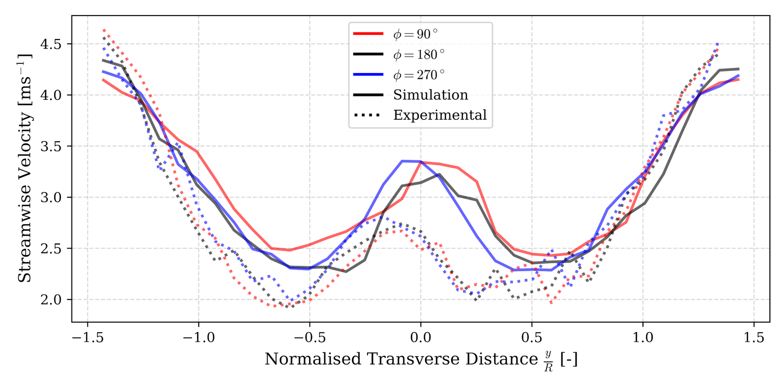


Figure 4. Horizontal phase averaged wake profile of a pitching turbine with harmonic platform motions described by $A = 1.3°, f = 1$Hz.

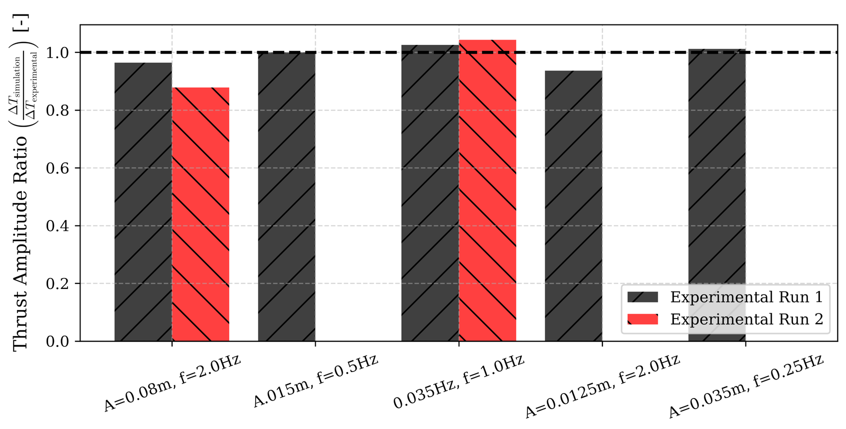


Figure 5. Comparison thrust variation for surging cases. Simulation thrust variation is normalised by the experimental thrust variation.

Rotor Forces:

- Rotor thrust oscillation amplitude shows good agreement across multiple cases with varying dynamics.

Rotor Wake:

- Phase-averaged wake results agree well within the outer wake region ($r/R > 0.7$). However, the absence of nacelle representation leads to an overprediction of the streamwise velocity near the hub.
- $Q$-Criterion contour shows how the actuator line method is able to resolve the complex wake structure and therefore any platform-induced interactions.

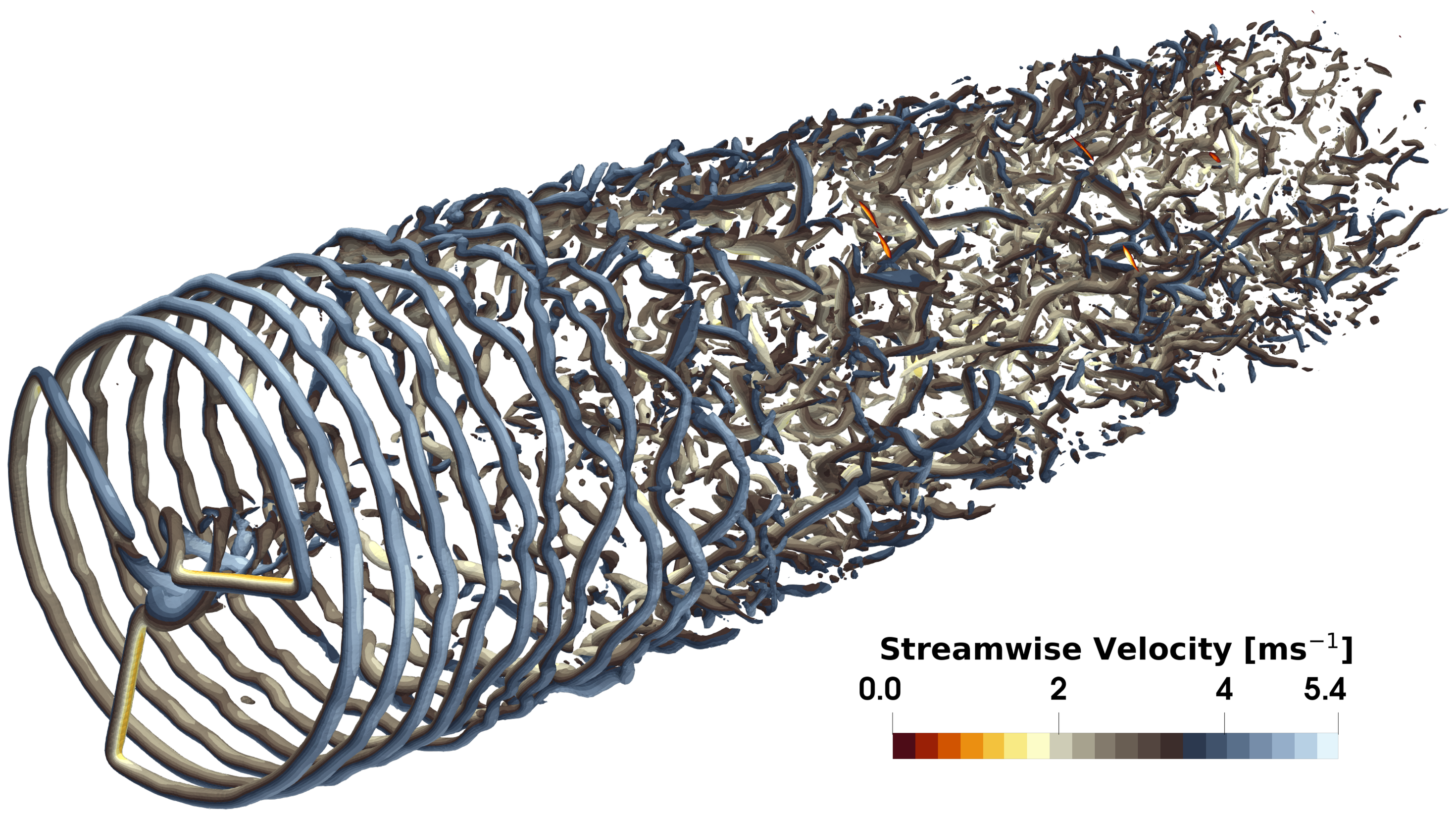


Figure 6. $Q$-criterion contour plot a of pitching turbine with harmonic platform motions described by $A = 1.3°, f = 1$Hz.

## 6. Conclusions / Key Takeaways

- Experimental and numerical results show good agreement in rotor force and wake prediction.
- The floating actuator line method is able to produce accurate results without explicit blade representation resulting in large computational savings.
- Turbulence produced by the divergence-free synthetic eddy method is able to reproduce experimental conditions.
- Future work: Actuator-based representation of floating towers and nacelles, characterisation of complex floating-motion-induced wake instabilities, comparative study of floating actuator line and disc wakes.

## Bibliography


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[2] A. Fontanella et al. "UNAFLOW: a holistic wind tunnel experiment about the aerodynamic response of floating wind turbines under imposed surge motion". In: *Wind Energy Science* 6.5 (2021), pp. 1169–1190.

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[5] R. Poletto, T. Craft, and A. Revell. "A New Divergence Free Synthetic Eddy Method for the Reproduction of Inlet Flow Conditions for LES". In: *Flow, Turbulence and Combustion* 91.3 (Oct. 2013), pp. 519–539. ISSN: 1573-1987.



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