Aerodynamic response of a wind turbine subjected to prescribed movements: experimental vs. numerical data

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Motivation

How do the floating motions affect a wind turbine?

Turbine performance

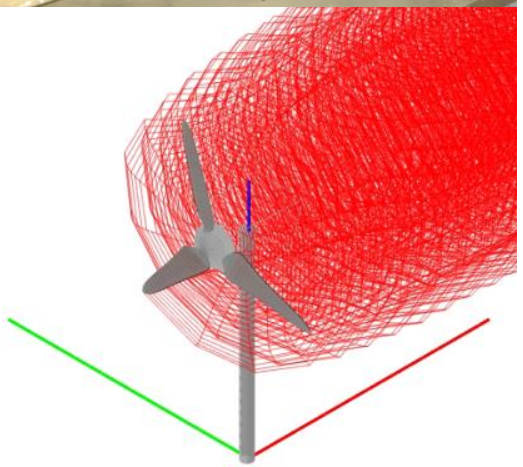
Wake behaviour

Wind tunnel measurements

- Wake
- Thrust
- Power

Engineering models

- Unsteady BEM
- LLFVW



Measurement campaign

MoWiTO 0.6:
- D = 0.58 m
- TSR = 5.9
- ω = 980 rpm

Galleria del Vento PoliMi:
- Boundary layer test section
- U = 5 m/s
- TI = 1.5%

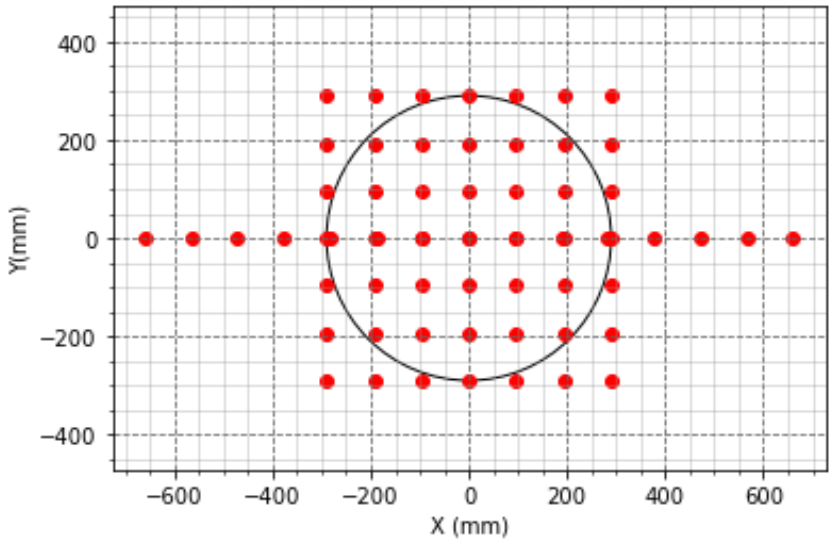
Floating motions:
- 6 DoF platform

$$\xi(t) = A_p \sin(2.\pi f_p t)$$

A_p = 6 mm
f_p = 3.3 Hz

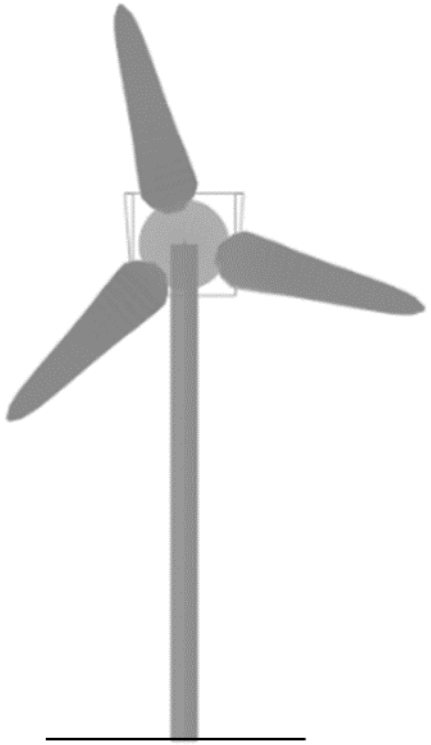
Test 1: Cp, Ct curves for fixed case

Test 2: Wake measurement using hot-wire array

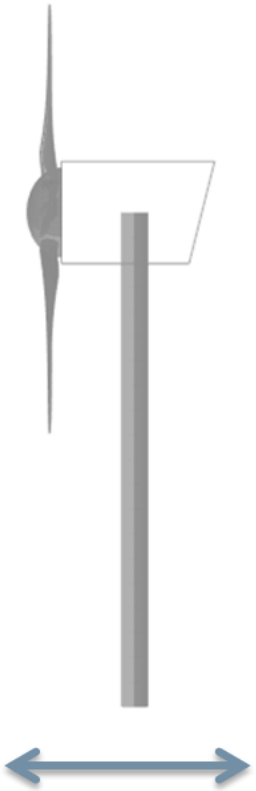


Cases studied

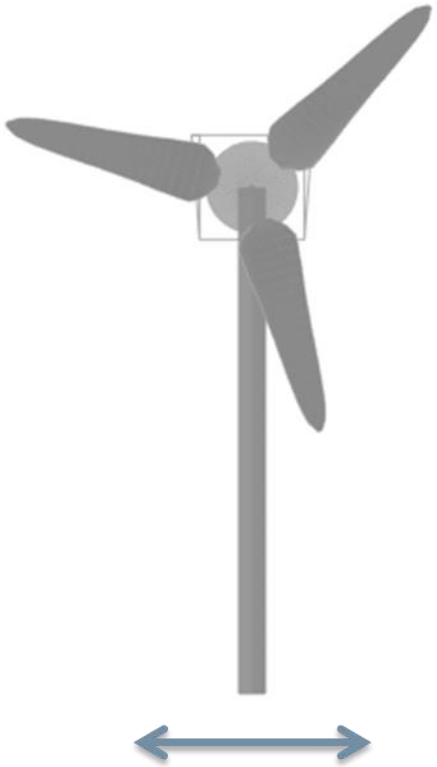
Fixed



Surge



Sway

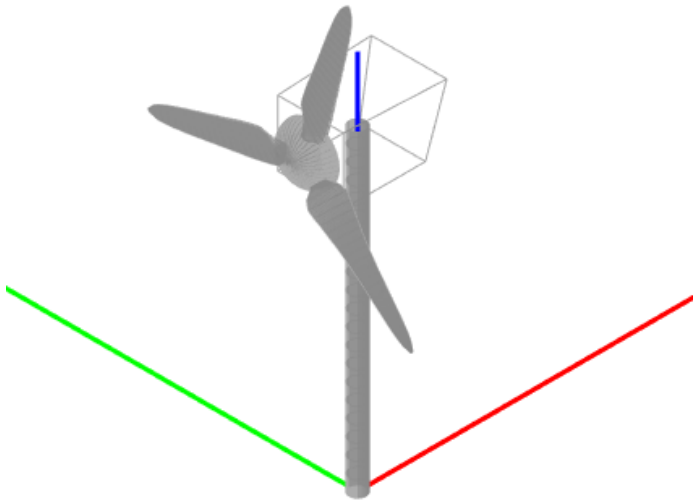


Engineering models

Unsteady blade element momentum theory

- 1D actuator disc + blade element
- time-varying inflow conditions
- tip loss factor and 3D correction included

Qblade CE

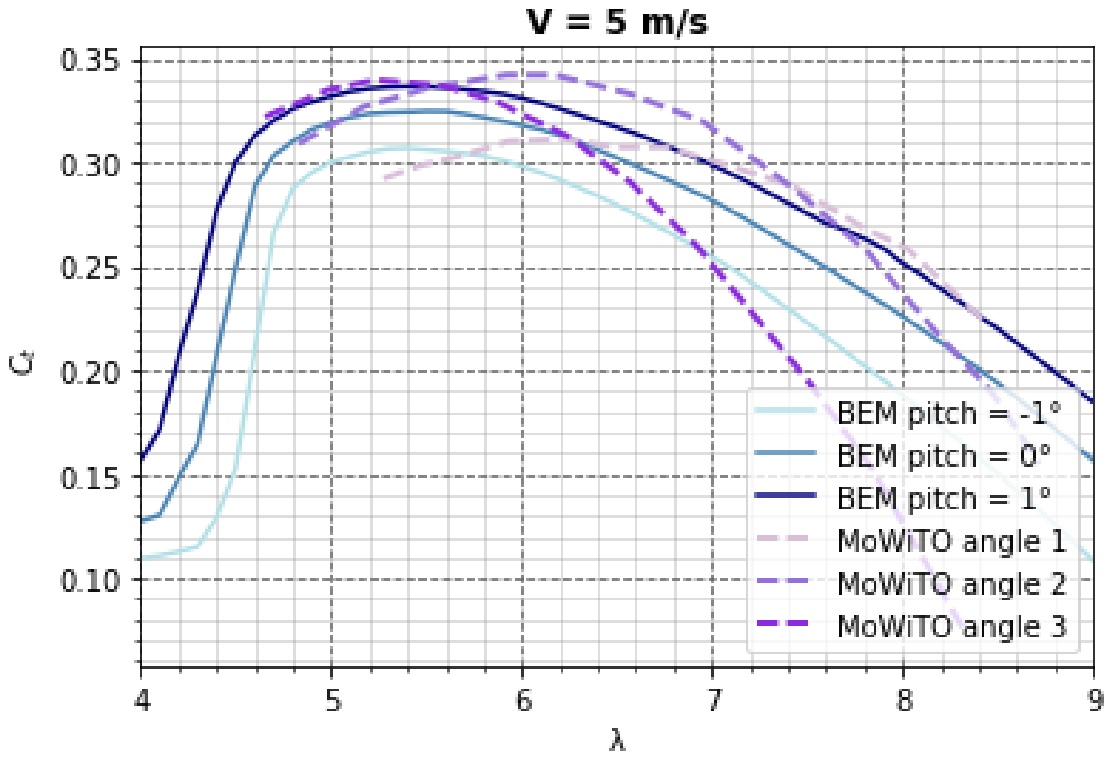


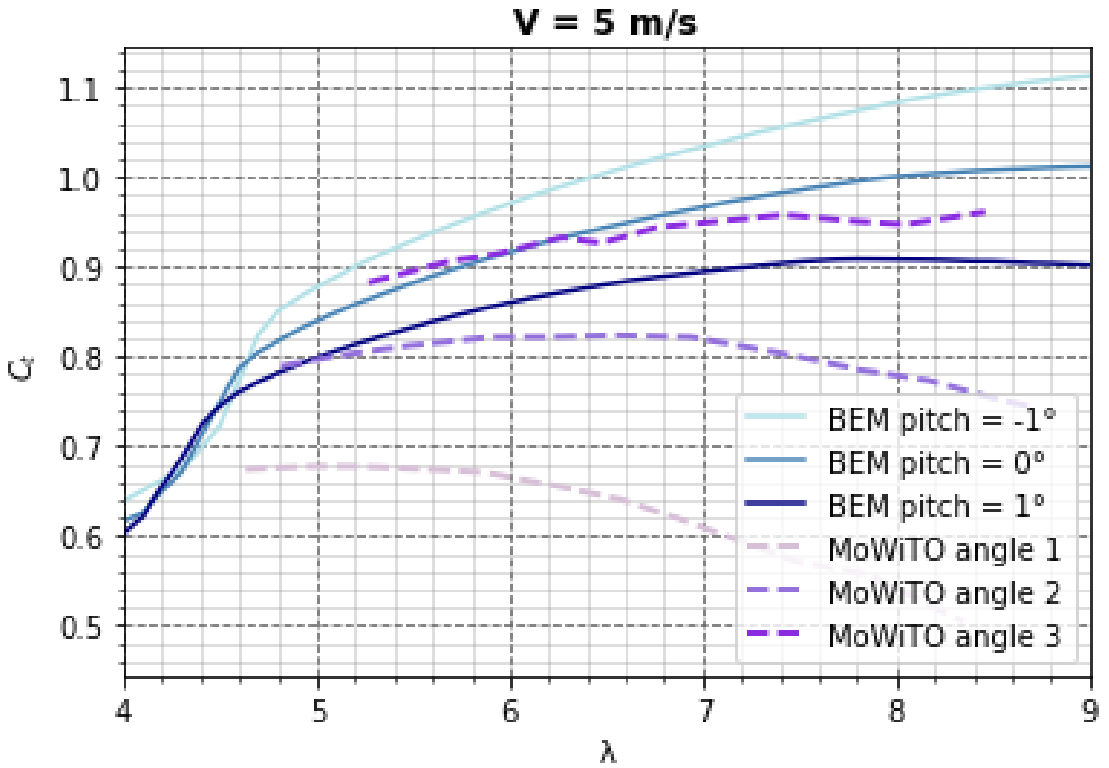
Lifting line free vortex wake method

- rotor represented by a lifting line
- considers induced velocities created by trailing vortices shed from blade
- circulation calculated from relative inflow velocity and cp, ct

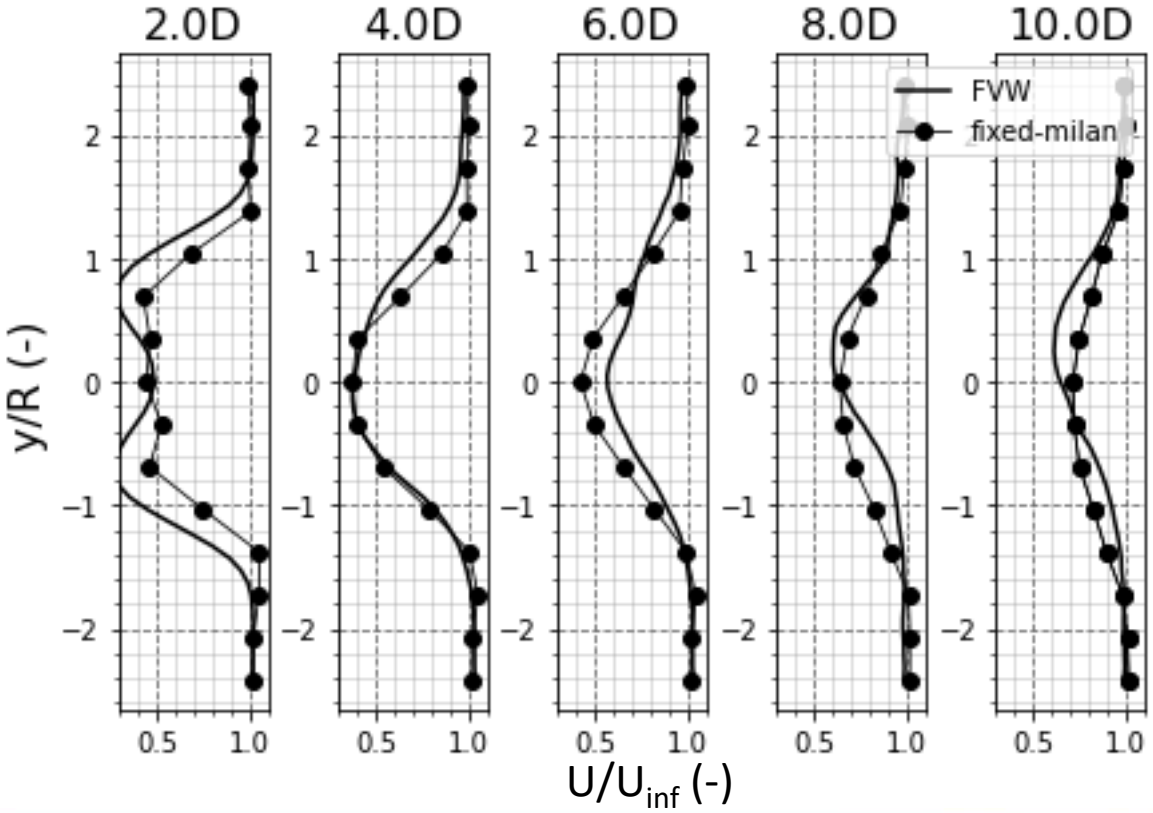
Fixed turbine characterization

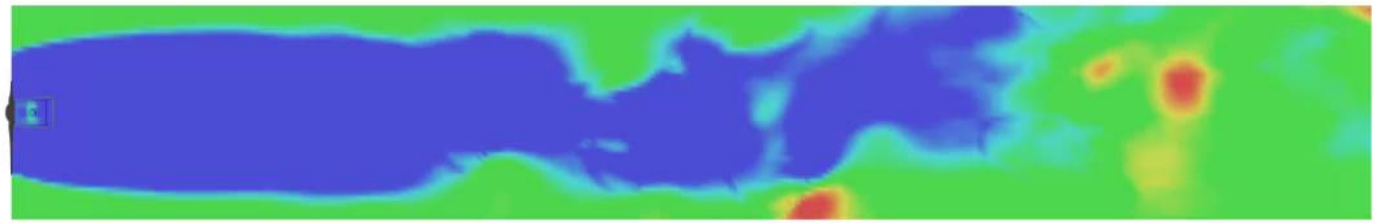
MoWiTO optimal pitch determined as 0.

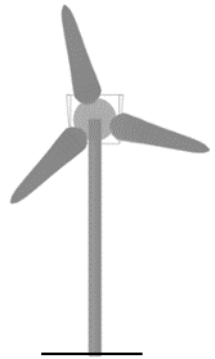




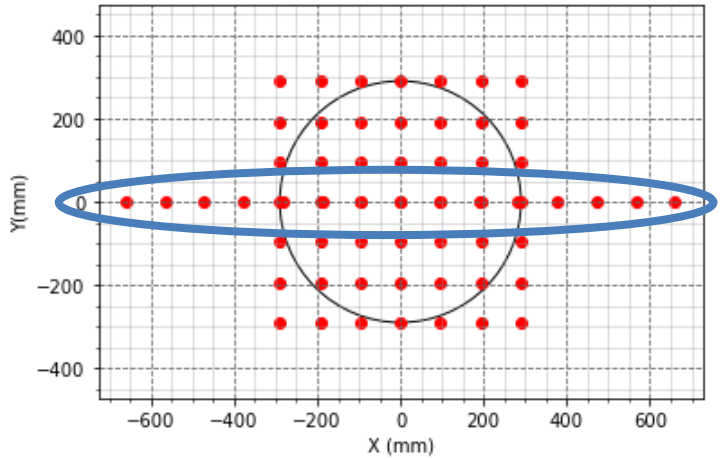
Wake deficit of fixed turbine



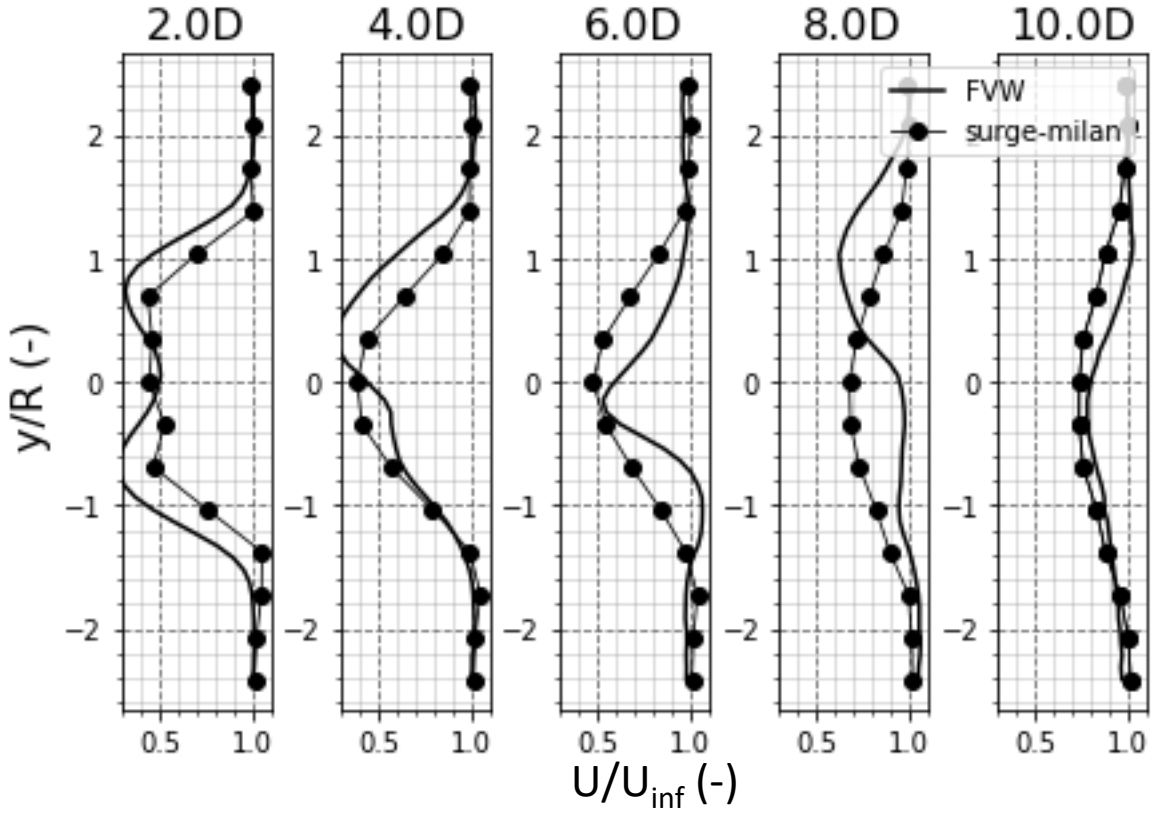


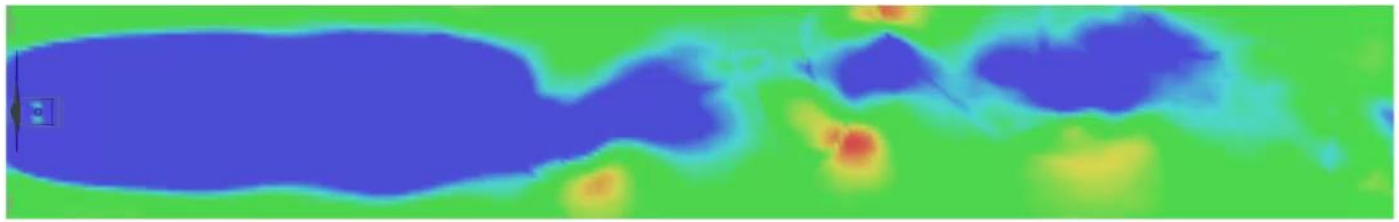


- Hot wire measurements vs. LLFVW
- 5 distances downstream from rotor analysed
- Horizontal plane at hub height



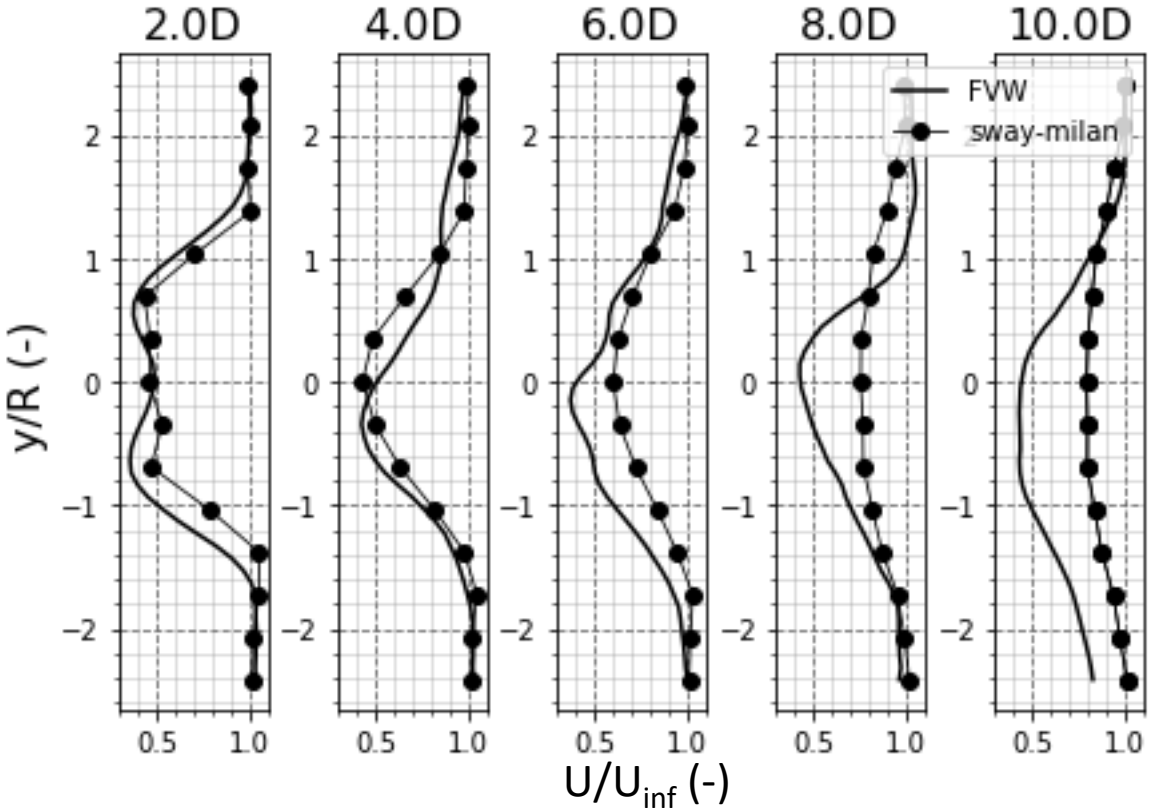
Wake deficit in surge case

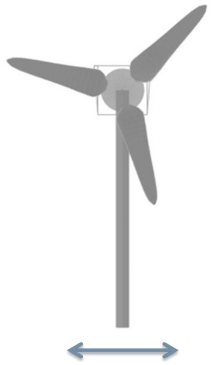


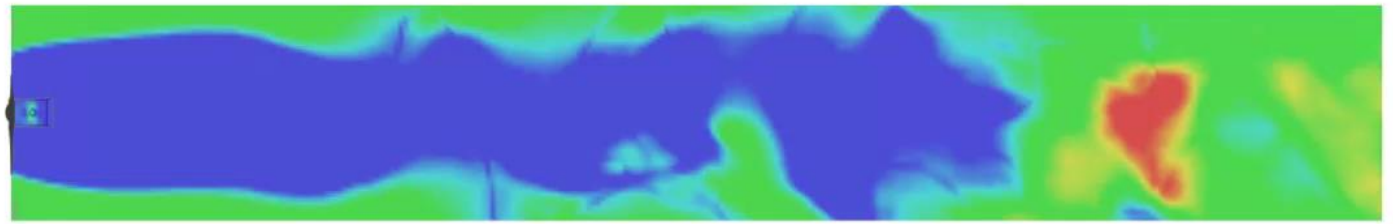


- Surging motion generates pulse in the wake
- Higher discrepancies between methods

Wake deficit in sway case



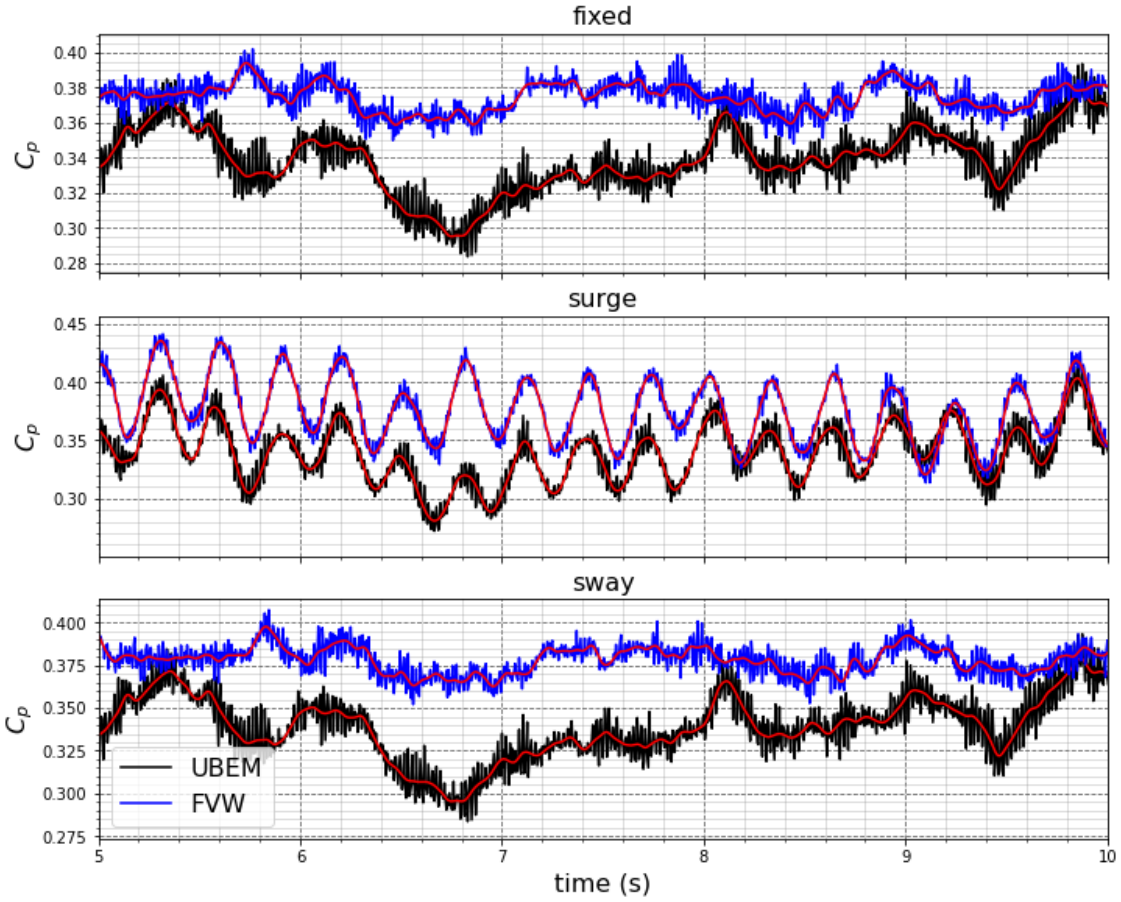


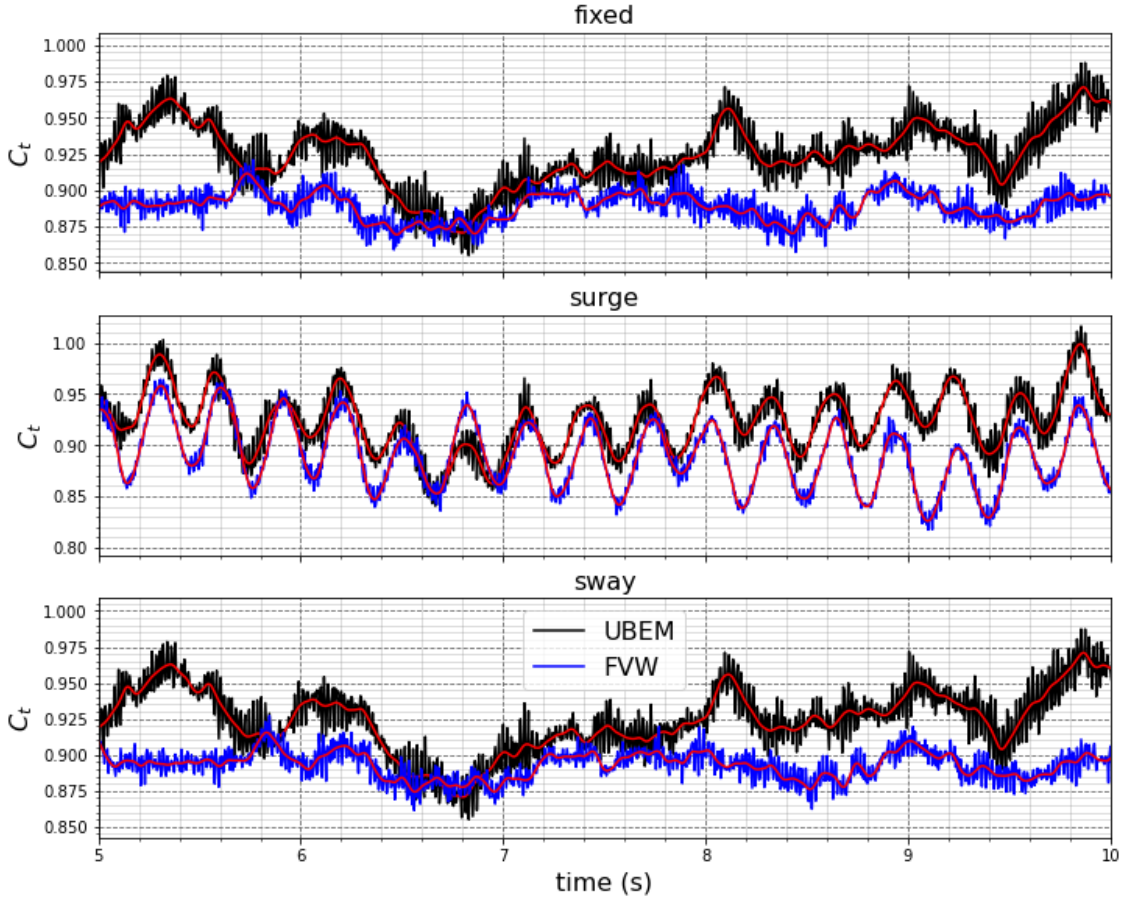


- No recovery in the far wake with LLFVW
- Sway motion causes meandering

Turbine performance

Results from both simulation models





Conclusions

Do prescribed motions affect the turbine's performance and its wake? How well do engineering models match wind tunnel measurements?

Wake measurements in the wind tunnel and using LLFVW

- LLFVW overestimates power
- Clear discrepancies in the far wake
- Motions do not have an overall effect on turbine performance*, but do affect the wake

Continuing work

New measurement campaign under same conditions

- Redo characterization of the turbine to validate model
- Power and thrust measurements
- Analyse results from different wind tunnels
- Include all DoF + complex motions

Numerical anaylsis

- Model validation
- Inclusion of CFD simulations

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FLOAting Wind Energy netwoRk

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