The need for dynamic inflow models

for vertical axis wind turbines

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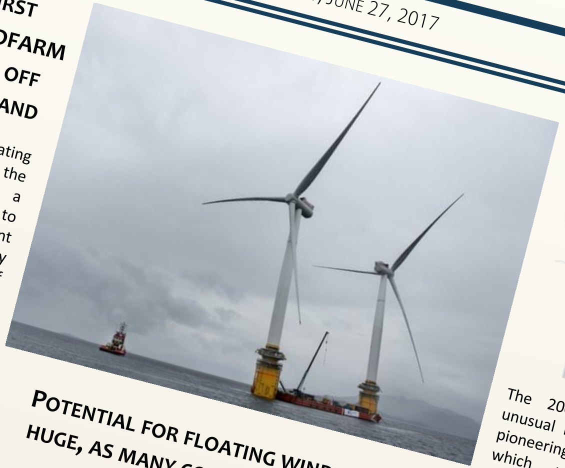
THE NEWS

Tuesday, June 27, 2017

World's first floating windfarm to take shape off coast of Scotland

The world's first floating windfarm has taken to the seas in a sign that a technology once confined to research and development drawing boards is finally ready to unlock expanses of ocean for generating renewable power.
After two turbines were floated this week, five now bob gently in the deep waters of a fjord on the western coast of Norway ready to be tugged across the North Sea to their final destination off north-east Scotland

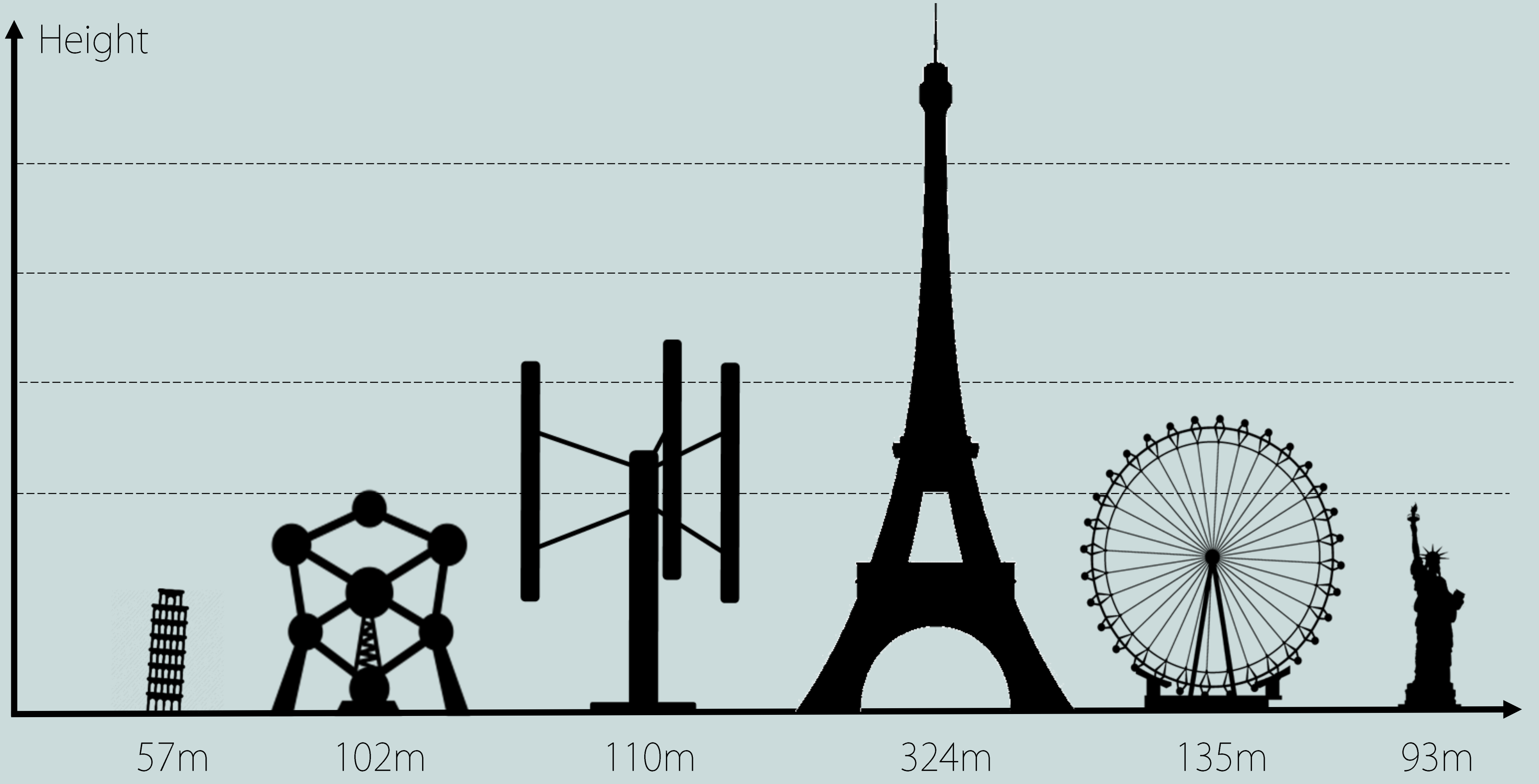


Potential for floating windfarms is huge, as many countries have windy sites close to shore

The 200m Hywind project is unusual not just because of the pioneering technology involved, which uses a 78-metre-tall underwater ballast and three mooring lines that will be attached to the seabed to keep the turbines upright. It is also notable because the developer is not a renewable energy firm but Norway's Statoil, which is looking to diversify away from carbon-based fuels.

06, 2017

VERTICAL-AXIS WIND TURBINES



Largest VAWT:

Eole4,4MW,Quebec

Dynamic inflow modelling techniques:

- Computational fluid dynamics or vortex methods
  - Wake modelled in time and space
  - Time-consuming
- Engineering models
  - Wake not modelled in time and space
  - Fast calculation

Floating vawts

Research Question

Do we need NEW DYNAMIC INFLOW MODELS to enhance the modelling of floating vertical axis wind turbines?

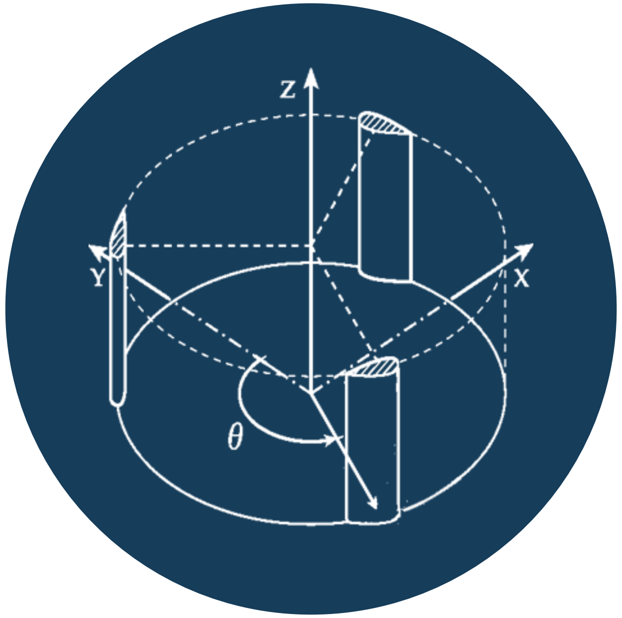
CONTENT

1

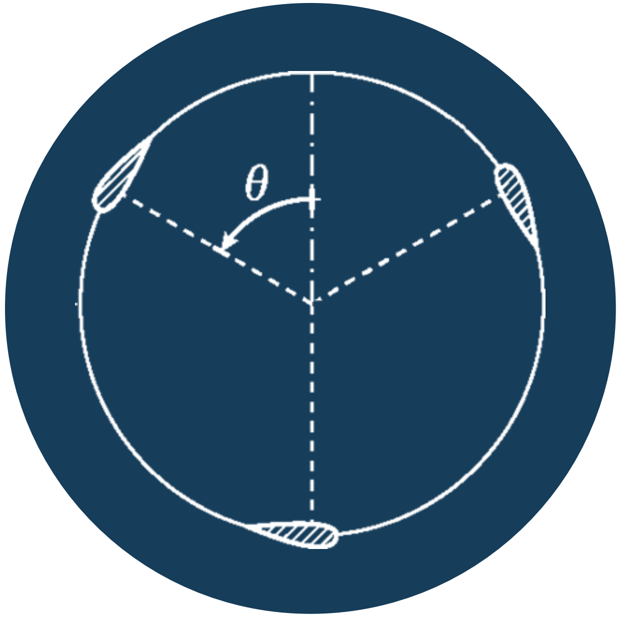
Theoretical approach

The flow around a uniformly loaded unsteady actuator disk: methodology, results and discussion

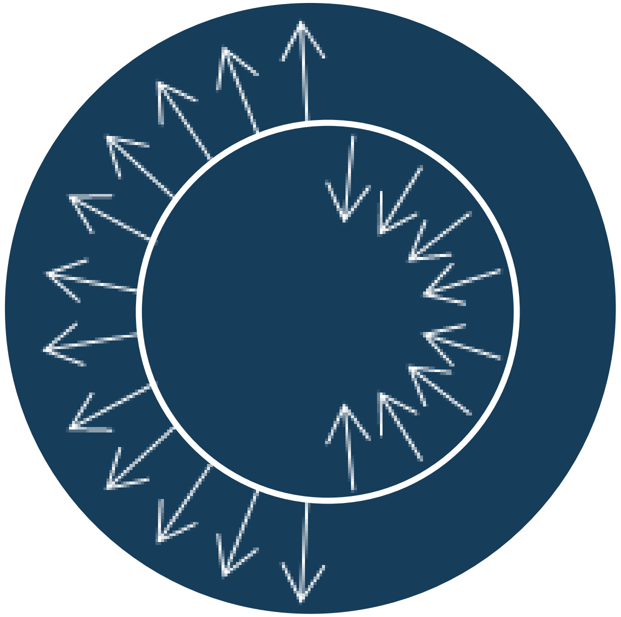
SIMPLIFY ROTOR



3D ROTOR



2D ROTOR



2D ACTUATOR

$$C_T(t) = C_{T0} + \Delta C_T \cdot \cos\left(\frac{2kV_\infty}{D}t\right)$$

Baseline thrust

Amplitude

Reduced frequency

Dynamic inflow > Dynamic thrust

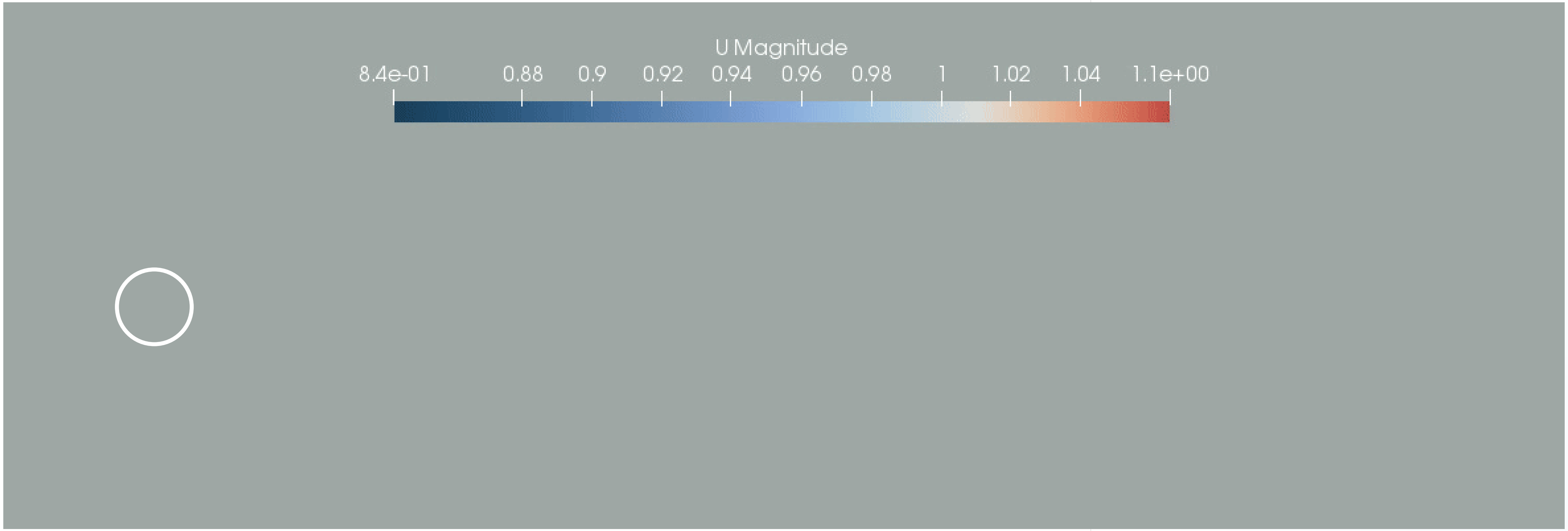
- Cyclic thrust coefficient
- Uniformly loaded
- Velocity field computed using CFD

Modelling velocity field

CFD model

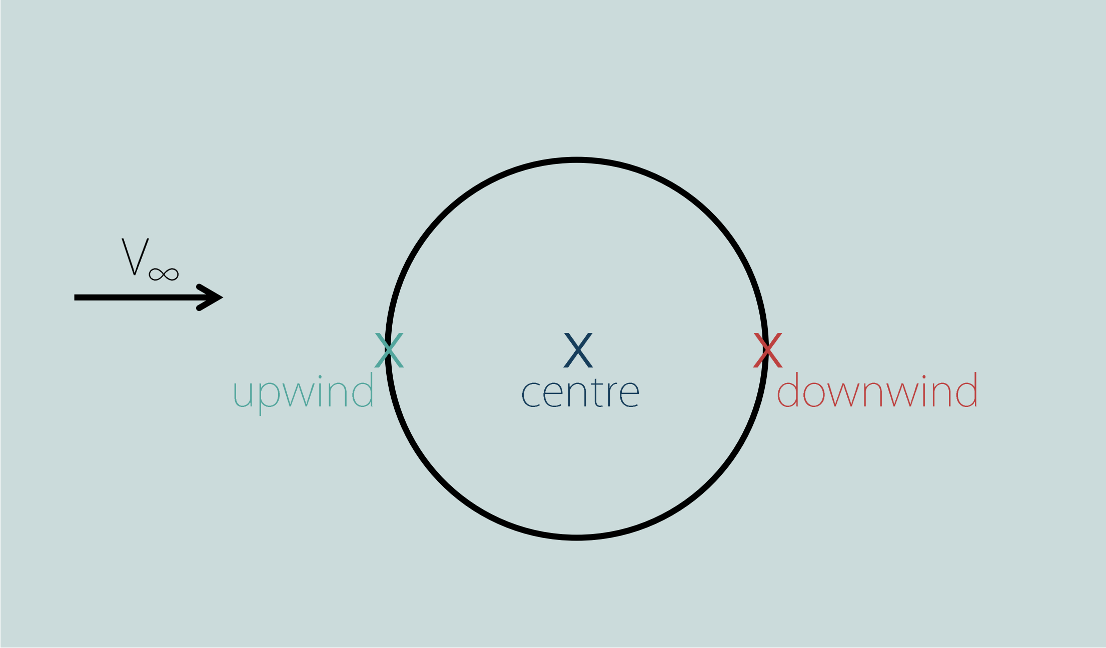
- 2D transient solver for incompressible flows (pisoFOAM)
- Uniformly distributed volume forces
- Grid dense around actuator, gradually coarser further away
- Initial conditions = steady case

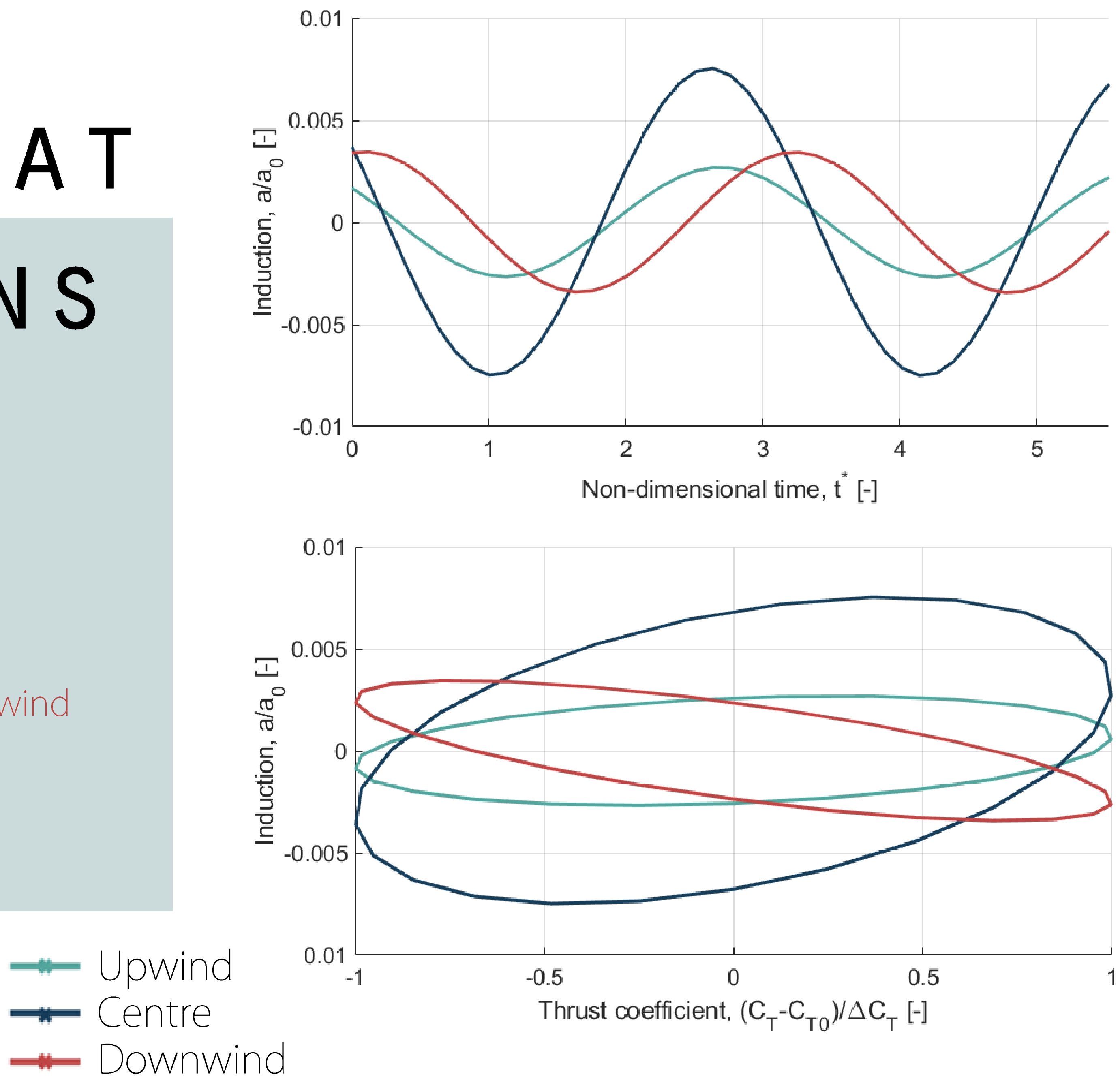
Modelling velocity field

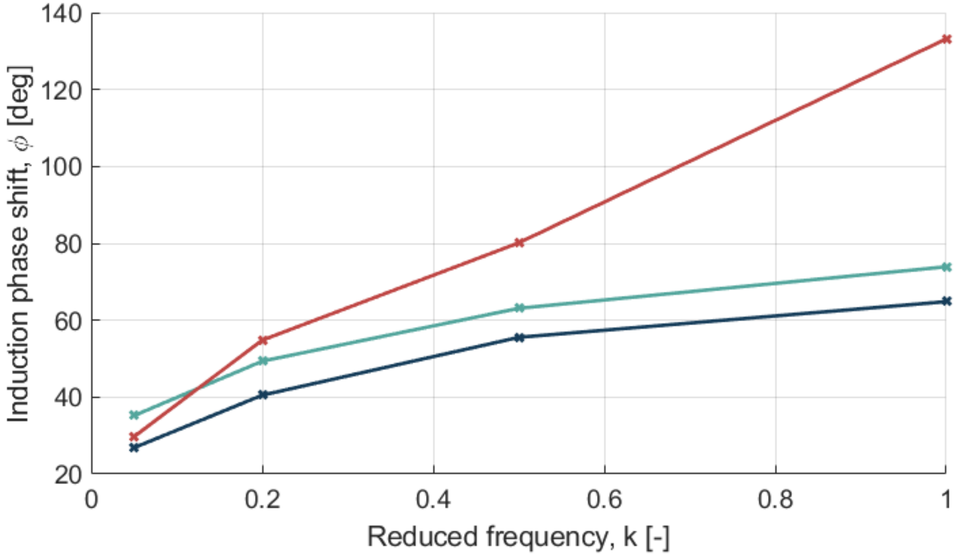


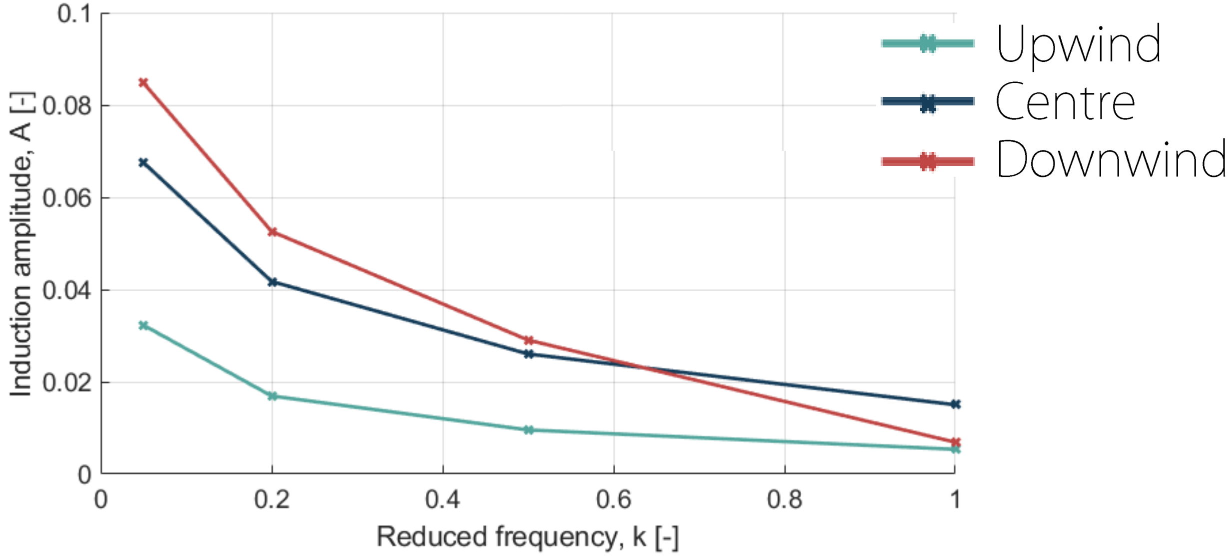
$C_{T0} = 0.11$, $\Delta C_T = 0.11$, $k=0.5$

Induction at 3 locations









PHASE SHIFT & AMPLITUDE

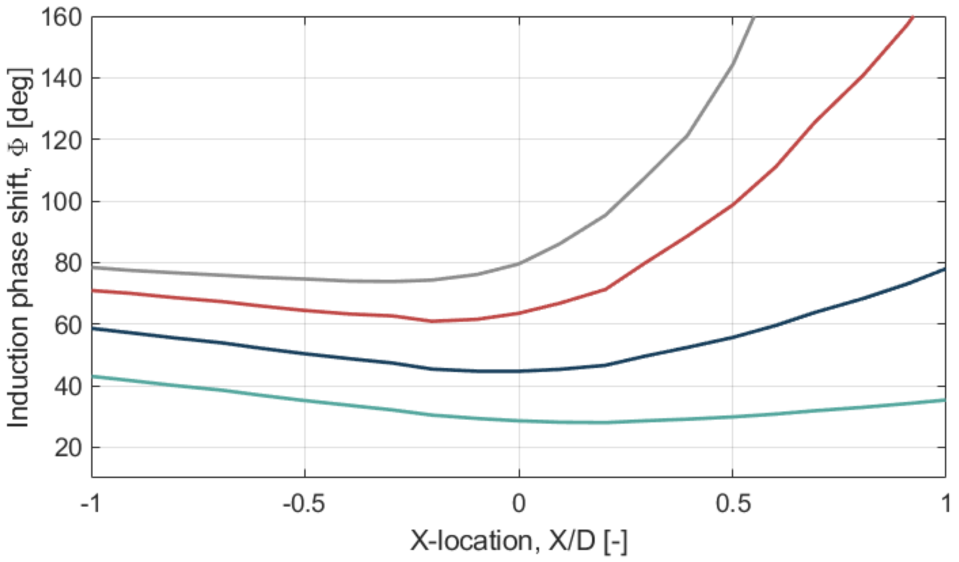
- Phase shift increases with reduced frequency
- Phase shift different for various locations

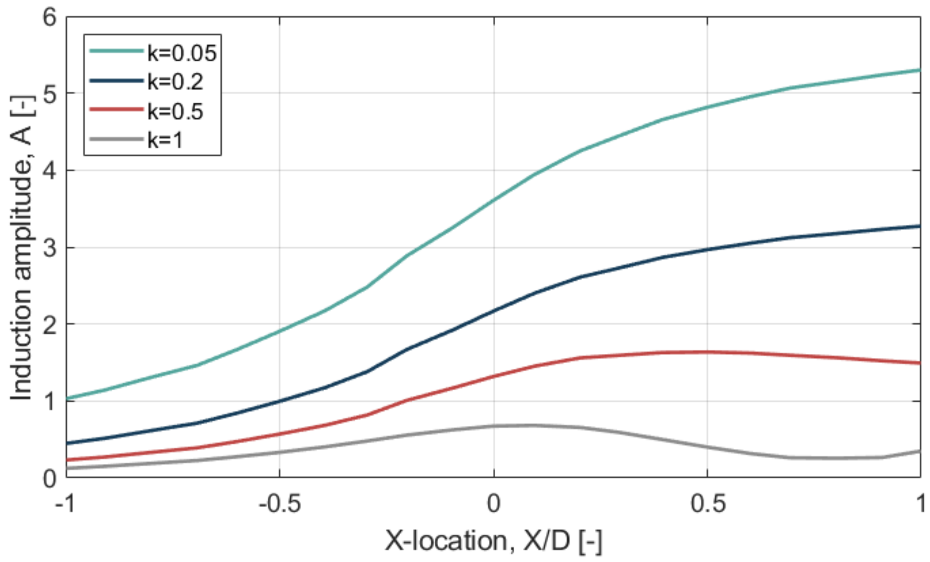
- Induction amplitude decreases with reduced frequency
- Induction amplitude different at various locations

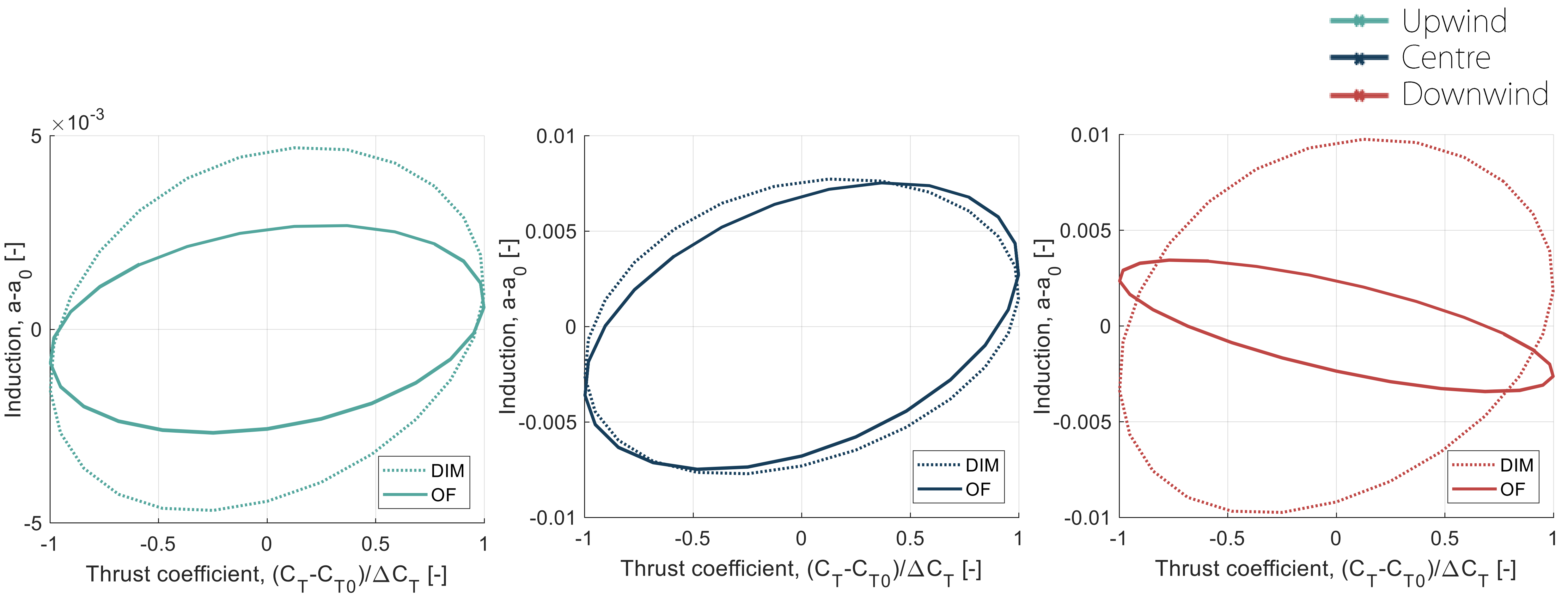
- Around the centre location, lowest phase shift
- Increasing rate highest downwind

- Induction amplitude decreases with increasing reduced frequency
- Induction amplitude increases with increasing x-location

PHASE SHIFT & AMPLITUDE







$C_{T0} = 0.77,\ \Delta C_T = 0.11,\ k=1.0$

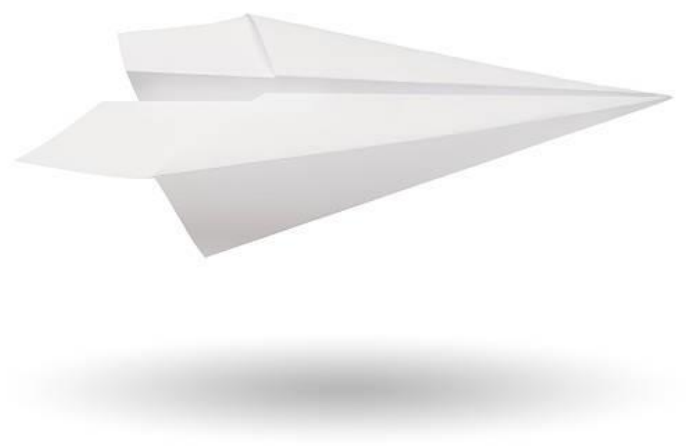
Larsen and Madsen dynamic inflow model

Overview

Behaviour of induction depends on

- Reduced frequency
- Baseline and amplitude thrust
- Location of interest

Larsen and Madsen model doesn't capture behaviour upwind and downwind



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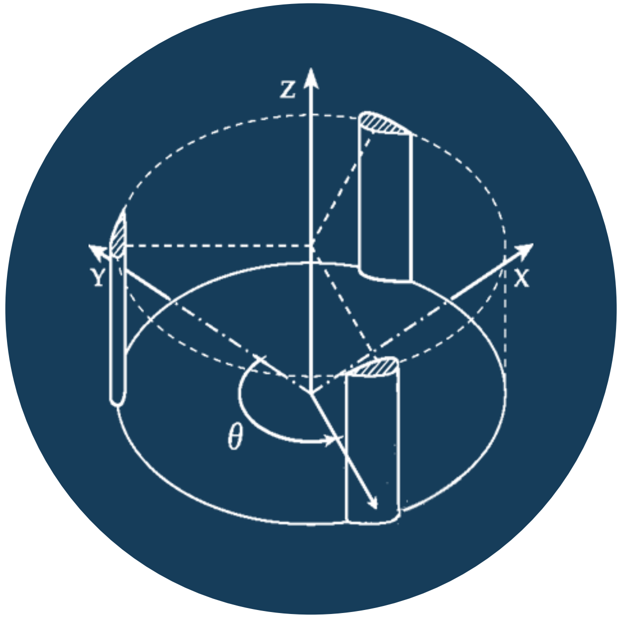
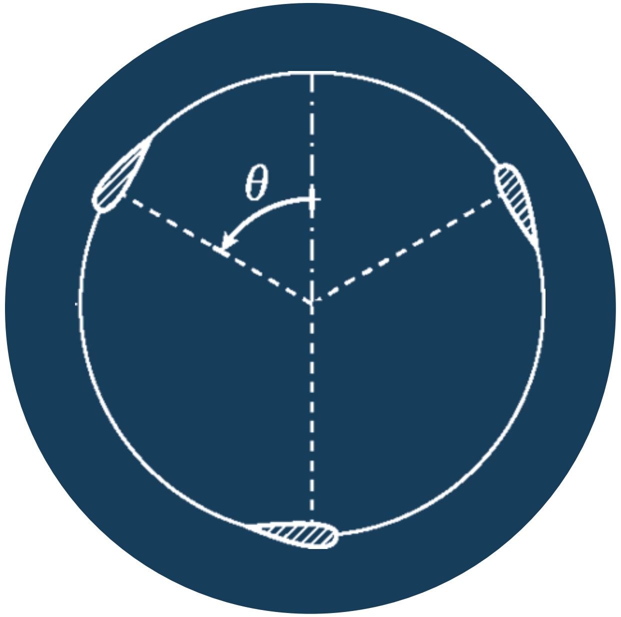
Practical approach

The performance of a cyclic surging VAWT: methodology, results and discussion

SIMPLIFY ROTOR



3D ROTOR



2D ROTOR

2D ACTUATOR

$$s(t) = s_0 + \Delta s \cdot \cos\left(\frac{2kV_\infty}{D}t\right)$$

Baseline surge

Amplitude

Reduced frequency

Dynamic inflow > Surging motion

- Cyclic surging motion
- Loading computed for reference turbine

Modelling Rotor loading

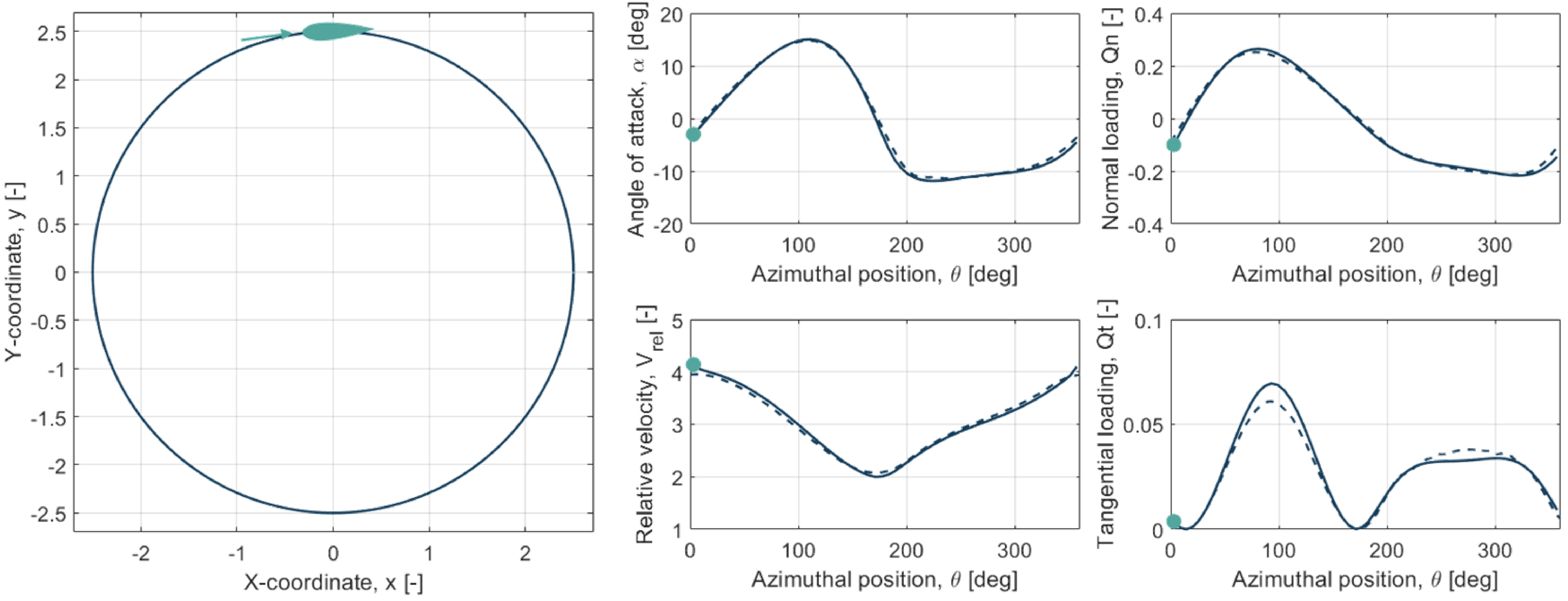
Actuator line OpenFOAM model

- 3D model
- TurbineFOAM library in OpenFOAM
- Blade element theory: 2D lift and drag
- Velocity field is modelled directly in space and time

Actuator cylinder model

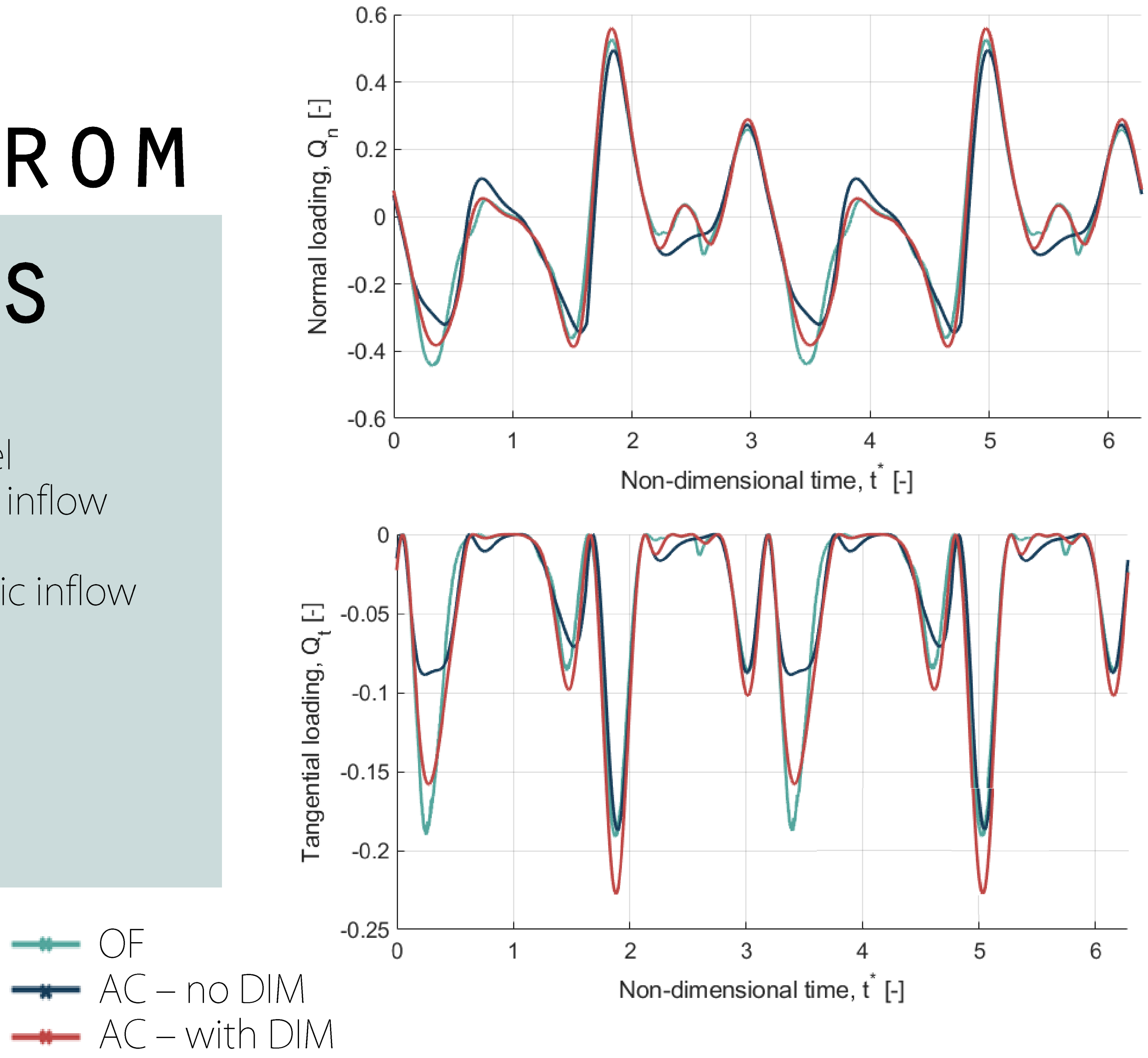
- 2D engineering model
- Blade element theory: 2D lift and drag
- Velocity field from 2D incompressible Euler equations and equation of continuity
- With and without Larsen and Madsen dynamic inflow model

Modelling Rotor loading



Loading from 3 models

- Actuator line OpenFOAM model
- Actuator cylinder – no dynamic inflow model
- Actuator cylinder – with dynamic inflow model

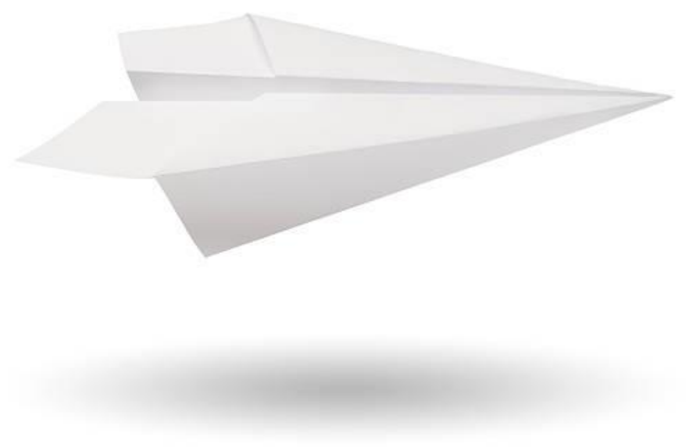


Overview

Engineering dynamic inflow model

- Capture overall behaviour better
- No improvement on average power coefficient

Current dynamic inflow model is not enough



3

Conclusion

Overall findings, future work and hypothesis

Conclusion

Research question

Do we need new dynamic inflow models to enhance the modelling of floating vertical axis wind turbines?

Yes, we do ...

Thank you!