

Floating offshore wind at TU Delft

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TWIND summer school
5 July 2021

Outline

- Overview of activities
- Design of floating turbines and farms
- Novel rotors for floating applications
- High-fidelity numerical models
- Conclusions



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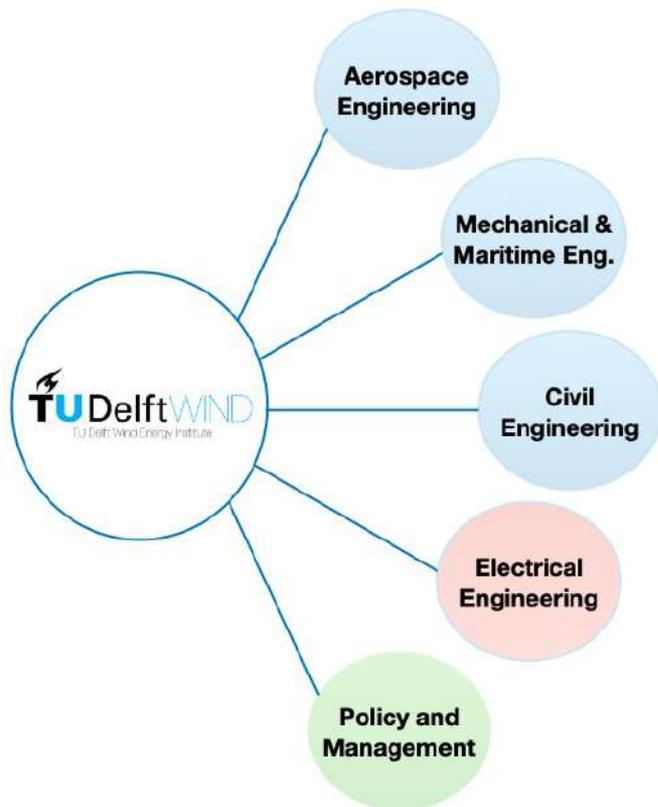


Andrei Metrikine



Jan-Willem van
Wingerden

Overview of activities



Design of floating wind turbines and farms

Floating foundations, moorings, anchors

Novel controls

Novel rotors

Optimisation with met-ocean conditions

Hybrid systems

Numerical models

Lab testing

Drive train

Grid integration

Energy markets

Social acceptance

Overview of activities

- Range of ongoing research projects (mostly EU)
- Well-established networks
- Growing visibility in the area
- Close collaboration with NREL (USA)
- Partner on a MoU with the Nippon Foundation (Japan)
- Floating offshore wind MSc course (2021-2022)

Design of floating turbines & farms



step4wind.eu

- Coordinator of the H2020 ITN project STEP4WIND
- Total budget: 2.8m€
- April 2020 – March 2024
- 10 Industrial PhDs (5 at TU Delft)

Beneficiaries



Partners



Design of floating turbines & farms

WP1 – Design

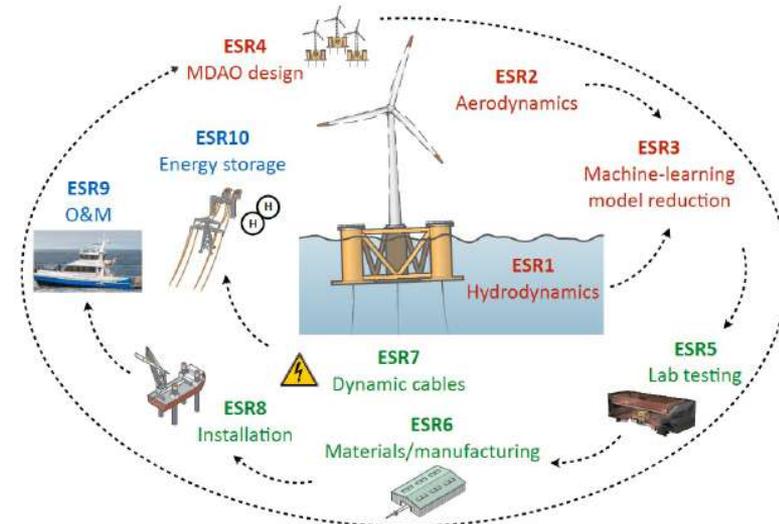
Develop engineering design tools capable of accounting for dynamic unsteady effects

WP2 – Production and deployment

Develop novel test and validation methods

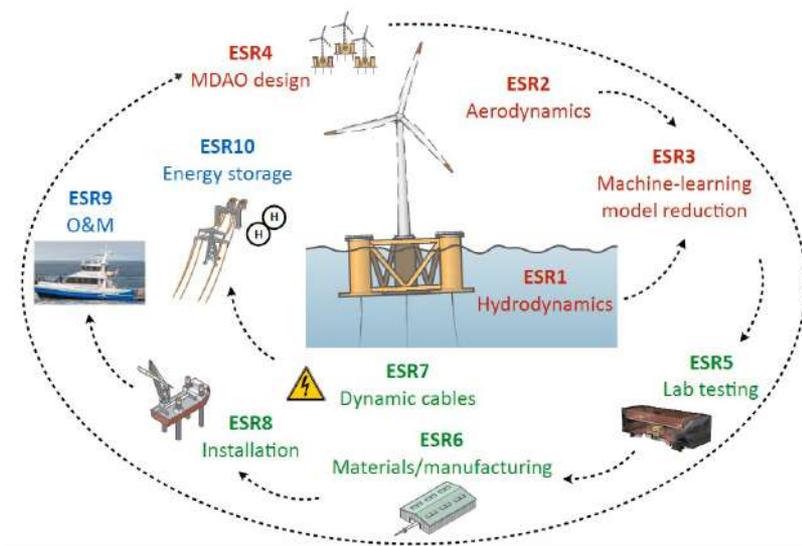
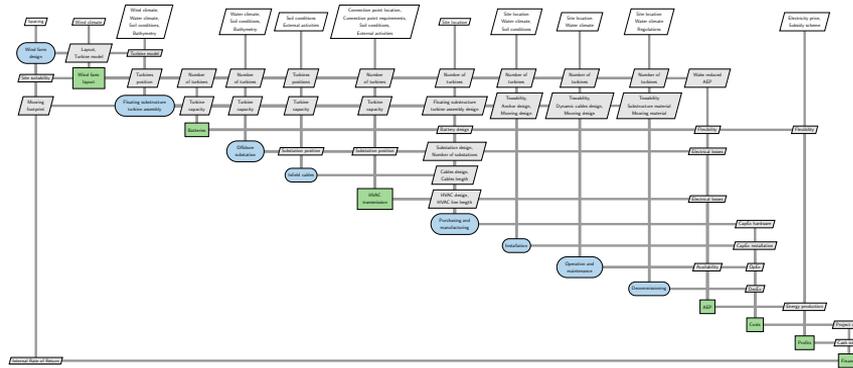
WP3 – Operation and scalability

Develop floating-specific O&M & blue economy activities



Design of floating turbines & farms

- WP leader on design aspects
- Improving engineering models based on high-fidelity
- Holistic system engineering



Design of floating turbines & farms



Likhitha Ramesh
Reddy

PhD student (ESR1)



Ricardo Amaral

PhD student (ESR2)



Deepali Singh

PhD student (ESR3)



Matteo Baudino
Bessone

PhD student (ESR4)



Felipe Novais

PhD student (ESR5)



Alejandro del Toro

PhD student (ESR6)



Huzaifa Syed

PhD student (ESR7)



Rahul Chitteth
Ramachandran



Omer Khalid

PhD student (ESR9)



Omar Ibrahim

PhD student (ESR10)

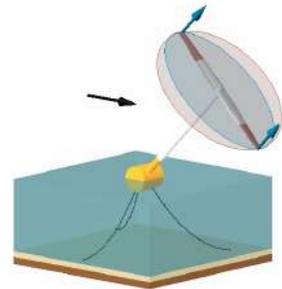
Novel rotors for floating applications

- TouchWind Proof-of-Concept: 2.8m€ TKI project
- Design of new rotors for floating applications
- From engineering tools to CFD
- Aerodynamics & Aero-elasticity



Novel rotors for floating applications

- 1.2-meter rotor diameter
- Pitch-teeter coupling
- Analysis with BEM and RANS (actuator line)
- Coupling with a rigid-body model for the hinge

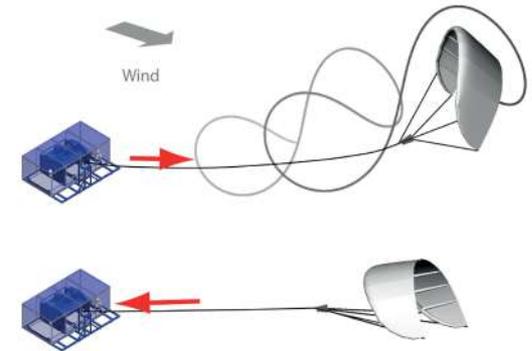


Novel rotors for floating applications

- VAWT can lower the center of gravity
- Wake deflection is possible without loss of frontal area
- Insensitive to 2D yaw and 3D wind veer

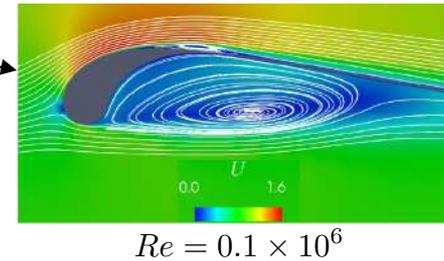
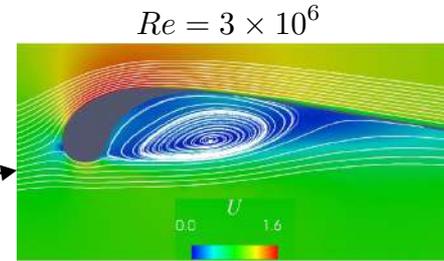
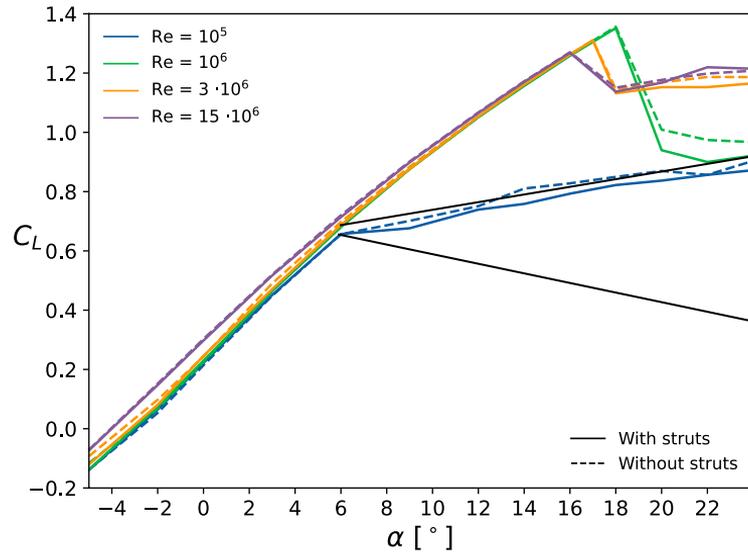
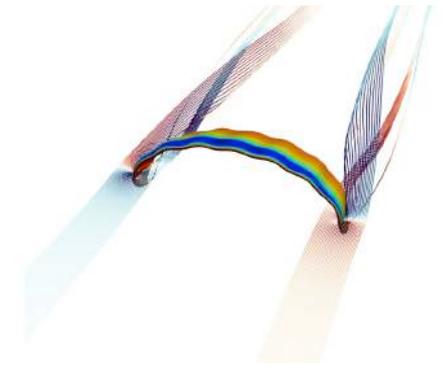


Novel rotors for floating applications

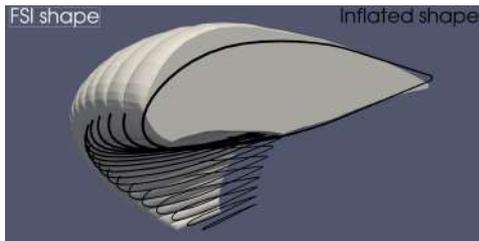
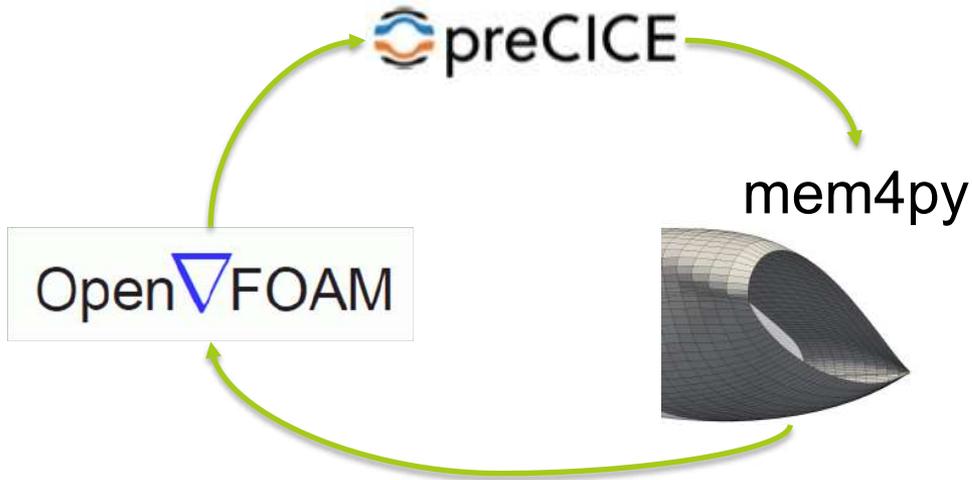


Novel rotors

- RANS CFD with transition model

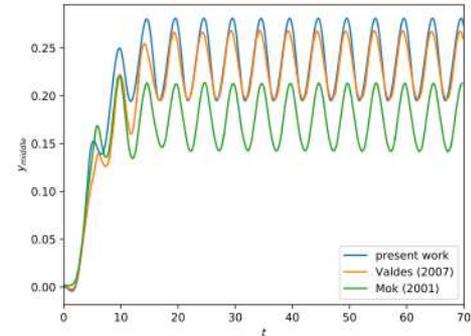
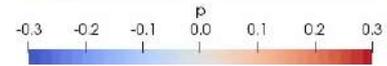
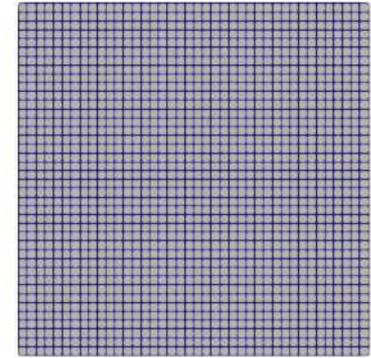


Novel rotors for floating applications



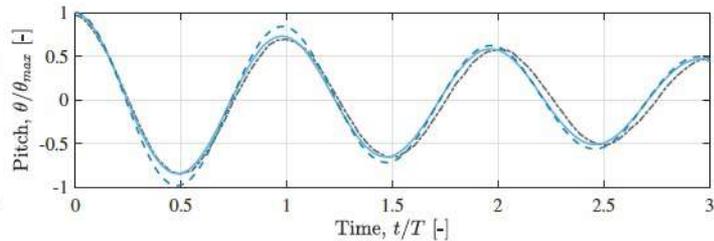
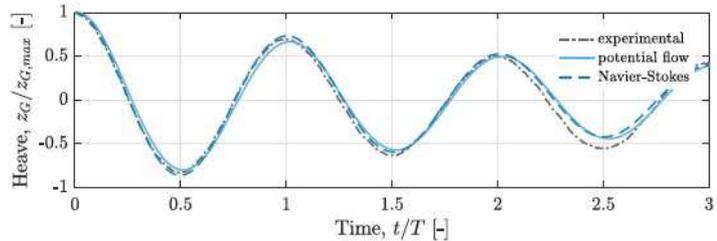
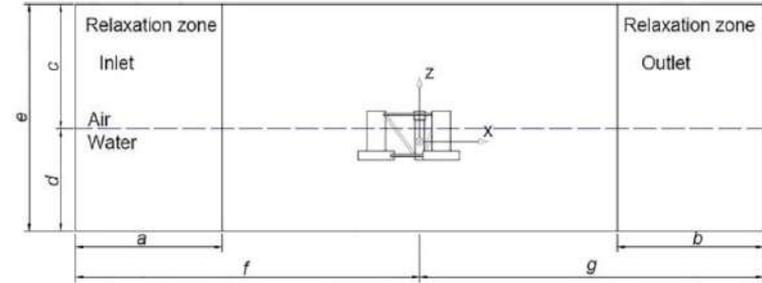
Folkersma et al., J. Physics: Conference Series (2020)

Time: 0.1



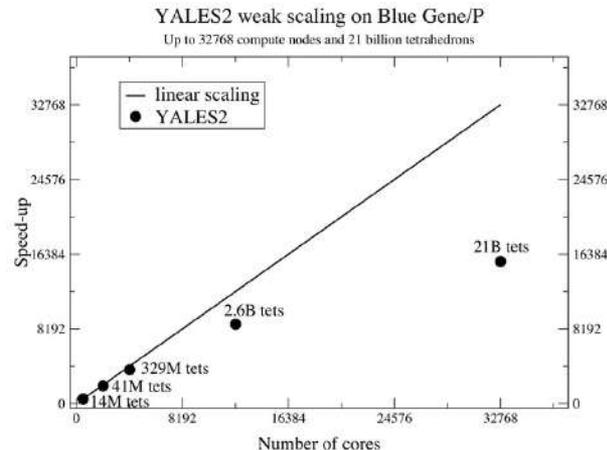
High-fidelity numerical models

- OpenFOAM
 - IEA Task OC6
 - Airfoil aerodynamics



High-fidelity numerical models

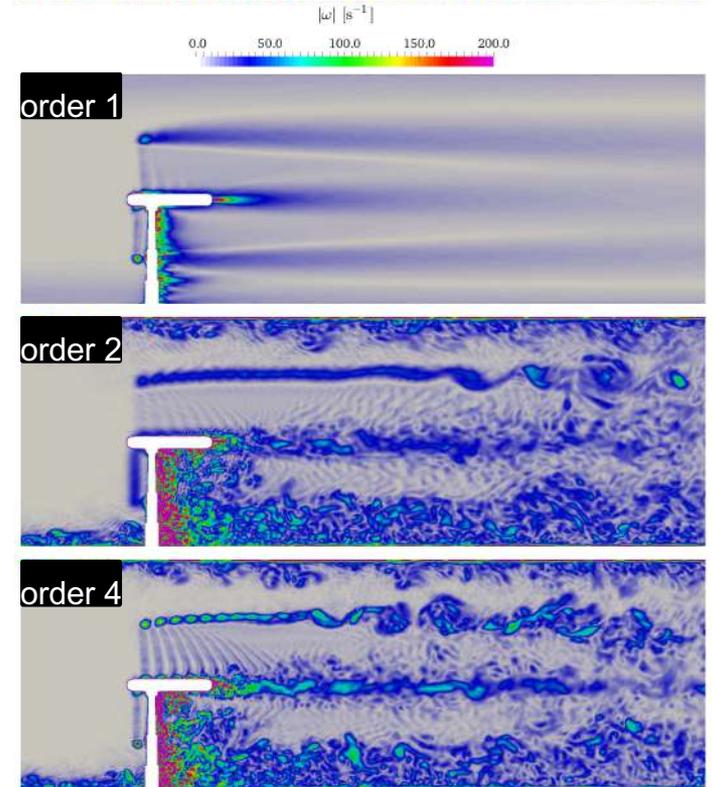
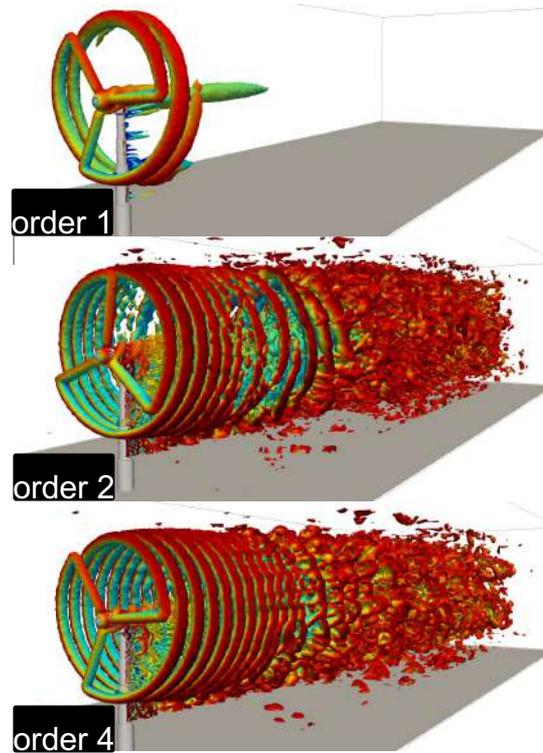
- YALES2
 - 4th order finite-volume
 - 4th order Runge-Kutta time integration
 - Massively parallelised
 - Mesh adaptation capabilities



High-fidelity numerical models

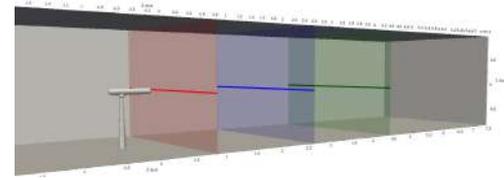
- YALES2

NTNU Blind test

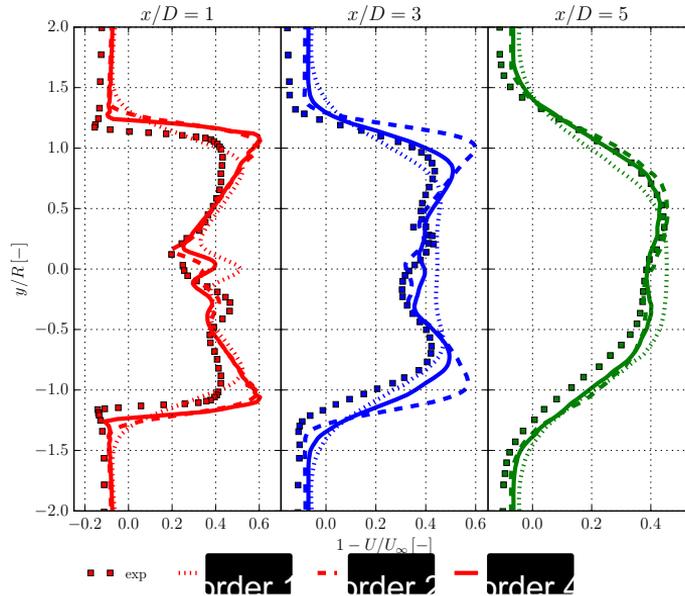


High-fidelity numerical models

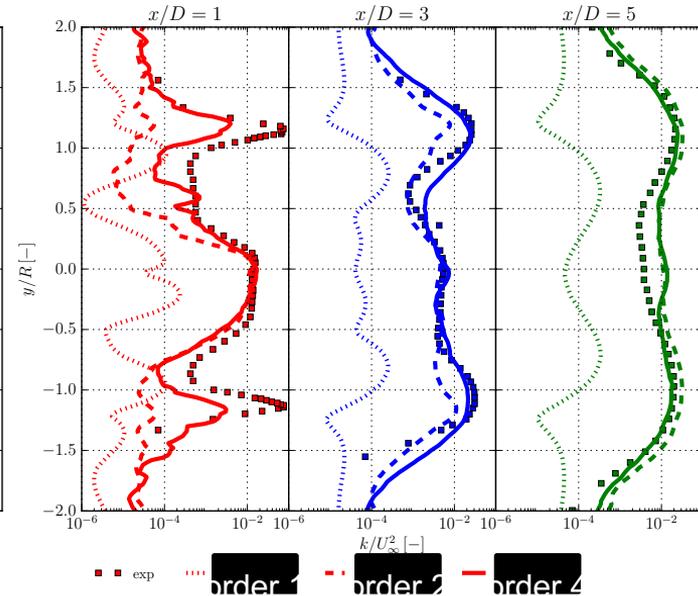
- YALES2



Velocity deficit



Turbulent kinetic energy

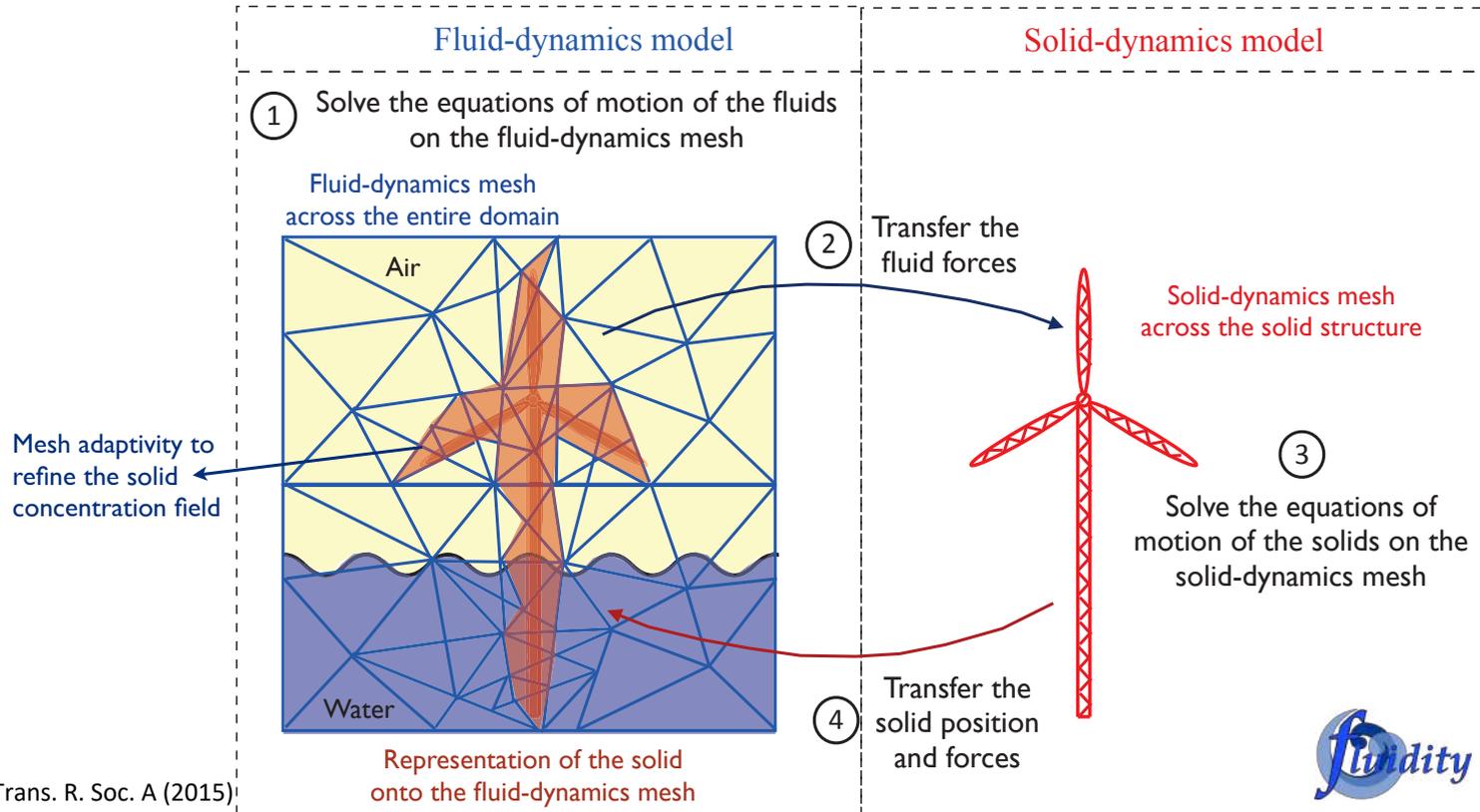


High-fidelity numerical models

- Fluidity
 - Finite-element discretisation
 - Arbitrarily unstructured meshes
 - Adaptive mesh refinement
 - Immersed-boundary for fluid-structure interactions
 - Originally an ocean model, then applied to wind energy

High-fidelity numerical models

- Fluidity



High-fidelity numerical models

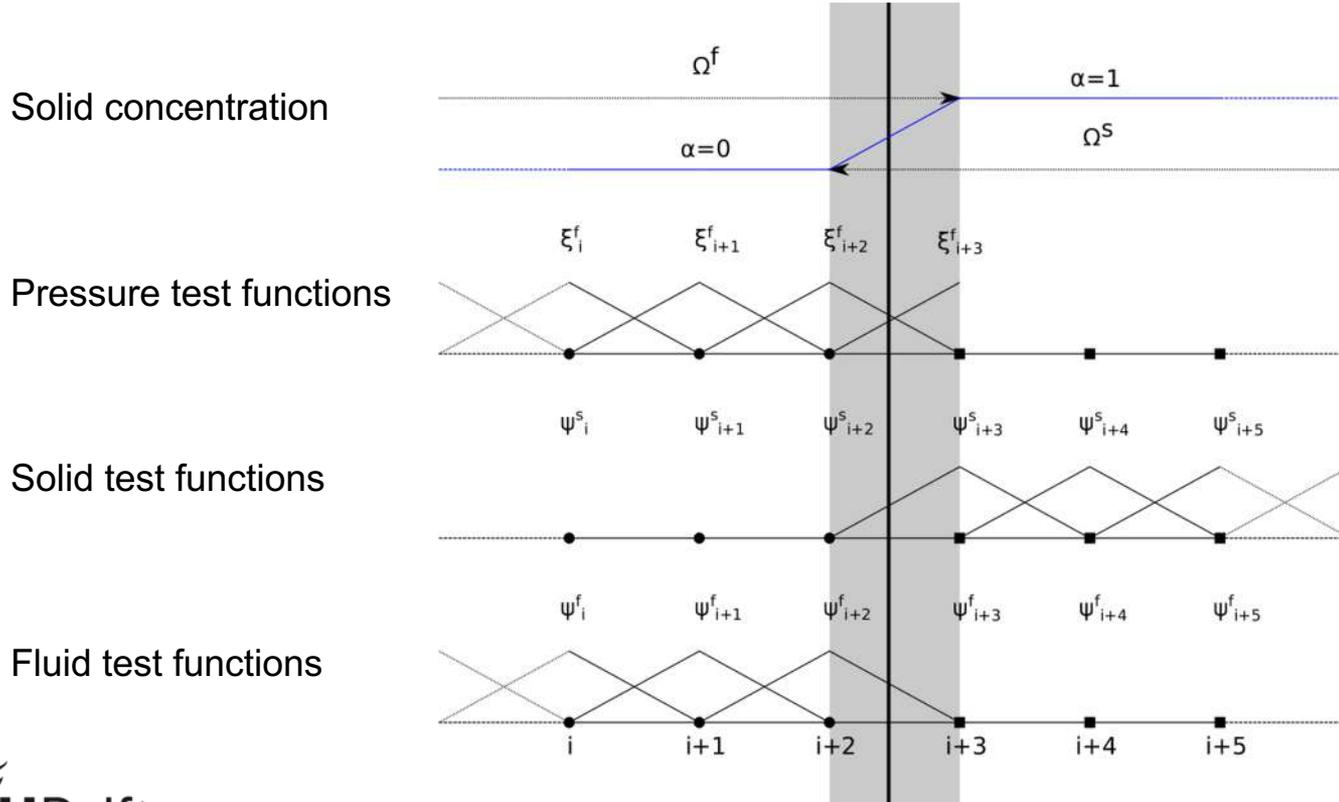
$$\rho \frac{\partial \mathbf{u}}{\partial t} + \rho (\nabla \mathbf{u}) \mathbf{u} = \nabla \boldsymbol{\sigma} + \mathbf{b} + \mathbf{f}$$

$$\operatorname{div} \mathbf{u} = 0$$

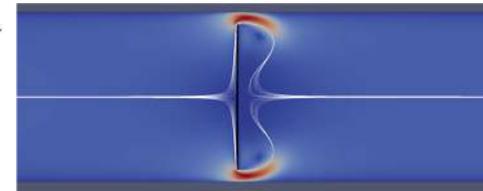
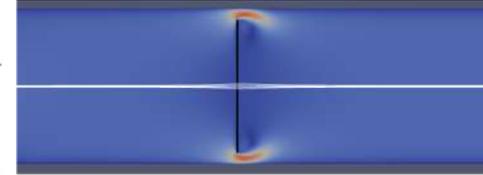
$$\boldsymbol{\sigma} = -p \mathbf{I} + \mu (\nabla \mathbf{u} + (\nabla \mathbf{u})^T)$$

1. Penalty method $\mathbf{f} = \beta \alpha_s (\mathbf{u}_s - \mathbf{u})$
2. Lagrange multiplier $\mathbf{f} = \alpha_s \boldsymbol{\lambda} \quad \int_{\Omega_s} \boldsymbol{\gamma} \cdot (\mathbf{u}_s - \mathbf{u}) \, d\Omega = 0$

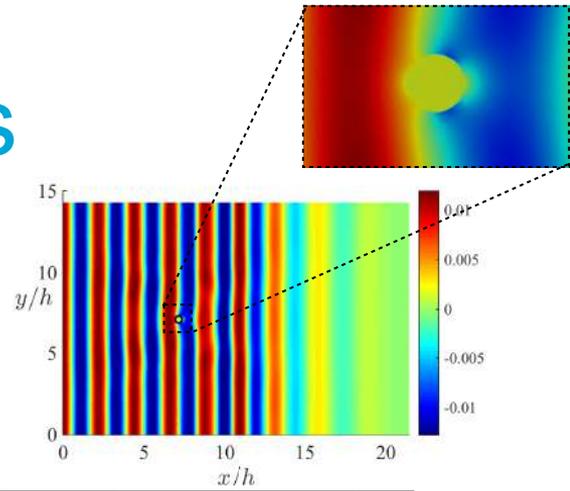
High-fidelity numerical models



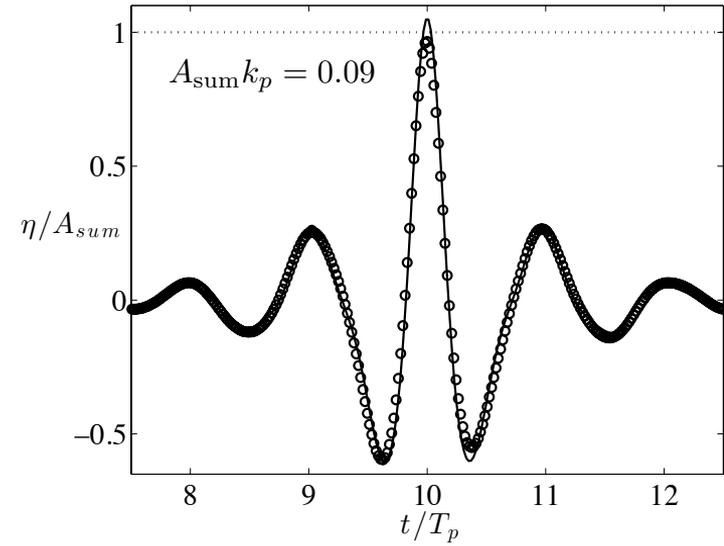
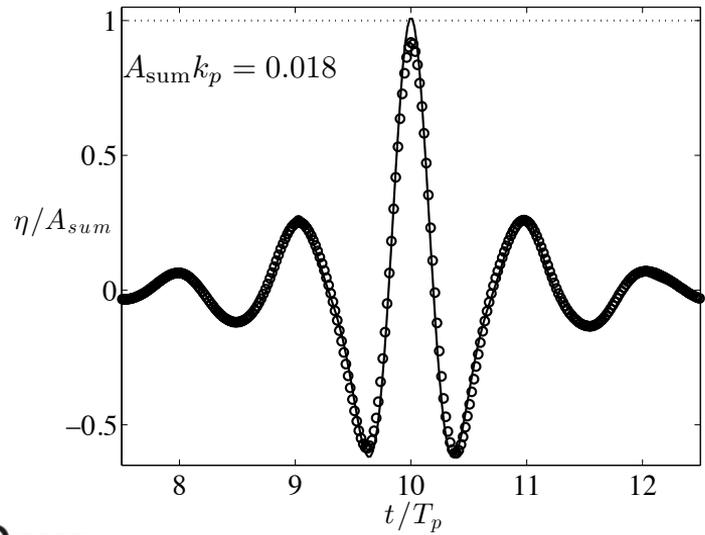
Weighted test functions limit the domain in which corresponding governing equations act



High-fidelity numerical models

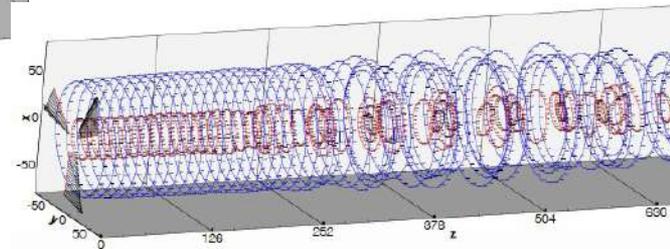
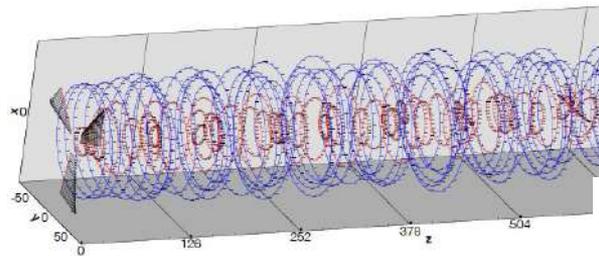
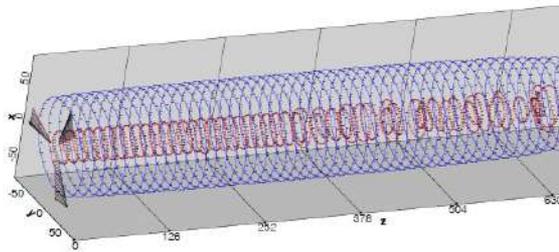


— Second-order solution
○ CFD

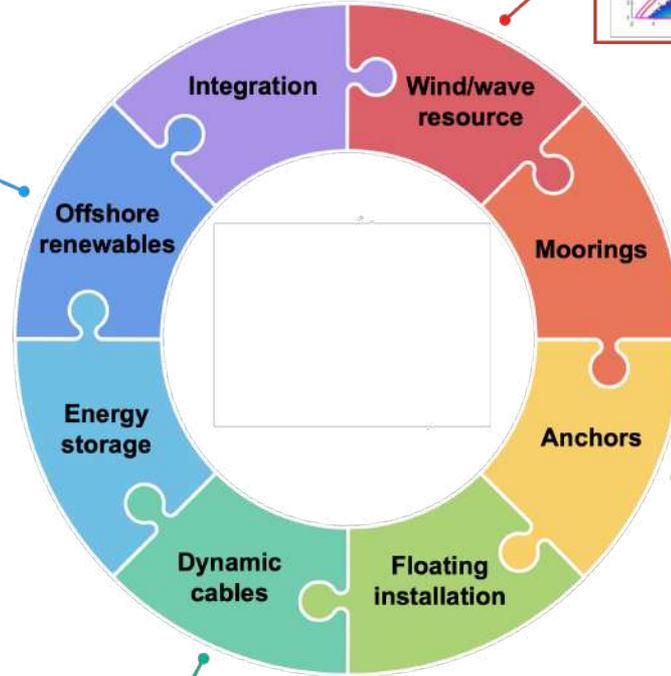


Mid-fidelity numerical models

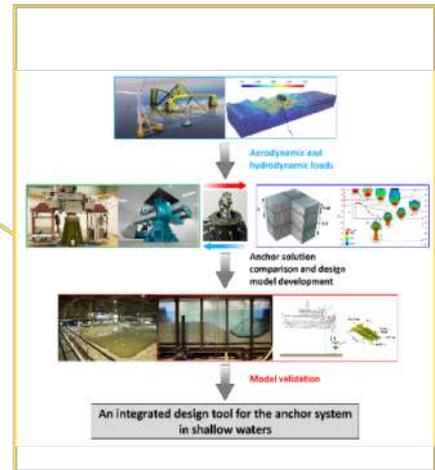
- Free-wake vortex ring model
 - Analysis of the different states of a floating turbine



And a lot more...



- Moorings with extreme events
- Multi-line anchors



- Multi-physical numerical models
- Experiments

Conclusions

- Broad set of skills and disciplines on floating wind at TU Delft
- Range of modelling tools, from high-fidelity to engineering models and system engineering approaches
- Range of experimental facilities

Thank you for your attention

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