# Aerodynamic Scaling Approach for FOWT Model Tests focussing on the Validation of numerical Methods

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## *Aerodynamic Scaling Approach for FOWT Model Tests focussing on the Validation of numerical Methods*

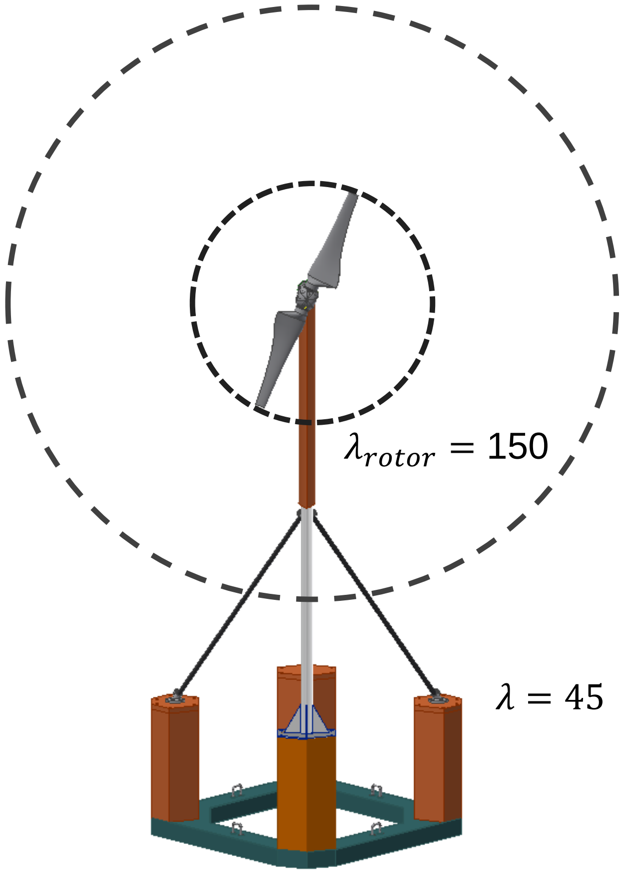
- Application of Froude scaling in FOWT model tests yields extremely low wind speed and **huge wind generators**
- High quality wind generators for required wind field dimensions often not feasible
- **Simple construction** of wind generators often lead to strong **disturbances in wind filed**
- Resulting **disturbances in aerodynamic loads** cause strong fluctuations of measured rotor thrust …
- … and **induce high repetition error**

**Alternative approach**

Reduction of rotor diameter & Reduction of wind field dimensions

→ **High quality wind generator feasible**

- Scaling approach applied **to validate panel method *pan*MARE** [1] with the **Curse Offshore SelfAligner** [2] downwind concept

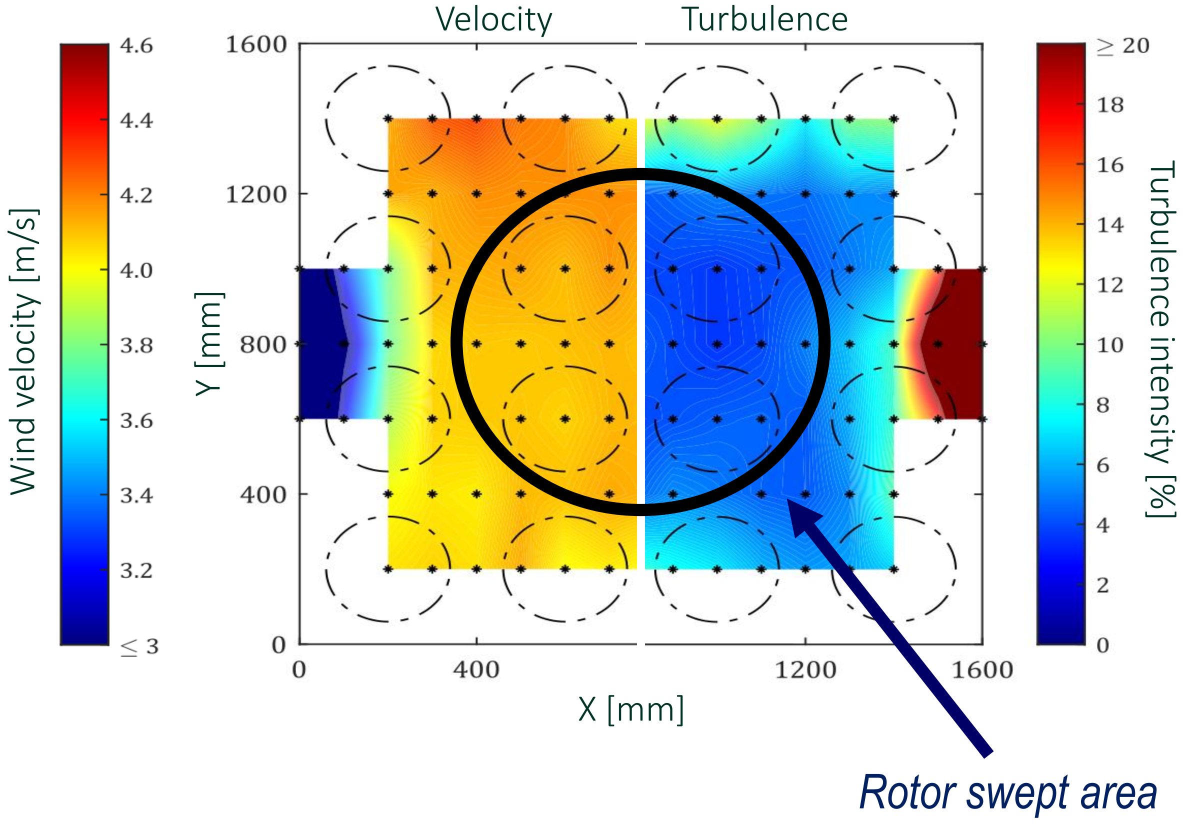


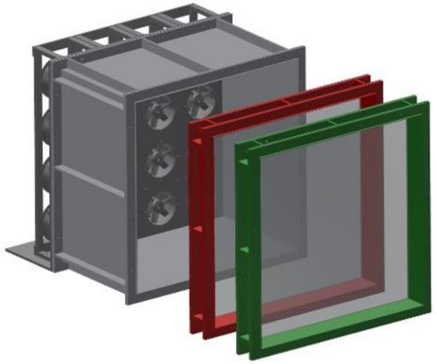

## Scaling

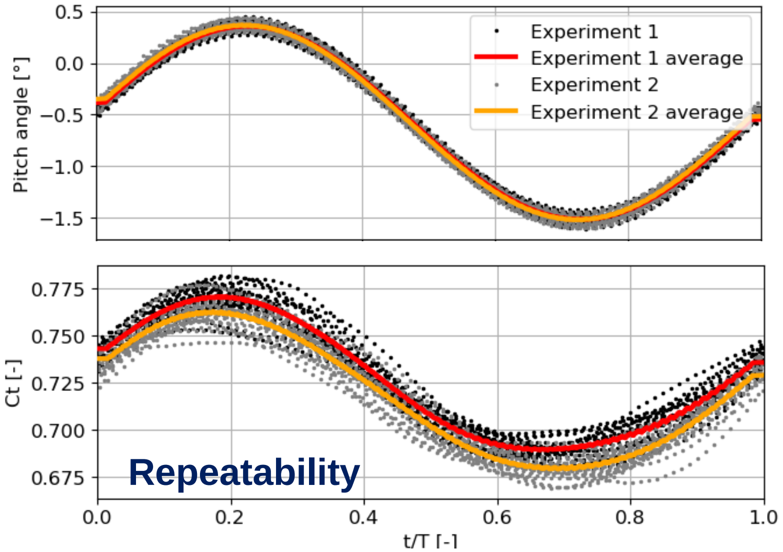
- Froude scaling applied to floating platform and environment except rotor: $\lambda = 45$
- Rotor scaled by $\lambda_{rotor} = 150$
- **Wind speed is approx. 3 times higher** compared to conventional scaling to maintain scaled thrust force according to Froude's law of similarity
- **Wind generator cross section area is approx. 9 times smaller** compared to conventional scaling
- Amplitude of rotor thrust force oscillation due to tower top motion is approx. 3 times smaller
- **Aerodynamic damping is present**, but reduced

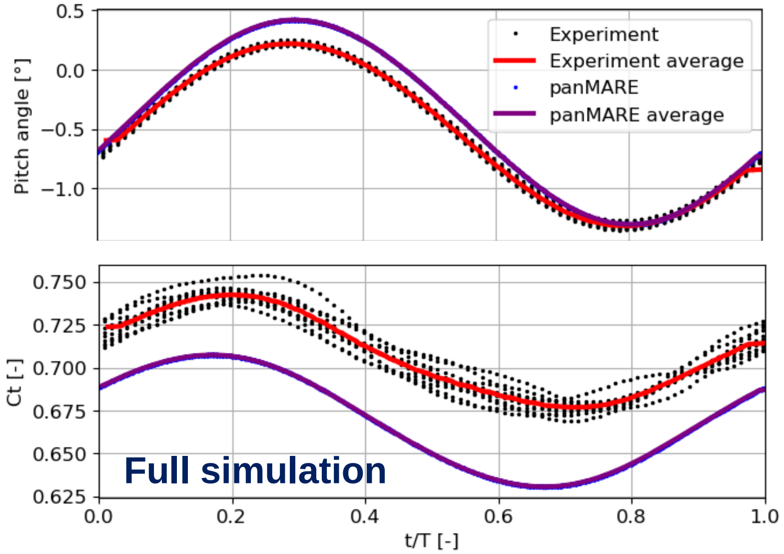
## Wind generator

- Cross section of 1.6 m x 1.6 m
- Homogeneous flow due to settling zone with a length of 1.4 m and 2 grid screens
- Complete coverage of the rotor swept area
- **Turbulence intensity below 5 %** inside rotor swept area
- Maximum spatial wind speed **non-uniformity of 2 %** inside rotor swept area






*Time shift compensated*

## Repeatability

- Wave generation inaccuracies and low speed current induce repetition error
- Repetition error can be reduced significantly by phase averaging
- Remaining **repetition error vanishing** for phase averaged 6-DOF motion
- Moderate repetition error of rotor thrust force due to motion compensation

## Comparison with simulations

*1. Hybrid simulations: Simulation model forced to measured 6-DOF motion*

- Aerodynamic and mooring loads investigated independent from wave loads
- Differences in rotor thrust amplitude in range of repetition error

*2. Full simulations*

- **Considerable agreement** between simulations and experiment in surge, heave and roll **decay tests**
- **Small deviations** at lower wave heights in **platform pitch motion and rotor thrust amplitude**

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## Conclusion

- Application of alternative scaling approach allows for the use of high quality wind generator and small wind turbine
- **Inertia force compensation** of tower top loads causes **uncertainty in thrust force below 3 %**
- Panel method *pan*MARE validated in aerodynamic and hydrodynamic domain
- Precise validation of **rotor thrust in time domain** possible
- **Scaling approach well suited for validation of numerical methods**

**Advantages**

- Smaller wind generator makes a more elaborate design with a **turbulence intensity below 5 %** and a maximum **non-uniformity of 2 %** feasible
- **Simple installation of the wind generator** without crane due to smaller cross section possible
- **Smaller size of the rotor** yields less restrictions due to light-weight design
- Complex aerodynamic phenomena like **aerodynamic damping can be observed precisely**

**Disadvantages**

- **Rotor thrust oscillation amplitude** caused by axial tower top motion **reduced**

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## Literature

[1] Netzband S, Schulz CW, Göttsche U, Ferreira Gonzales D, Abdel-Maksoud M. 2018*. A Panel Method for Floating Offshore Wind Turbine Simulations with Fully-Integrated Aero- and Hydrodynamic Modelling in Time Domain*. Sh. Technol. Res.

[2] Cruse J, Abdel-Maksoud M, Düster A, Bockstedte A, Haake G and Siegfriedsen S. 2021. Self-aligning floating wind turbine has deep water potential. Ship & Offshore, No. 1, p. 24-29