DNV·GL

ENERGY

# JIP on Coupled analyses of FOWTs

## Testing philosophies for floating offshore wind turbines

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19 January 2017

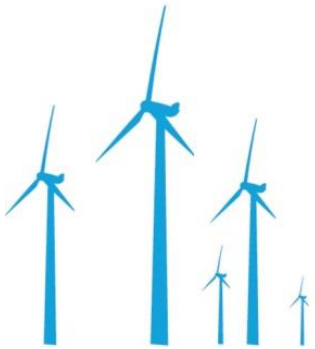

# JIP on Coupled Analysis of FOWTs

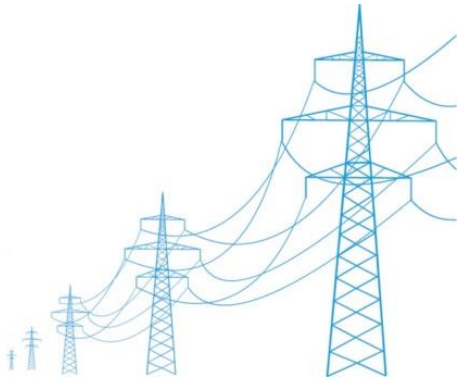
- DNV GL joint industry project (JIP) together with thirteen global partners
- Developing a Recommended Practice (RP) for coupled analysis of floating offshore wind turbines
- Building on the experience from the application of the Offshore Standard DNV-OS-J103
- Work package 6, consisting of DNV GL, MARIN and SINTEF Ocean (fmr. MARINTEK), considers model tests of FOWTs.

# Purpose of this presentation

- Present on overall level
  - Why perform model tests?
  - Challenges with testing FOWT
  - Methods for testing FOWT

- Get your input to the RP development:
  - What kind of model tests are preferred?
  - What challenges have been experienced?
  - What simplifications have been necessary?



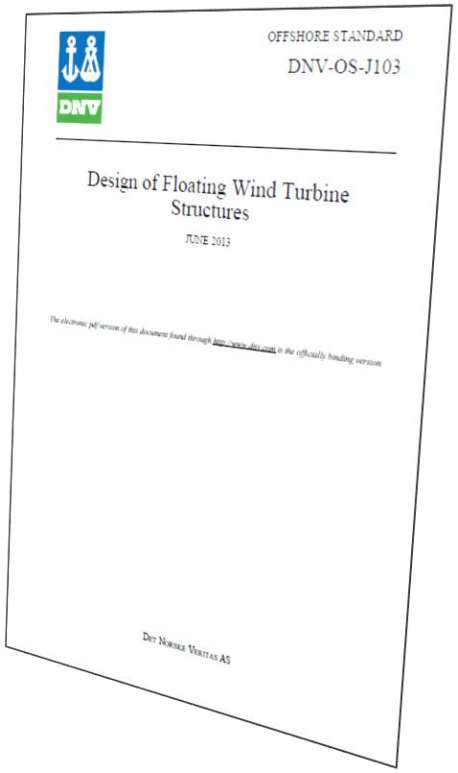


# Why perform model tests?

- DNV-OS-J103 clause 6.2.1 states:

  *"Model tests shall be carried out to validate software used in design, to check effects which are known not to be adequately covered by the software, and to check the structure if unforeseen phenomena should occur."*

- Validation of numerical and analytical models
- Calibration of hydrodynamic coefficients
- Study of global behaviour or other special effects



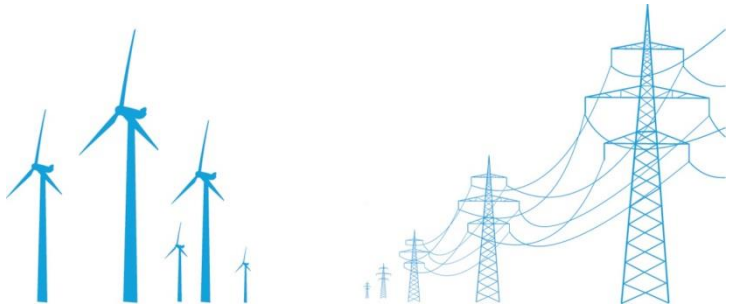
# General challenges of coupled hydro-aero testing of FOWTs

- Froude scaling is usually applied in hydrodynamic tests.

  ⇒Too low Reynolds number for aerodynamic loads on the rotor

| | Definition | Description |
|---|---|---|
| **Froude** | $Fr = \frac{U}{\sqrt{gL}}$ | Ratio inertia force to gravity force |
| **Reynolds** | $Re = \frac{UL}{\nu}$ | Ratio inertia force to viscous force |

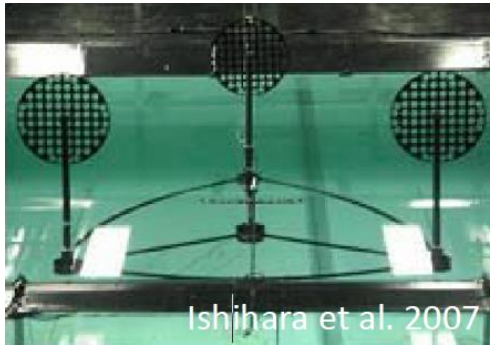
- Representation of aerodynamic loads
- Generation of wind fields with high quality
- Size of rotor



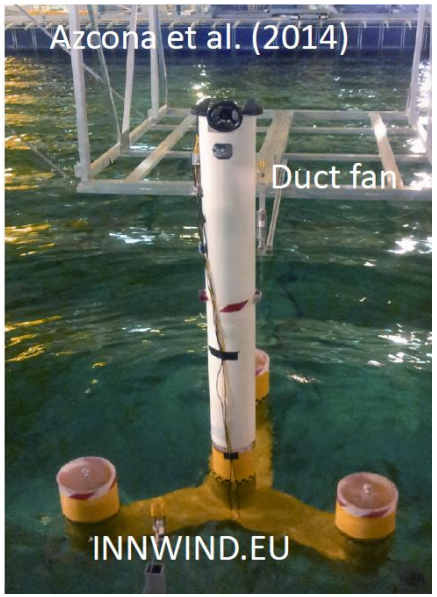
# Representation of aerodynamic loads

## Introduction

- For FOWTs, both hydrodynamic and aerodynamic loads can be significant for global behaviour and design driving loads
- With Froude scaling, which is necessary to scale wave loads correctly, Reynolds number is wrong and aerodynamics are not reproduced correctly
- Representation of aerodynamic loads in such low Reynolds regime is key to reliable model tests of FOWTs in model basins
- What methods are applicable for different purposes?

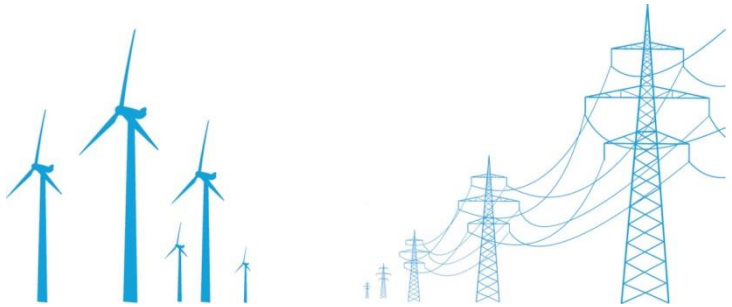




# Testing philosophies for hydrodynamic model tests of FOWTs

- Three main philosophies:
  - Passive methods (simplified)
  - Physical wind turbine
  - Hybrid test methods

- Tests in wind tunnels are not considered here (c.f. presentation by I. Bayati from Politecnico di Milano later today)



# Quick survey

# Quick survey

**How many of you have performed or been involved in (as e.g. stakeholder) a model tests campaign?**

# Quick survey

## Do you favour passive methods?

## Do you favour active methods?

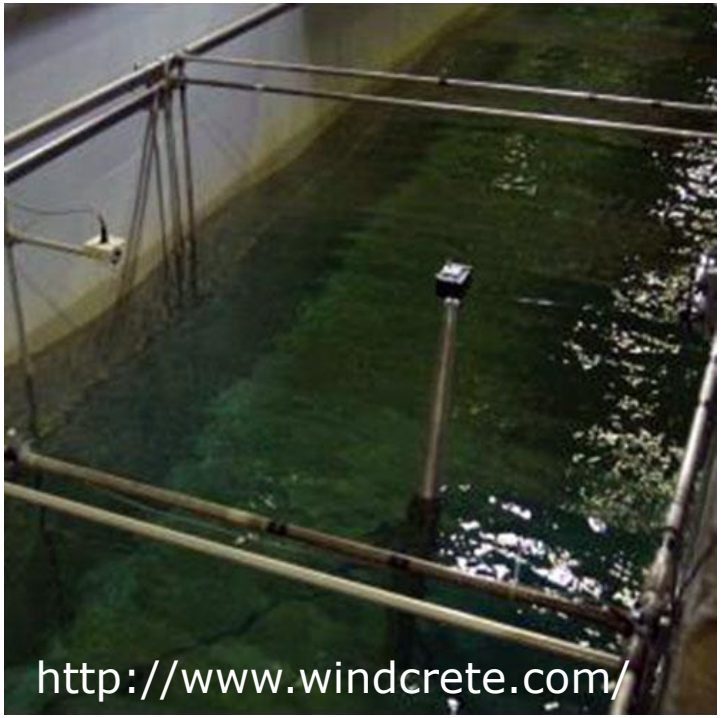
# Quick survey

**Particular challenges you experienced in your campaigns?**

**What did work / what did not work?**

# Passive Method: Wire applying constant force

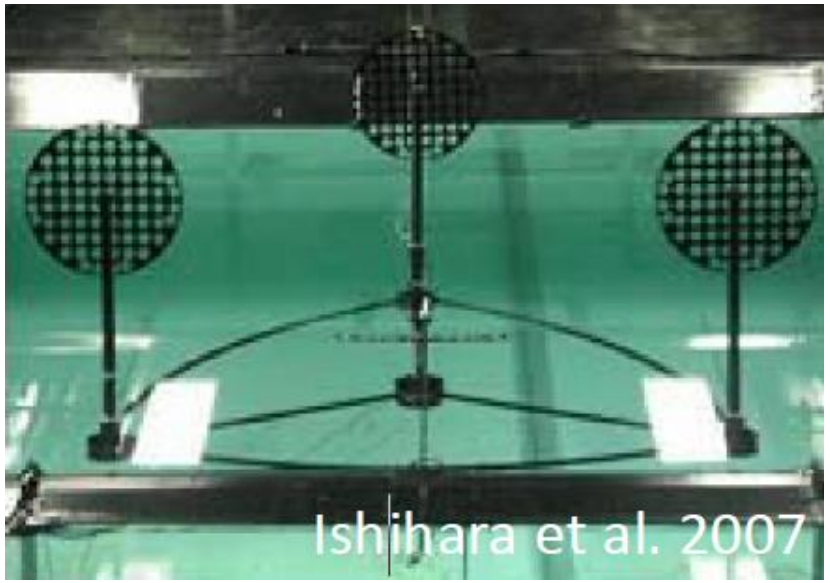
- Wire applying constant horizontal force on the tower
- Mean thrust
- Drawbacks include:
  - Only steady thrust is modelled (variation of thrust and aero-hydro-coupling are deficiently modelled)
  - Other aerodynamic loads neglected
- Examples: AFOSP/Windcrete - Matha et. al (2014) and Molins et. al (2014)



# Passive method: Obstructing disk

- Solid or perforated disc
- Wind generated by fans
- Size of disc adjusted to give correct mean force
- Gyroscopic loads included if the disc can spin, or by rotating a rod with proper mass distribution

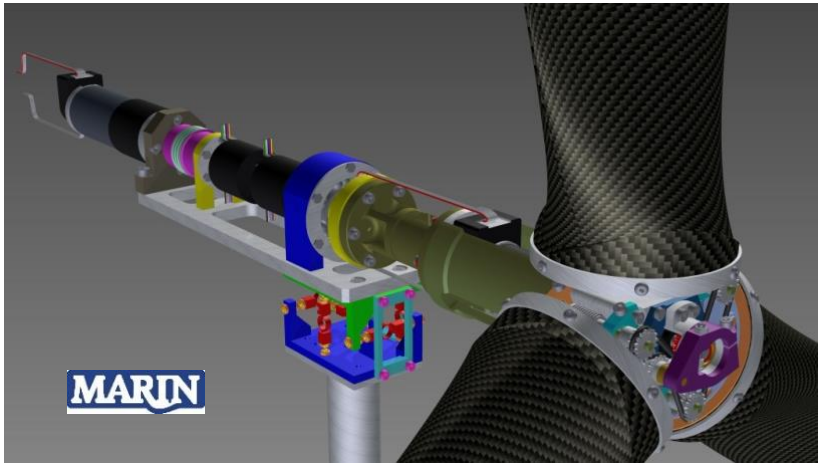
- Drawbacks:
  - Blade/tower interactions (tower shadow) omitted
  - Aerodynamic torque omitted
  - Varying drag loads due to flow issues around disc



# Refined methodology: Physical wind turbine

- Scaled down functional rotors
- Wind field generated by fans (Froude scaled)
- **Performance scaling** of blades
- Includes many more effects than the passive methods

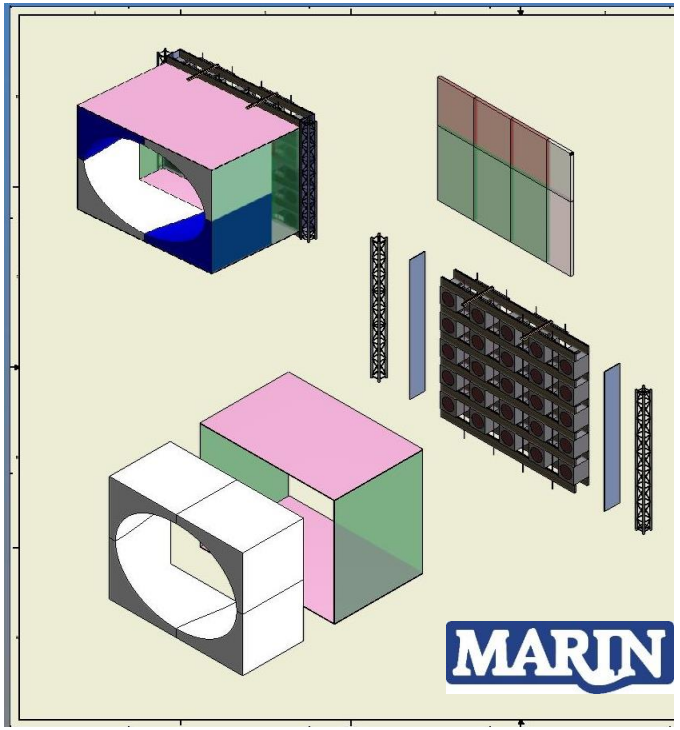

- Challenges and limitations:
  - Mass distribution (heavy turbine)
  - Accuracy of generated wind field
  - Other aerod. load comp. than thrust
  - Validity of performance scaling outside calibrated range of wind velocities
  - Redesign of the blades is not easy and it results in a different rotor



# Generation of wind

- Wind field can change rapidly in space as it circulates in the model basin
- Shear with water surface, walls and ceiling
- Low wind speeds required for Froude scaled wind - see e.g. Koch et. al (2016)
- Wind field characteristics should be documented before tests are initiated

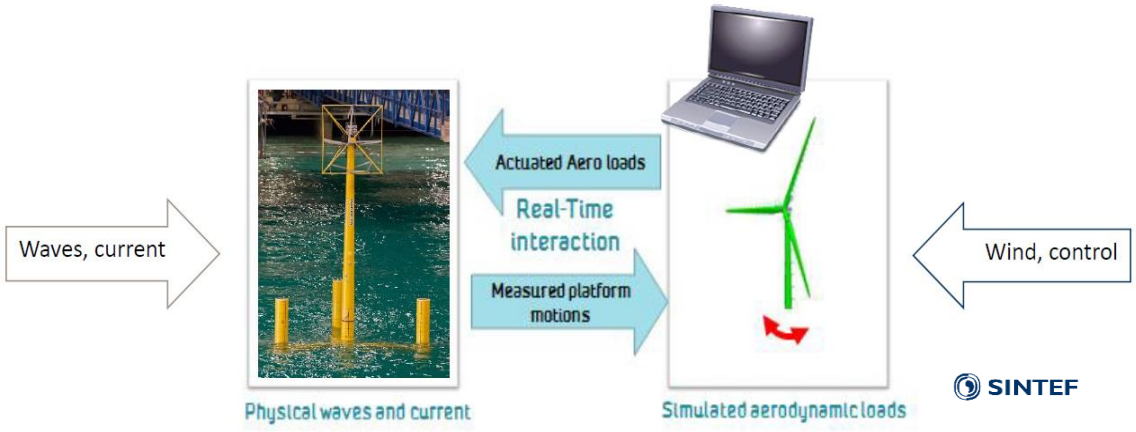
- Common ways to improve wind field:
  - Nozzles and honeycomb grid
  - Larger basins are advantageous for recirculation of the air flow



# Hybrid testing methods

- Floating foundation tested physically at model scale, while virtual model of wind turbine simulated in real-time on computer
- Real and virtual model connected by sensors and actuators, e.g.:
  - Small fans mounted in a matrix layout
  - Cable-driven robots

- Challenges and limitations:
  - Complexity of interface between real and virtual model, e.g.
    - Time delays
    - Application of high frequency loads
    - Dynamic response of actuators
  - Aerodynamic loads 'as good as' numerical model



# Summary – Mitigation of Froude/Reynolds scaling issues for model tests of FOWTs

| Method | Mitigation strategy |
|---|---|
| Passive wire, obstructing disc or fan/jet | Calibrate thrust load rather than wind speed |
| Physical wind rotors | Redesign blades |
| Hybrid methods | Aerodynamic loads are calculated in software at full-scale, and resulting loads are applied by actuators at model scale |

# Experience from the industry

The following items are being discussed in the JIP work package, but we are interested in hearing experiences made by the industry (both from the JIP participants and the general industry)

- What model scales have been applied in your tests?
- What important simplifications was necessary in your tests?
- Did you use a passive or active system to model aerodynamic loads? Are tests with passive solutions of any value?
- Was a blade pitch controller included in your tests? Was the controller changed after the model tests – and do you plan to perform new tests with the updated controller?

# Experience from the industry ctd.

- What was the reason for performing the model test? Calibration/validation of model/software or verification of concept/design?
- Has the concept changed after the model tests – and are the model tests deemed valid for the updated concept?
- What is your opinion on the value of full scale tests versus controlled model scale tests?
- What is important when selecting the format of model tests?
  - Methodologies for testing FOWT
  - Quality of tests
  - Simplicity of tests
  - Expertise and experience

# Literature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# Please join us for a chat after the session

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