WIND TUNNEL TESTING OF A FLOATING WIND TURBINE MOVING IN SURGE AND PITCH

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1. MOTIVATION

Large water depths (> *50 m*) in many costal regions around the world, e.g. Norway, Spain, Portugal, Japan or United States

Floating offshore wind turbine concepts could be an economic option

+ various concepts for floating structures proposed
+ higher flexibility of installation and easier decommissioning

Floating turbine concepts pose new challenges

- controlling of wind and wave induced turbine motion
- complex modelling in the design process: coupling of wind-wave climate, wind turbine, its support structure and mooring lines

Floating wind turbines are exposed to larger motions due to wave-induced hydrodynamic forces

⇨ Turbine rotor might move into and out of its own wake under certain wind and wave conditions

⇨ Need for computational codes that are capable to simulate aerodynamics correctly

2. OBJECTIVE

Investigation of rotor and wake aerodynamics affected by harmonic surge and pitch motions

- Rotor thrust C_T and turbine performance C_P
- Rotor induced velocities
- Wake bunching effect

} at different oscillation frequencies and amplitudes

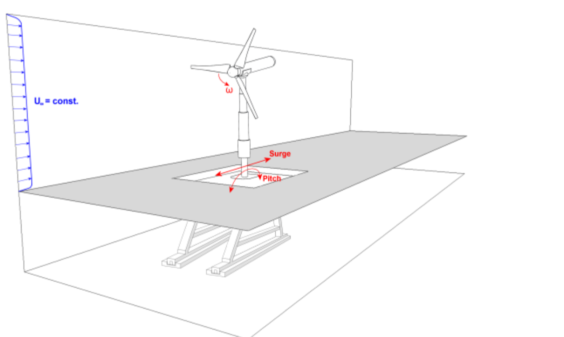

Fig.1: *Sketch of the model wind turbine installed on a surge-pitch test rig in the wind tunnel*

3. EXPERIMENTAL METHODS

TEST FACILITIES

- Closed-loop wind tunnel with a test section of *1.9 m* (height) x *2.7 m* (width) x *11.0 m* (length) at NTNU EPT
- 2D surge-pitch test rig capable to induce motions of approximately *1.0 Hz* (frequency) and *1.0 m* (amplitude) at NTNU IMT

MODEL WIND TURBINE AND INSTRUMENTATION

- Model wind turbine with a rotor diameter $D_{Rotor} = 0.90\ m$
- Turbine equipped with torque sensor and RPM sensor for power measurements
- Turbine placed on force plate for thrust force measurements
- Hot-wire probe for mean and turbulent velocities in wake

4. ILLUSTRATION OF WAKE FLOW

Effect of wake bunching at different oscillation modes

⇨ *Computational study by J. B. de Vaal, M.O.L. Hansen, T. Moan (NTNU/DTU)*

⇨ *Vortex Ring CFD model aimed at capturing unsteady rotor inflow*

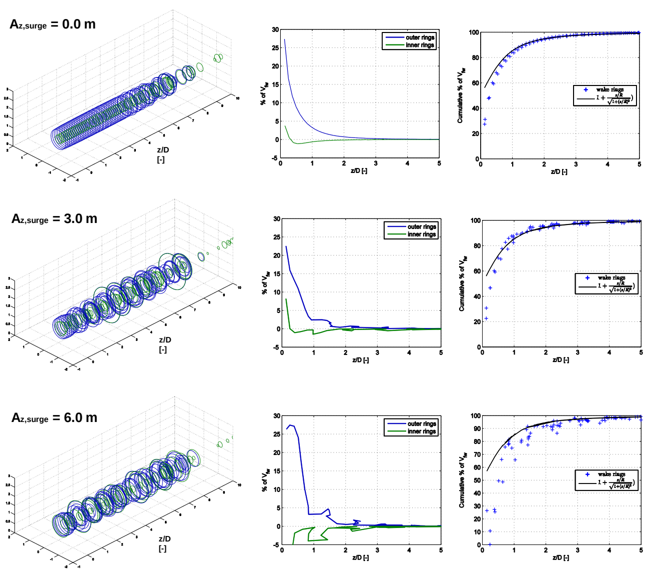

Fig.2: *Wake shape (left), Incremental induced velocity (middle) and cumulative induced velocity (right) computed for a simplified NREL 5MW wind turbine operated at $U_{wind} = 11.4$ m/s and TSR = 7.0, oscillating in surge at a frequency $f_{surge} = 0.08$ Hz*

[Source Fig. 2: with kind permission of Jacobus B. de Vaal, Institute of Marine Technology, NTNU]

5. EXPERIMENTAL CHALLENGES

Unsteady effects on aerodynamic forces and wake are expected for **fast motions** and **large motion amplitudes**

⇨ oscillation motion should reach convective wake velocity

⇨ not possible to impose fast motions and large amplitudes with test rig

High frequencies and motion amplitudes imply very high inertial forces

⇨ for accurate measurements the aerodynamic forces on the rotor should be in the same order as the inertial forces due to the turbine movement

EXPERIMENTAL PROGRESS PLAN

1. Solid **drag disc** in **surge** motion: Drag force and wake measurements
2. **Turbine** in **surge** motion: Rotor thrust & power and wake measurements
3. **Turbine** in **pitch** motion: Rotor thrust & power and wake measurements

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