Tidal Turbine Benchmarking Exercise: Geometry Specification and Environmental Characterisation

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Introduction: Why Do a Benchmarking Exercise?

- Tidal turbine operate in a hostile hydrodynamic environment:
  - Turbulence
  - Wave-induced unsteadiness
- Improving mathematical and engineering models for tidal turbines requires validation data yet few datasets exist
- Objective is to conduct a large laboratory scale experiment on a highly instrumented 1.6m diameter tidal rotor
- Two rounds of blind benchmarking in which engineers from academia and industry will be invited to predict the loading experienced by the turbine
- Test Conditions:
  1. Uniform flow
  2. Uniform flow + waves
  3. Uniform flow + grid generated turbulence

Figure: Inspection of Sustainable Marine Energy Plat-I turbine blades [1]

Benchmarking Rotor Design: Overview

- Blades designed with RANS - BEM methodology with NACA 63-415 profile
- Two blades instrumented with strain gauges at six radial locations
- Remaining blade instrumented with fibre Bragg sensors
- Individual blade loads measured with hub-integrated root bending sensors
- Torque and Thrust measured by shaft mounted transducer

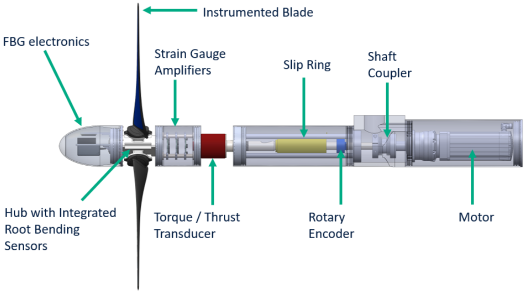

Figure: Illustration of benchmarking rotor

Benchmarking Rotor Design: Current Assembly Progress

- All nacelle components machined
- Blades complete and currently undergoing testing
- Corrosion resistant coatings still to be applied

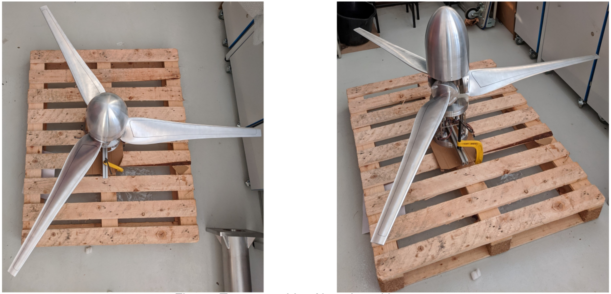

Figure: Test assembly of benchmarking rotor

Facility Selection and Experimental Setup

- QinetiQ towing tank facility, Haslar, Portsmouth UK
- Originally built by Robert Froude, son of William Froude
- 270 m (L) $\times$ 12.2 m (W) $\times$ 5.4 m (D) - blockage of around 3 $\%$
- Speeds of up to 12.25 m s^{-1} and drag loads up to 5 kN

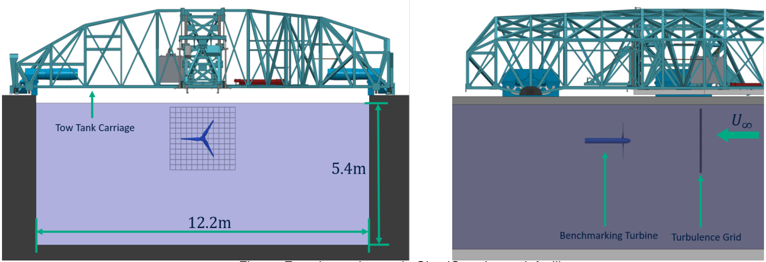

Figure: Experimental setup in QinetiQ towing tank facility

Turbulence Grid Characterisation: Overview

- Flow velocity measured with 3 Acoustic Doppler Velocimeter (ADV) probes
- ADV positions to be adjusted to obtain a horizontal, vertical and diagonal profile each with 6 points

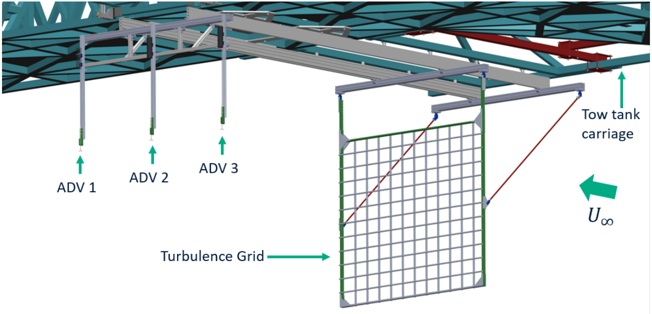

Figure: Turbulence grid flow characterisation: experimental setup

Turbulence Grid Characterisation: Streamwise Velocity Profile

- Identification and removal of spikes performed with velocity correlation filter [2]
- Minimum streamwise velocity of $0.913U_\infty$ at centre of turbulence grid
- Average value of $0.917U_\infty$ across turbine with $\pm0.5\%$ variation
- Streamwise turbulence intensity across turbine between 2.9% and 4.3% with 3.5% mean

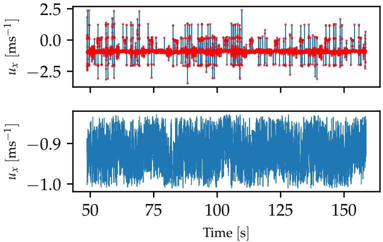

Figure: Example of spike identification and removal from ADV signal

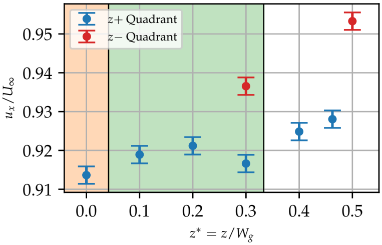

Figure: Vertical streamwise velocity profile

Conclusions

- Benchmarking turbine designed and manufactured and is on schedule for testing in late March
- Flow characterisation of turbulence grid found an average streamwise velocity deficit of $0.917U_\infty$ across turbine with $\pm 0.5\%$ variation
- Streamwise turbulence intensity across turbine between 2.9% and 4.3% with 3.5% mean
- Email for details of how to take part in the benchmarking exercise: sam.harvey@eng.ox.ac.uk

References

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- L. Cea, J. Puertas, and L. Pena, “Velocity measurements on highly turbulent free surface flow using adv,” *Experiments in fluids*, vol. 42, no. 3, pp. 333–348, 2007.