Tidal Benchmarking Project: Description of Released Data

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Revision History

Revision	Date	Description
1.0	04/07/2022	Initial release of document

1 Introduction

The tidal turbine benchmarking project has conducted a large laboratory scale experiment on a highly instrumented 1.6 m diameter tidal rotor, with the aim of providing a well-documented experimental dataset that will be used in a benchmarking exercise that will compare a range of modelling methodologies for tidal turbines. This document describes the different forms of data that have been released and provide guidance on its use by modellers participating in the benchmarking study.

2 Benchmarking Test Cases and Experimental Parameters

The excel spreadsheet entitled `Benchmarking Cases and Experimental Parameters.xlsx` can be found at the top level of the data release directory and contains a table of the cases to be modelled for both the clean and turbulent conditions. Within the Experimental Parameters tab a table of all of the key parameters for the experiment is presented, including the properties of water to be used by modellers. The stated water density and dynamic viscosity are linearly interpolated from the tables provided in the CRC Handbook of Chemisty and Physics [1].

3 Geometry Data

3.1 Blade Geometry Data

The blade is constructed with a single NACA 63-415 profile that has been thickened using the thickening function described in section 3.2 to provide a constant non-dimensional trailing edge thickness along the span. There is hence only a single non-dimensional hydrofoil profile that must be scaled and twisted to form the blade. The data required to generate the blade geometry can be found in the folder path: `R_001\Turbine Geometry\Blade Geometry`. This folder contains the text file `chordandtwist.txt`, that provides the chord and twist distributions of the blade. The thickened and original hydrofoil profiles are available in the `Non_Dimensional Blade Profile` folder, while the blade profile at a number of radial sections can be found in `Blade Sections (Radial)`, which are provided on curved sections of constant radial coordinate.

Modelling results will be compared to in-blade measurements via bending moments evaluated at the in-blade sensor locations. The directory `R_001\Turbine Geometry\Blade Geometry\Instrumentation Locations` contains tab-delimited text files specifying the sensor locations for both the strain gauged and fibre Bragg instrumented blades.

3.2 Hydrofoil Profile Thickening Function

The thickening function implemented for the blade profile was adapted from Xu et al [2] and is defined by the equation,

$$y_t = \begin{cases} y_0 & 0 \leq x_t \\ y_0 \pm 0.5\delta c \left(\dfrac{x - x_t c}{c - x_t c} \right)^n & \mathrm{x}_t \leq c. \end{cases} \tag{1}$$

The parameters δ, n and x_t are tabulated in table 1.

Table 1: Parameters of thickening function

Parameter	**Symbol**	**Unit**	**Value**
Normalised trailing edge thickness	δ	-	0.006 25
Thickening function exponent	n	-	2.0
Normalised thickening distance	x_t	-	0.349

3.3 3D CAD Data

3D CAD data in STEP format can be found within the `R_001\Turbine Geometry\3D CAD Data` directory. The file `blade.STEP` provides 3D CAD data for the blade, with the internal instrumentation channel removed for simplicity and is cut-off where it enters the 0.2 m diameter nacelle. The file `turbine assembly.STEP` provides the turbine assembly including the tower, with the rotor coloured differently from the rest of the nacelle. The internal structure of the turbine has been removed for simplicity.

4 CFD Data

4.1 2D Hydrofoil Simulation Data

2D lift and drag coefficients for the thickened NACA 63-415 profile are provided at a Reynolds number of 288 000, which relates to normalised radial location $r/R = 0.8$ at the design tip speed ratio of 6, and a range of turbulence intensities from 0 % to 10 %. The simulations utilised a k-ω SST RANS turbulence model on a wall-resolving mesh with the first cell $y^+ \sim 1$. Although the variation of chord-based Reynolds number with radial location is small, variation across the tip speed ratios within the benchmarking cases is significant and hence it is recommended that modellers consider this in the construction of their lift and drag tables. The 2D simulation results have been validated against experimental studies at Reynolds numbers of 3.2×10^5 and 1.6×10^6 [3, 4].

References

[1] D. Lide, *CRC Handbook of Chemistry and Physics, 90th Edition*. Taylor & Francis, 2009.

[2] H. Xu, W. Shen, W. Zhu, H. Yang, and C. Liu, "Aerodynamic analysis of trailing edge enlarged wind turbine airfoils," in *Journal of Physics: Conference Series*, vol. 524, p. 012010, IOP Publishing, 2014.

[3] A. C. Daud Filho, H. Cerón-Muñoz, F. Catalano, and E. d. E. de São Carlos, "Experimental study of the influence of vortex generators on airfoils for wind turbines," in *VI Congreso Internacional de Ingenieria Mecanica y IV de Ingenieria Mecatronica IV Congreso Internacional de Materiales, Energia y Medio Ambiente*, 2013.

[4] C. Bak, P. Fuglsang, J. Johansen, and I. Antoniou, "Wind tunnel tests of the naca 63-415 and a modified naca 63-415 airfoil," 2000.