Data article

Title: *Environmental & Load Data: 1:15 Scale Tidal Turbine subject to a variety of Regular Wave Conditions*

Authors: S. Draycott[a], G. Payne[b], J. Steynor[a], A. Nambiar[a], B. Sellar[a], V. Venugopal[a]

Affiliations:

[a] School of Engineering, Institute for Energy Systems, The University of Edinburgh, Edinburgh, EH9 3DW, UK

[b] Naval Architecture, Ocean and Marine Engineering, University of Strathclyde, Glasgow, G4 0LZ, UK

Contact email: S.Draycott@ed.ac.uk

Abstract

An experimental study was carried out to investigate the effect of waves on the loads and performance of tidal turbines. A fully instrumented 1:15 scale tidal turbine was installed in the FloWave Ocean Energy Research Facility, and a wide range of regular wave conditions were generated; systematically varying both wave frequency and height. Waves are generated both following and opposing a fixed mean current velocity of 0.81 m/s. Data are made available of the measured turbine loads and environmental conditions obtained for five repeats of 24 wave conditions and a description is provided in this article. The analysis and presentation of the described dataset can be found in [1].

Specifications Table

Subject area	*Engineering*
More specific subject area	*Tidal stream turbines*
Type of data	*Text files (.txt)*
How data was acquired	***Environmental:*** *surface elevations measured using a resistance wave gauge, and current velocities (x, y, z) using a Nortek Vectrino Profiler.* ***Loads:*** *AMTI OR6-7 used to measure 6DOF loads on the whole turbine and structure. Turbine instrumentation (thrust, torque, rotor position) acquired using bespoke transducers and an encoder.*
Data format	*Raw text files*
Experimental factors	*All instrumentation calibrated prior to testing, with the wave gauge calibrated daily. Each morning zeroes are taken, and removed, for all instruments prior to testing.*
Experimental features	*A 1:15 scale tidal turbine is subject to combined wave-current conditions. These conditions are generated in a circular combined wave & current test tank: The FloWave Ocean Energy Research Facility. The measured conditions, and corresponding loads measured on the turbine are provided.*
Data source location	*Edinburgh, UK (Latitude: 55.922048 Longitude: -3.178620)*
Data accessibility	*The data is available in this repository*

Related research article	*S. Draycott, G. Payne, J. Steynor, A. Nambiar, B. Sellar, and V. Venugopal, "An experimental investigation into non-linear wave loading on horizontal axis tidal turbines," J. Fluids Struct., vol. 84, pp. 199–217, 2019. https://doi.org/10.1016/j.jfluidstructs.2018.11.004*

Value of the data

- This large open-source dataset will facilitate increased understanding into the nature and extent of wave-induced loads on tidal stream turbines: informing design and control requirements.
- These data can be used to validate numerical models such as those based on Blade Element Momentum Theory (BEMT) codes or Computational Fluid Dynamics (CFD).
- This extensive benchmark dataset can also be used for comparison to other tidal stream turbines in similar conditions, or to the same turbine design in different conditions. This can facilitate increased understanding of inter-turbine and inter-facility differences.

1. Data

The data described in this article was obtained from experimental tank testing of a 1:15 scale tidal stream turbine subject to a range of regular wave conditions in the presence of a fixed mean current velocity. Waves are generated both following and opposing the current direction, and wave frequencies and amplitudes are systematically varied. Turbine load data, along with corresponding surface elevations and velocity measurements are provided.

2. Experimental Design, Materials and Methods

2.1 The turbine and set-up

The Tidal Stream Turbine (TST) model is a three-bladed horizontal axis machine with a diameter of 1.2 m. The design of the turbine is covered in detail in [2], with CAD drawings and baseline turbine data available for download at http://dx.doi.org/10.7488/ds/1707 [3]. On-board sensors measure thrust, *T*, torque, *Q*, and angular position, θ.

In addition to the sensors integrated into the TST model, there is additional instrumentation installed in the FloWave Ocean Energy Research Facility as summarized in Table 1. Environmental conditions are measured using a resistance-type wave gauge to measure water surface elevation, *η, and* an Acoustic Doppler Velocimeter (ADV) to measure current velocity in the *x, y* and *z* directions (*U, V, W*). Additional load measurements are obtained using a bottom-mounted six-axes (6-DOF) load cell: measuring forces, *F*, and moments, *M*, on the entire TST structure (blades, TST body and tower). The test set-up is illustrated in Figure 1 where the turbine is depicted to scale in conjunction with the installed instrumentation.

Table 1: Description of installed instrumentation including position relative to the turbine rotor plane centre

Type of instrumentation	Model	Variables measured	Sample Rate [Hz]	Rel location [m]		
				X	Y	Z
ADV	Vectrino Profiler	*U, V, W*	100	-2.4	0	0.6
Wave Gauge	FloWave	*η*	128	0	0	-
TST Instrumentation	UoE	T, Q, θ	256	0	0	0
Load Cell	AMTI OR6-7	*Fx, Fy, Fz, Mx, My, Mz*	256	0.49	0	-1

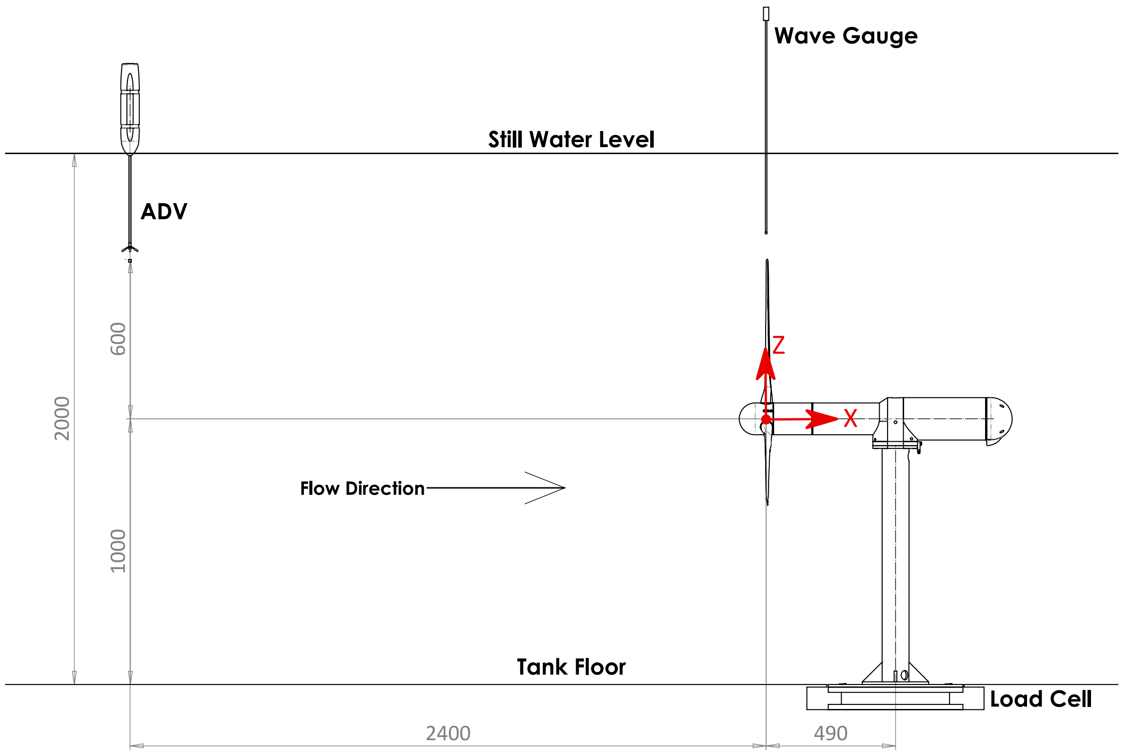

Figure 1: Location of test instrumentation in the FloWave basin relative to the rotor plane (dimensions in mm)

2.2 Test Conditions

For all tests the mean current velocity (with no turbine present) is kept at 0.81 m/s. Regular waves are generated both following and opposing the current; varying both wave frequency and height. Six wave frequencies are generated for following waves and three for opposing waves, as defined in Table 2 and Table 3. For every frequency-direction combination initially wave heights of 0.1 m are targeted using a correction procedure. Once correct (reasonably), additional wave amplitudes are obtained using a linear gain applied to these corrected wave amplitudes for 0.308Hz and 0.4Hz waves.

Table 2: Frequencies and relative amplitudes used for waves in a nominal following current of 0.81 m/s. Each test is repeated five times

Frequency	Relative input wave height							
[Hz]	0.25	0.5	1 (0.1m)	1.5	1.75	2	2.25	4
0.308	X	X	**X**	X				
0.348			**X**					
0.4			**X**	X	X	X	X	
0.444			**X**					
0.5			**X**					
0.545			**X**					

Table 3: Frequencies and relative amplitudes used for waves in a nominal opposing current of 0.81 m/s. Each test is repeated five times

Frequency	Relative input wave height							
[Hz]	0.25	0.5	1 (0.1m)	1.5	1.75	2	2.25	4
0.308		X	**X**	X		X		X
0.348			**X**					
0.4		X	**X**	X		X		X

2.3 Cropping Data

As detailed in [1], prior to creating files for analysis, the time-series are cropped to only include good quality data where the conditions are stable, and no wave reflections are present. The cropped test times used for each frequency-direction combination (applies to all amplitudes) are detailed in Table 4.

Table 4: Cropped test times for opposing and following waves of differing frequencies

Frequency [Hz]	Repeat time T_R [s]	Following wave test times [s]	Opposing wave test times [s]
0.308	3.25	8-14.5	13-16.25
0.348	5.75	8-13.75	16-21.75
0.4	2.5	10-20	27-34.5
0.444	2.25	10-29	
0.5	2	13-25	
0.545	5.5	13-24	

2.4 File Details and Structure

As there are different sample frequencies for each of the instrument types (see Table 1) there are three files created for every test. All data is provided in SI units. The specifics of the test are given in each filename as follows:

[Wave height ID]_[Frequency ID]_[Wave Direction ID]_[DAQ ID]_[Repeat ID]

The identifiers are defined below:

Table 5: Wave height file identifiers

Wave height ID	H1	H2	H3	H4	H5	H6	H7	H8
Relative wave height	0.25	0.5	1	1.5	1.75	2	2.25	4

Table 6: Wave frequency file identifiers

Wave frequency ID	F1	F2	F3	F4	F5	F6
Wave frequency [Hz]	0.308	0.348	0.4	0.444	0.5	0.545

Table 7: Wave direction file identifiers

Wave Direction ID	O	F
Wave direction	opposing	following

Table 8: Data type file identifiers

DAQ ID	WG	ADV	LOADS
Channels	η	*U, V, W*	*T, Q,* θ, *Fx, Fy, Fz, Mx, My, Mz*

Table 9: Repeat number file identifiers

Repeat ID	R1	R2	R3	R4	R5
Repeat number	1	2	3	4	5

As an example, for the opposing wave condition with a relative wave height of 1, and a frequency of 0.4 Hz. The name of the file containing the load data for the third repeat would be:

H3_F3_O_Loads_R3.txt

Acknowledgements

The authors are grateful for financial support from the UK Engineering and Physical Sciences Research Council (EPSRC) through FloWTurb: Response of Tidal Energy Converters to Combined Tidal Flow, Waves and Turbulence (EP/N021487/1) and SuperGen UK Centre for Marine Energy Research, UK (EP/M014738/1). The authors also acknowledge support from the EPSRC for funding the FloWave Ocean Energy Research facility (EP/I02932X/1).

References

[1] S. Draycott, G. Payne, J. Steynor, A. Nambiar, B. Sellar, and V. Venugopal, “An experimental investigation into non-linear wave loading on horizontal axis tidal turbines,” *J. Fluids Struct.*, vol. 84, pp. 199–217, 2019.

[2] G. S. Payne, T. Stallard, and R. Martinez, “Design and manufacture of a bed supported tidal turbine model for blade and shaft load measurement in turbulent flow and waves,” *Renew. Energy*, vol. 107, pp. 312–326, 2017.

[3] G. Payne, “Experimental tidal turbine model external geometry CAD files and measurements data of tank tests carried out with that turbine model, [dataset].” University of Edinburgh. http://dx.doi.org/10.7488/ds/1707. School of Engineering, Institute for Energy Systems, 2017.