Supergen Assembly 2017

Grand Challenge:

Dynamic **L**oadings on **T**urbines in a **T**idal **A**rray

(DyLoTTA)

Academic partners: Cardiff University, University of Strathclyde

The DyLoTTA project

Research motivations:

- Situating tidal turbine arrays in open sea wave climates with high wave-current interactions will influence:

power generation structural integrity product durability maintenance requirements

……and hence the project costs and viability

Research aims:

- ✓ Quantify the effects of wave-current interactions on the performance and integrity of TST devices when sited in an array
- ✓ Develop operational procedures to mitigate the impacts of these extreme loading patterns

Methodology:

- Combined approach - numerical modelling, physical modelling at scale, field data analysis

Project partners:

Ansys Arup Bosch Rexroth ORE Catapult Lloyds Register SKF
Nautricity Airborne Composites National Instruments

The DyLoTTA project

Approx. Date	Physical testing schedule	
Sub task	**Turbine design and build**	**Experiment design and testing**
Year 1 q1-q4	Design and build 1 turbine	Select instrumentation, test programme, test facilities
Year 2 q2	Where we are now in the project	Wave-tow testing of 1 turbine
Year 2 q2-q3	Review and finalise turbine design	
Year 2 q3		Turbulent current testing of 1 turbine
Year 2 q3-q4	Build 2nd and 3rd turbines	
Year 3 q2		3 turbine array testing under tow
Year 3 q3		3 turbine array testing under wave-current

The DyLoTTA project

Areas of work:

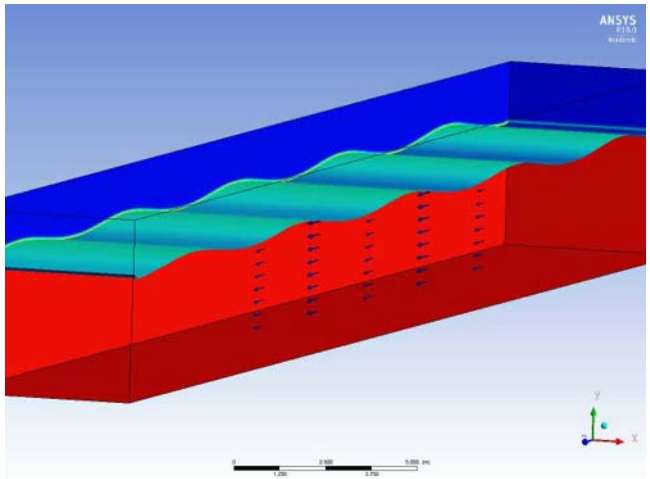
- Scaled turbine design and instrumentation *(Matt Allmark)*
- Laboratory experiment design and methodology *(Matt Allmark, Kate Porter, Stephanie Ordonez-Sanchez)*
- Lab turbine blade geometric and structural design *(Rob Ellis)*
- Blade element momentum theory modelling *(Stephanie Ordonez-Sanchez, Rob Ellis)*
- Numerical modelling of turbines in Ansys at laboratory and field scales *(Cath Lloyd, Rob Ellis)*
- Experimental data analysis *(Kate Porter, Stephanie Ordonez-Sanchez, Matt Allmark)*
- Field data analysis *(Stephanie Ordonez-Sanchez, Kate Porter)*

Progress update

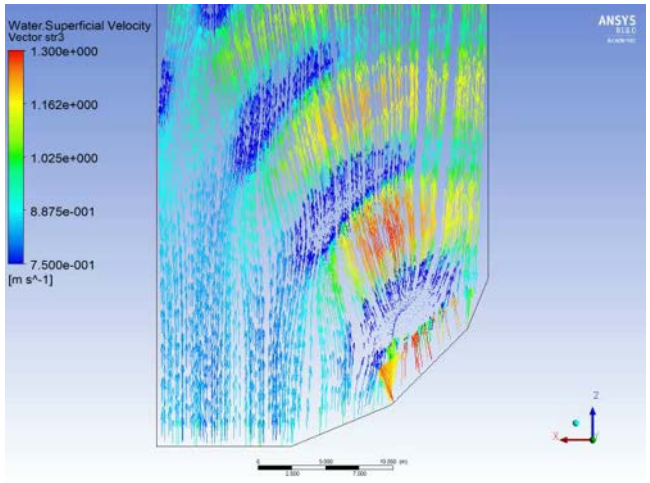
- Just over one year into the project…
- …and things are progressing very well!
- Ongoing numerical modelling – CFD, BEMT see poster today and EWTEC paper (Ordonez-Sanchez at al. 2017)
- Experimentation – turbine design, blade design, experimental set-up, preliminary results

Numerical modelling

- Cath Lloyd: Developing wave-current Interaction model in Ansys CFX, including oblique waves and ultimately the turbine at laboratory scale
- Rob Ellis: Turbine performance modelling at laboratory scale in Ansys CFX, comparison with BEMT
- Move on to field scale models and array interaction modelling later in the project



Co-directional waves and current



Oblique model: waves at 45 degrees to current

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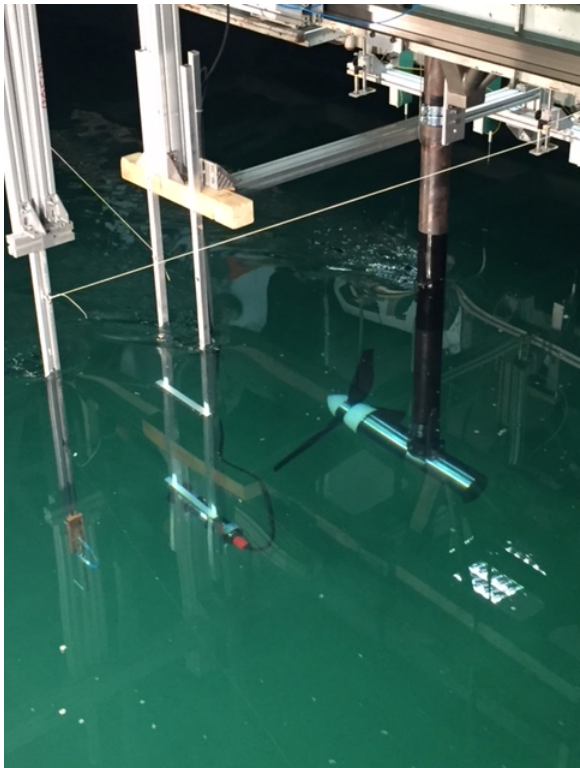
Experimental work

Funding secured from Marinet 2 first call

Testing campaign completed just last week (Nov 2017)

3.5 x 9 x 220 m wave-tow tank at CNR-INSEAN, Rome



Experimental work

Objectives for first test campaign:

1. First test of new turbine design, assess and review design

2. Turbine performance under tow only, comparing speed and torque control

3. Turbine performance under tow into large regular waves, comparing speed and torque control

4. Turbine performance under tow into smaller regular waves, comparing speed and torque control

5. Turbine performance under tow into irregular waves, comparing speed and torque control

Experimental work

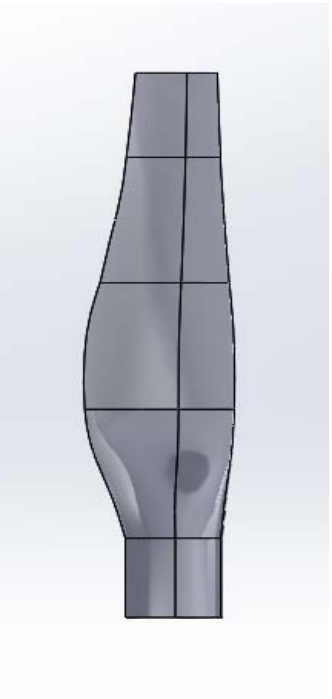
Turbine design

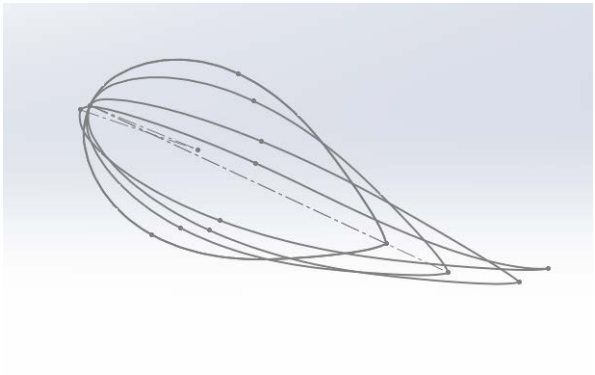
- 3 bladed, 0.9 m diameter turbine, driven by Bosch-Rexroth motor
- Designed for sustained flow velocity of up to 1.3 m/s
- Applied Measurements thrust-torque transducer on drive shaft just behind rotor
- Thrust and torque gauges on each blade root
- Thrust gauge on stanchion
- Encoder fitted at end of drive shaft
- LabView used for data acquisition

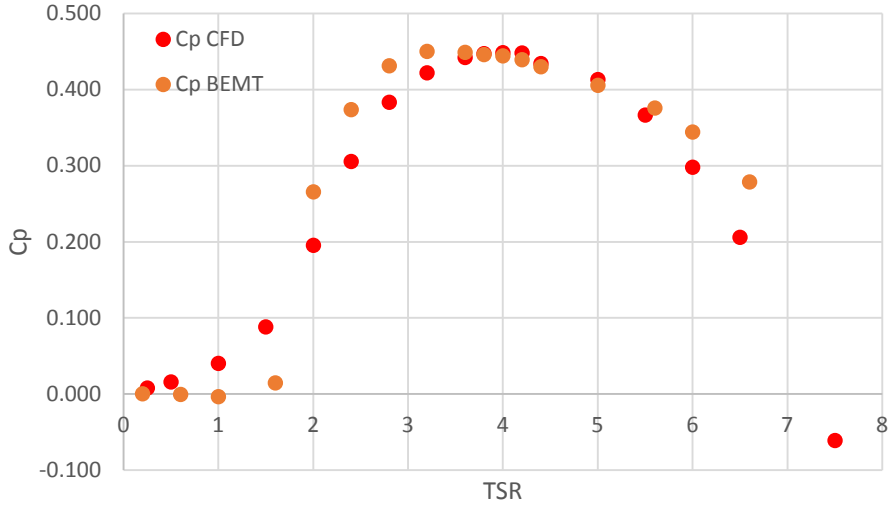
Experimental work

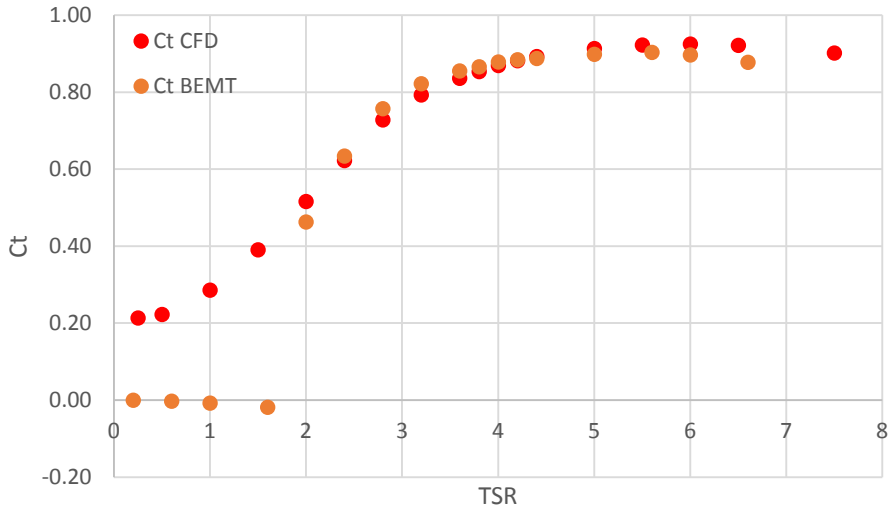
Blade design

- Wortmann FX 63-137 profile, except at blade root
- Design peak $C_P = 0.45$
- Design peak $C_T = 0.9$
- Good agreement between BEMT and CFD models of blade performance



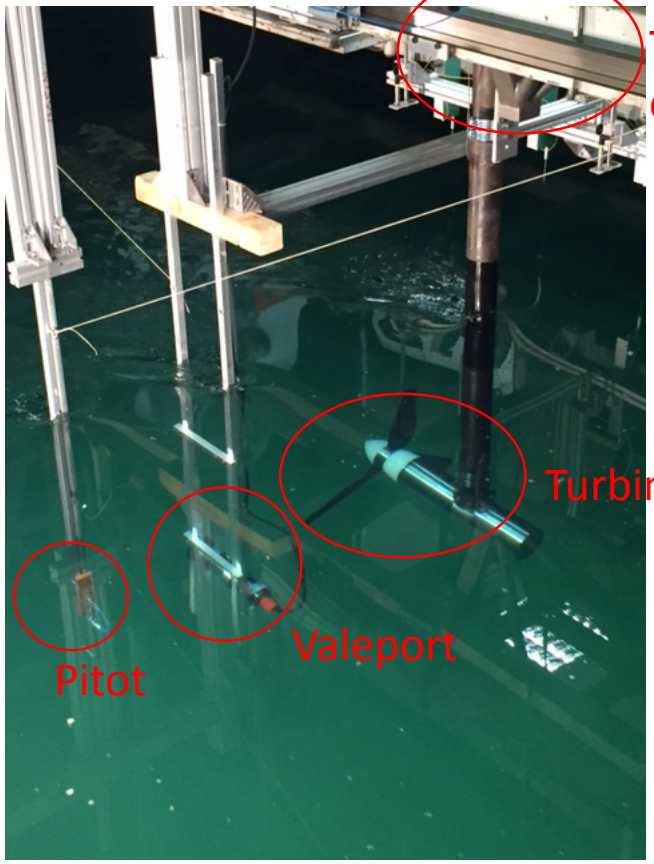


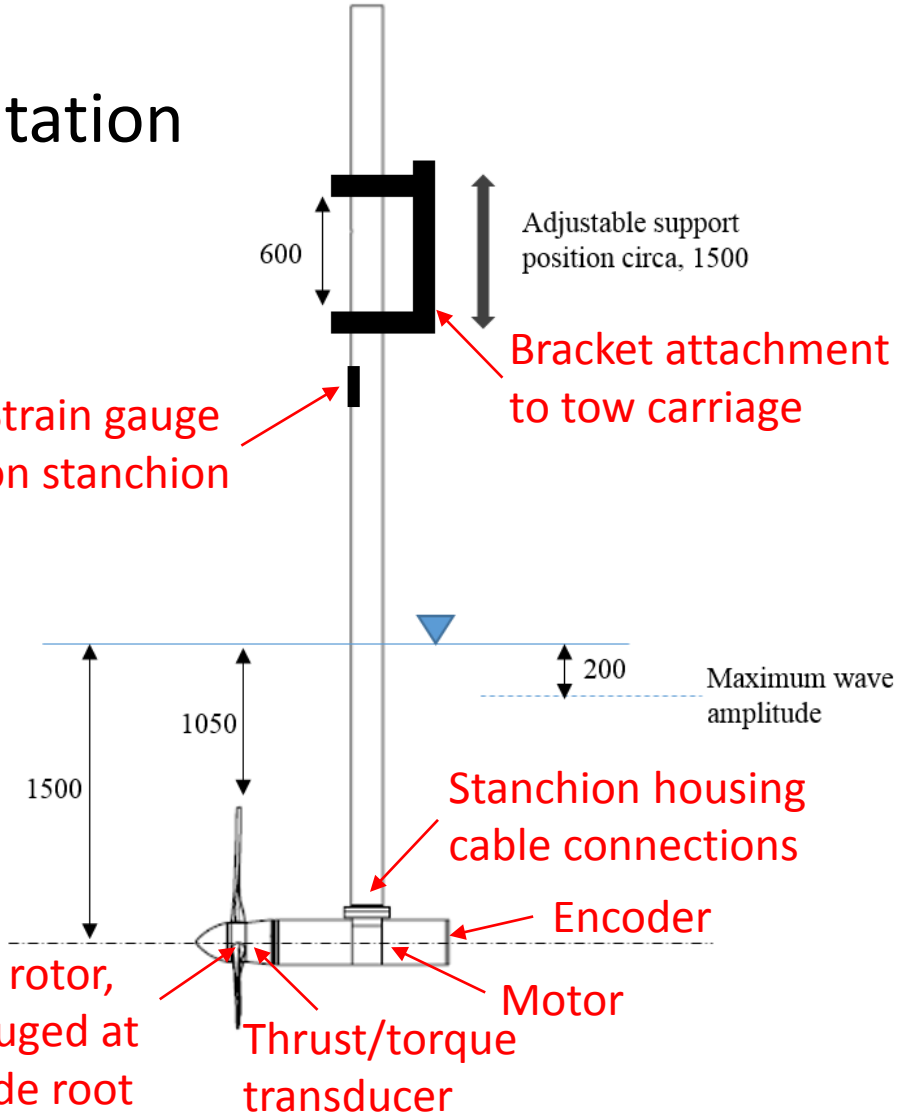




Experimental work

Test set-up and instrumentation





Experimental work

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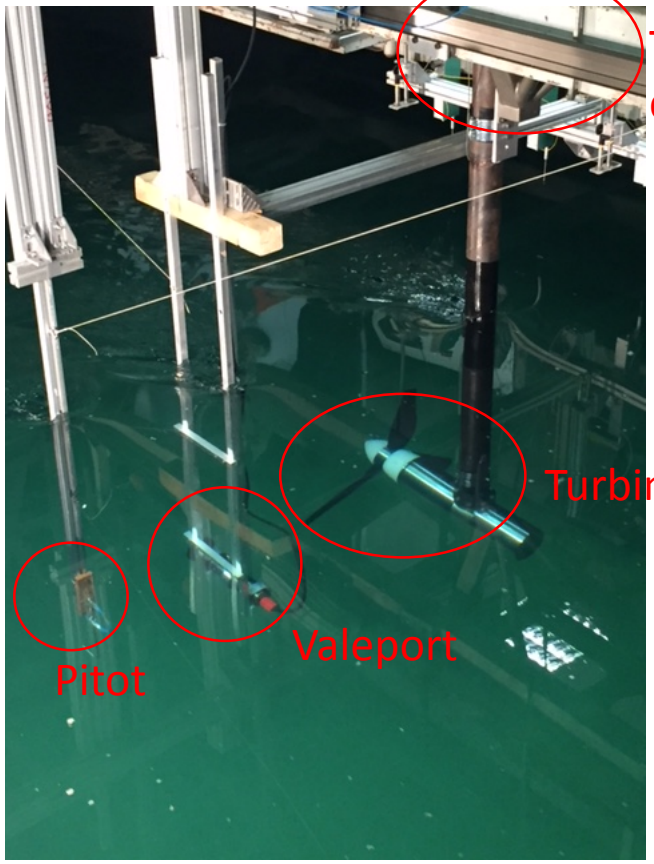
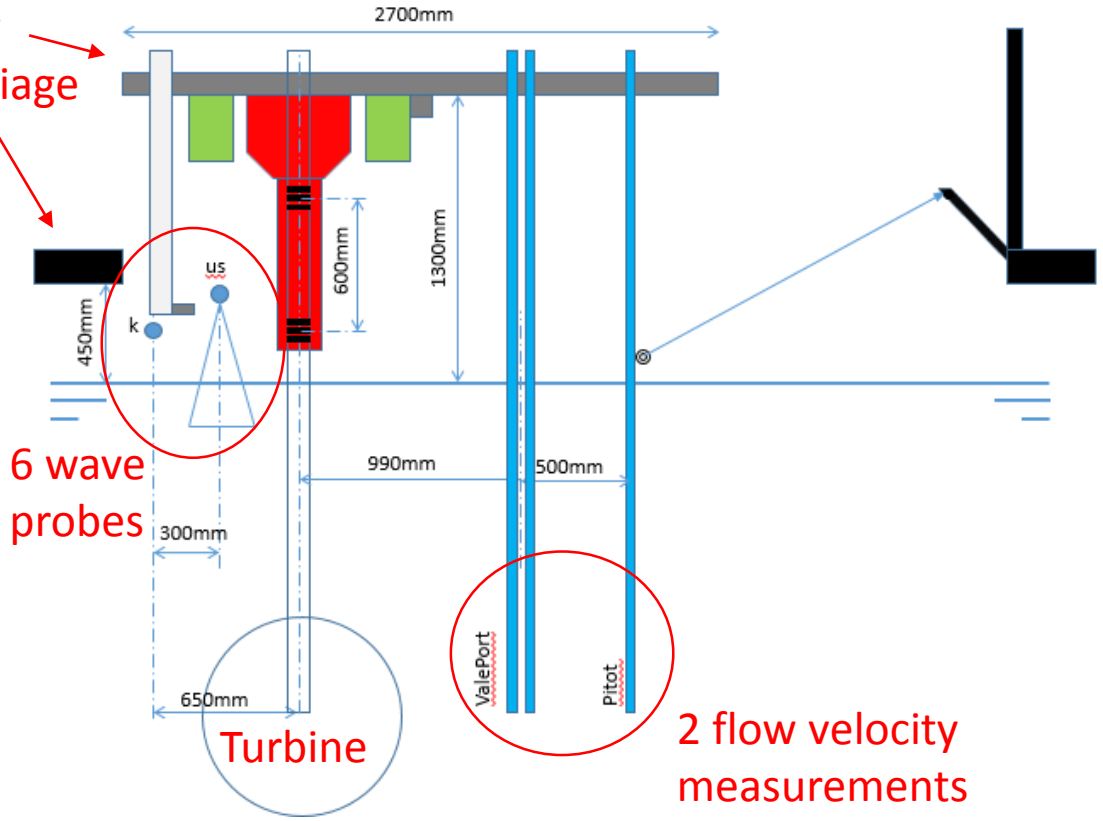
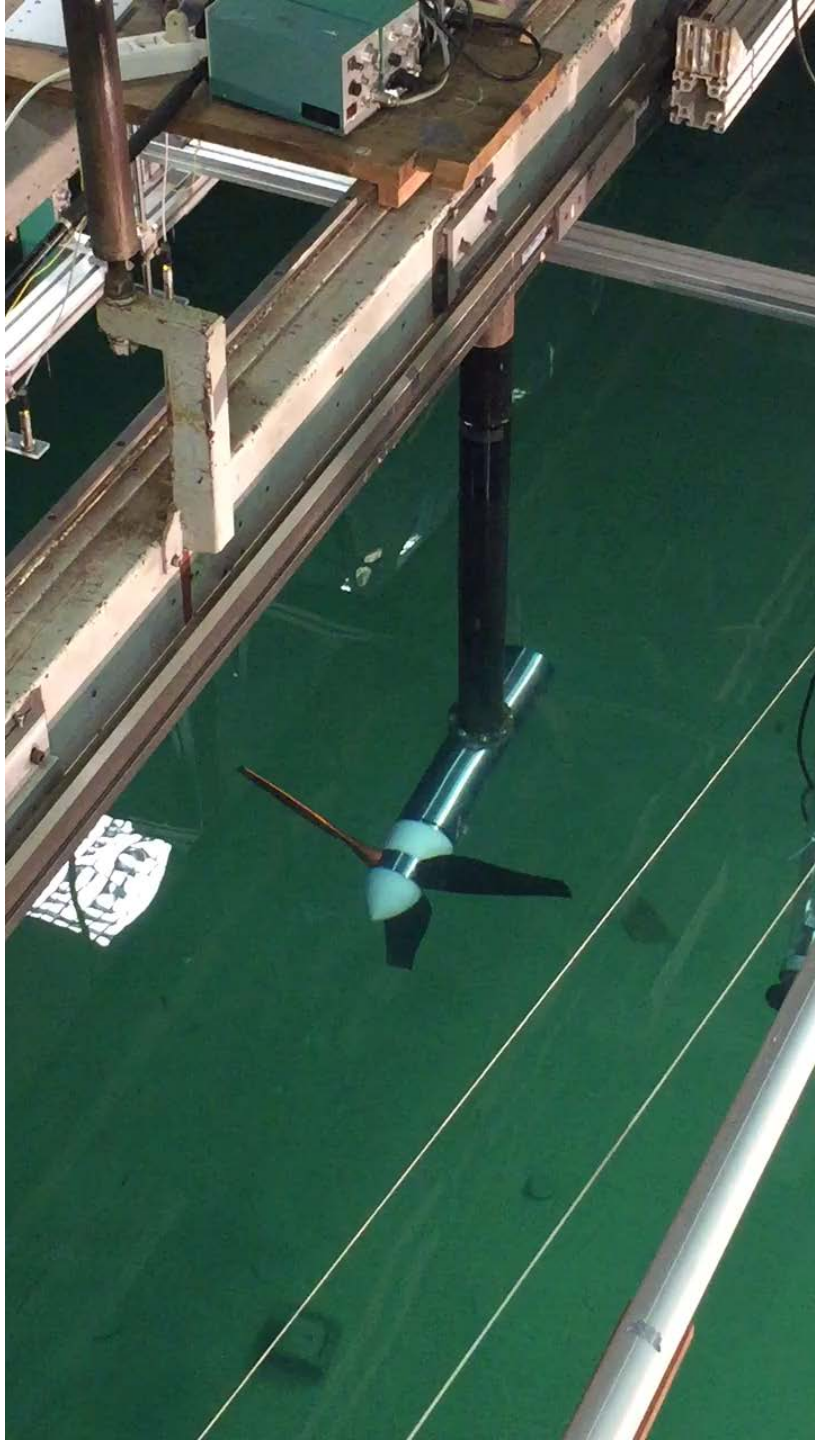




Test video

- Tow only test
- Torque control

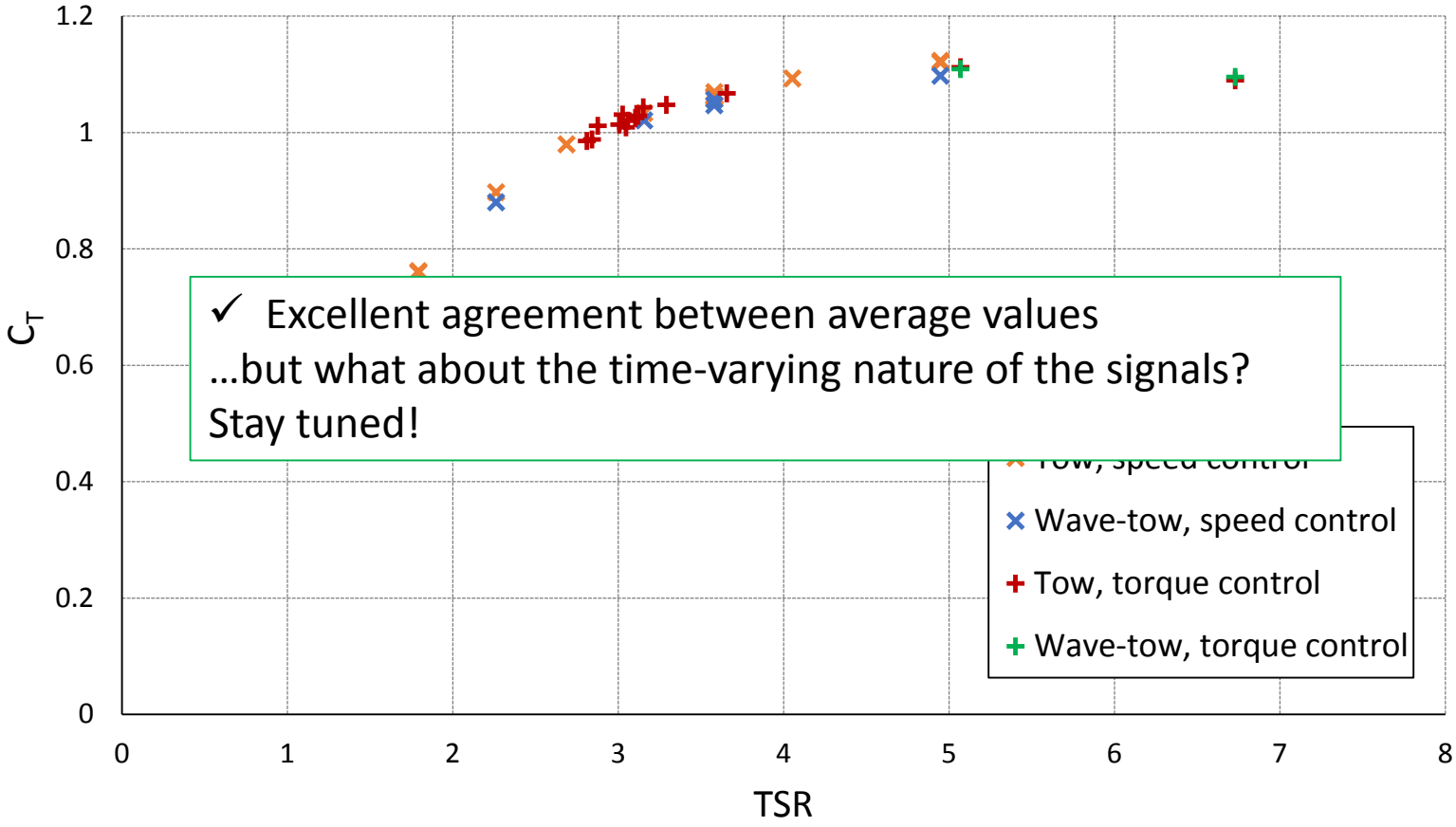
1. From stationary
2. Self starting
3. Freewheeling
4. Torque applied



Preliminary results

Averaged coefficient of rotor thrust:

- Tow versus wave-tow, speed versus torque control



DyLoTTA: next steps

- Expected outcomes in next 12 month period
  - Four abstracts will be submitted to the Asian Wave and Tidal Energy Conference, Taiwan, September 2018.
  - Journal paper will be prepared detailing the results from the first test campaign at INSEAN, November 2017.

- Future work in next 12 month period
  - Review turbine design and testing methodology
  - Finalise design and build of 2nd and 3rd turbines ready for array testing
  - Prepare for and conduct next experimental campaign, IFREMER, May 2018
  - Ongoing numerical model development, and field and laboratory data analysis

DyLoTTA: publications

- Allmark et al., *An approach to the characterisation of the performance of a tidal stream turbine*, **Renewable Energy**, vol. 111, 2017, pp 849-860.

- Allmark et al., *Detection of tidal stream turbine rotor imbalance faults for turbulent flow conditions and optimal λ control,* **EWTEC 2017, Cork.**

- Ordonez-Sanchez et al., *Numerical modelling techniques to predict rotor imbalance problems in tidal stream turbines,* **EWTEC 2017, Cork.**

Thank you. Any questions?

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