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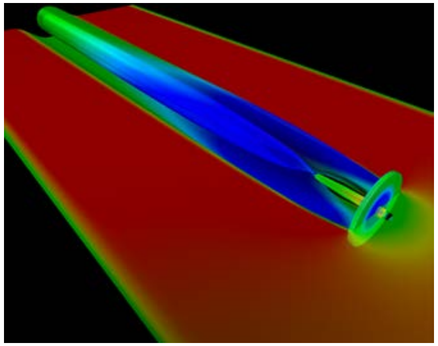

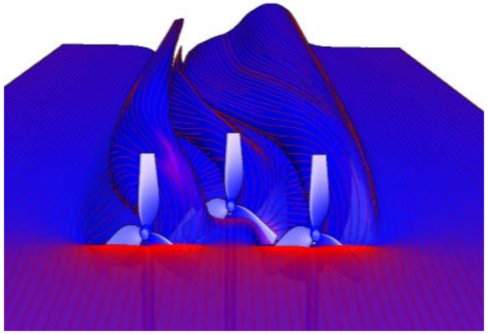

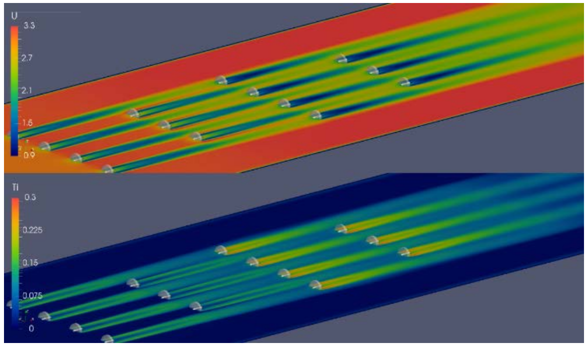

WP4 – Array Interaction

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WP4 – Array interaction

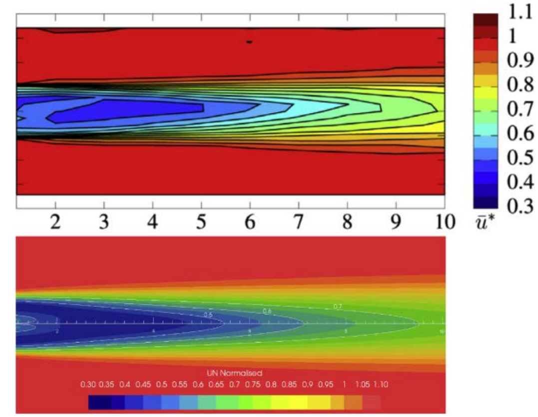
- Investigate impact of wave-current flow interactions on tidal arrays
- Development and verification of tools
  - Generalized actuator disk (GAD)-CFD
    - Swansea
  - Unsteady wave coupled BEMT (UWC-BEMT)
    - Strathclyde
- Inform spatial planning of arrays in dynamic tidal flows to maximise energy yield

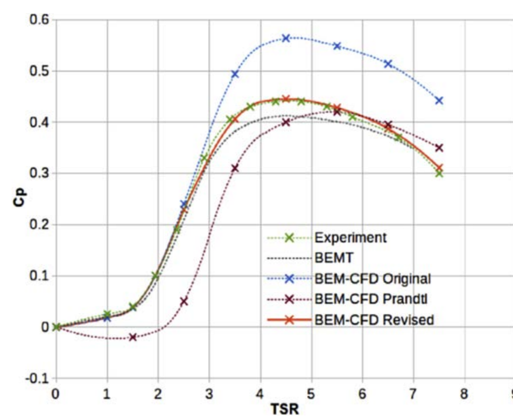
Tasks

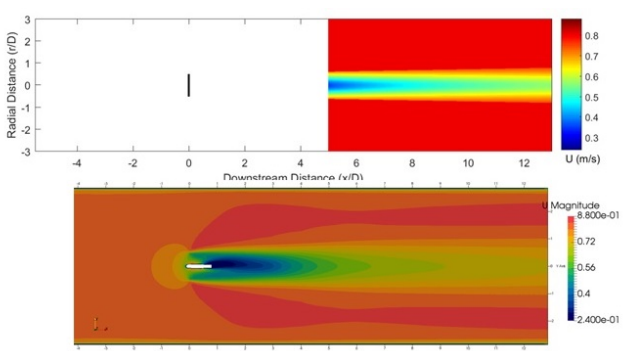
- Bench marking, calibration and verification of models
- Investigate how unsteady tidal flows propagate through tidal array field
  - UWC-BEMT and GAD-CFD
- Apply models to small arrays in realistic sea conditions
  - Inner Sound, Ramsey Sound, Fair Head
- Determine appropriate array configurations for different technology types
  - Bed mounted, mid water column, surface floating

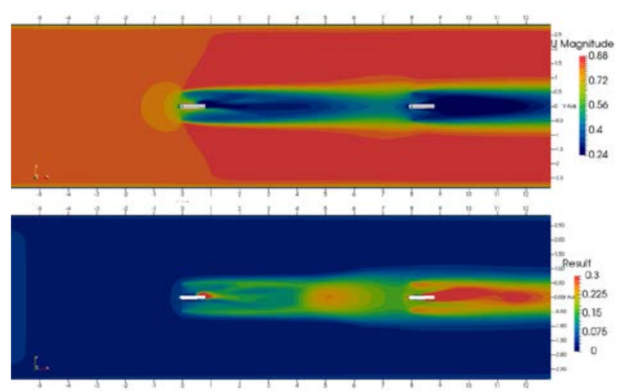
Calibration of GAD-CFD

- Validated[1] against Mycek et al[2] papers
  - Single and dual rotors
- Collaboration with Jim VanZwieten[3], Florida Atlantic University
- Results show sensitivity to turbulence intensity and dissipation rate









[1] Edmunds et al, Renewable Energy, 2017
[2] Mycek et al, Renewable Energy, 2014
[3] Masters et al, ECCOMAS Marine, 2017

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Calibration of GAD-CFD

- Working with Edinburgh as part of completion of Supergen 3+
- Validate/calibrate model using experimental results from FloWave tests
  - Single rotor
  - Three rotor array
- Aiming to include some measurements of turbulence intensity to calibrate the base model

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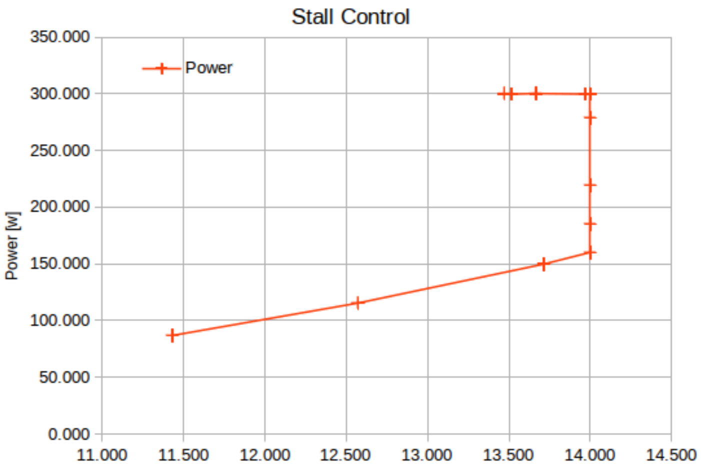
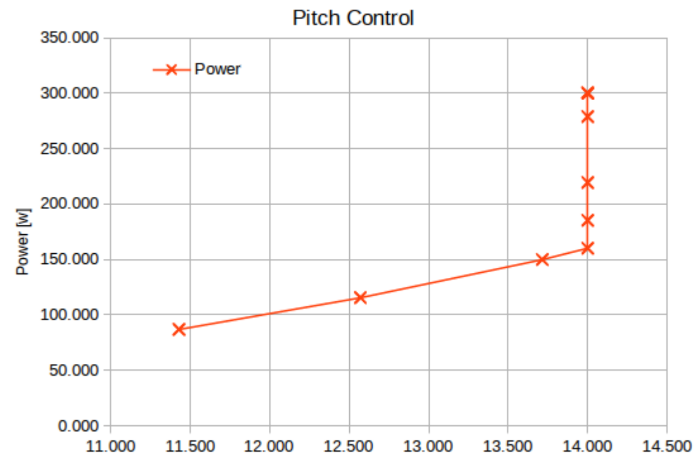
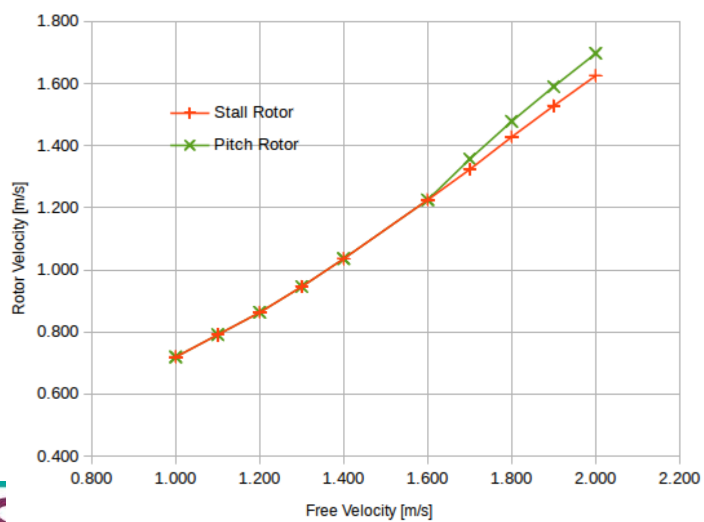
Rotor control

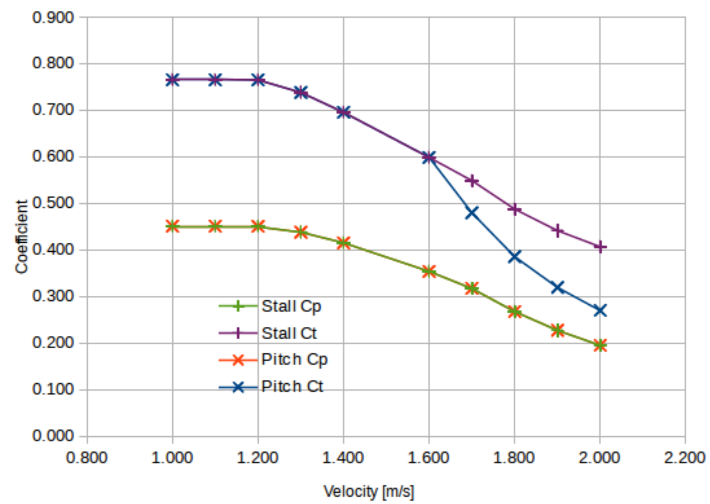
- Stall and pitch controlled GAD-CFD model developed
  - Allow insight into site wide loading dynamics
  - Provide understanding about downstream wake dynamics when power limiting
  - Understand potential site wide optimisations to improve power yield
- Results presented at EWTEC, Aug 17
  - Edmunds et al, Power shedding from stall and pitch controlled tidal stream turbines

Stall and pitch control algorithms



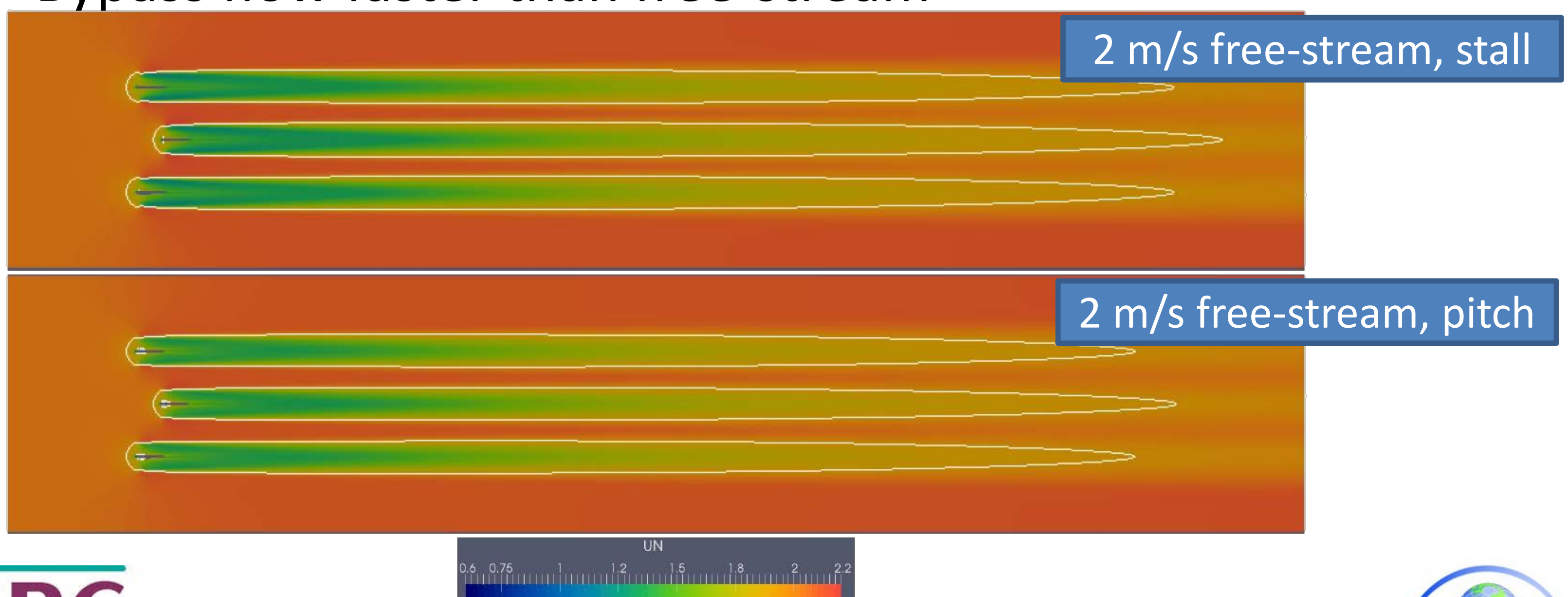






Comparison of stall and pitch control

- Higher average disk averaged velocity for pitch control
  - Faster wake recovery
- Centre rotor starts limiting before the outer rotors
  - Bypass flow faster than free-stream



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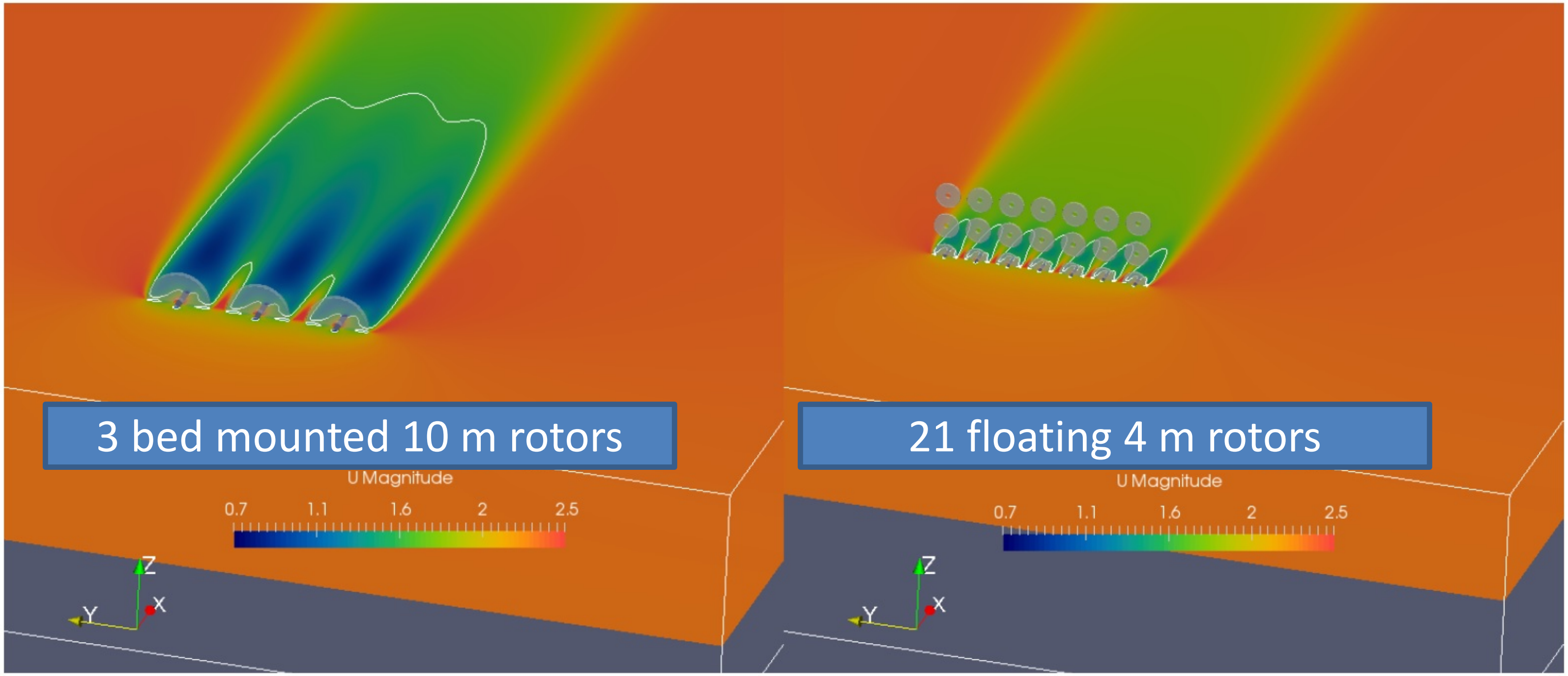
Comparison of different technologies

- 3 turbine array
  - 10 m rotors
  - Bed mounted
- 21 turbine array
  - 4 m rotors
  - Floating in upper water column



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Effect of inlet flow profile

- 3 inlet velocity profiles tested
  - Plug flow 2.41m/s
  - 1/7th power law inflow (2.41 m/s at sea level)
  - Flow profile from Ramsey Sound (averaging 2.41 m/s)

Case	Plug Flow		Power Law		Ramsey Sound	
	c_p	Power (kW)	c_p	Power (kW)	c_p	Power (kW)
3 x 10 m	0.433	713.4	0.425	461.6	0.404	650.4
21 x 4 m	0.405	746.3	0.399	624.6	0.395	735.4

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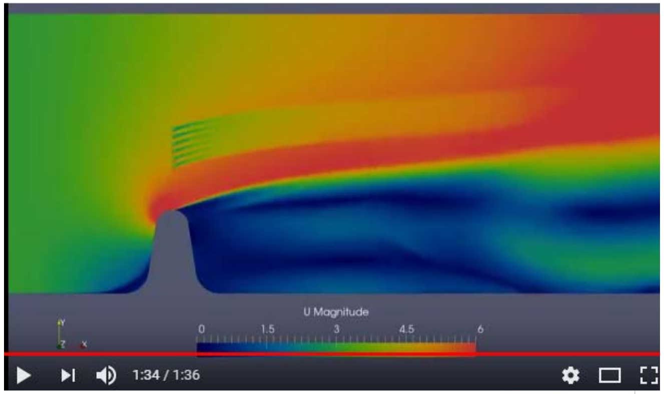
Unsteady GAD-CFD model

- Unsteady generalized Actuator Disk (GAD)-CFD Model has been implemented
- Example shows unsteady flow around headland
  - 6 x 10m rotors
  - Domain – 2km x 1km x 30m (constant depth)
  - Real time – 2 hours
  - Simulation time approx 50 hours
- https://youtu.be/otoMAsSyfnE



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Next steps

- To validate GAD-CFD array model using FloWave experimental data
- To develop actuator line model
- To build and test array models using realistic sea conditions

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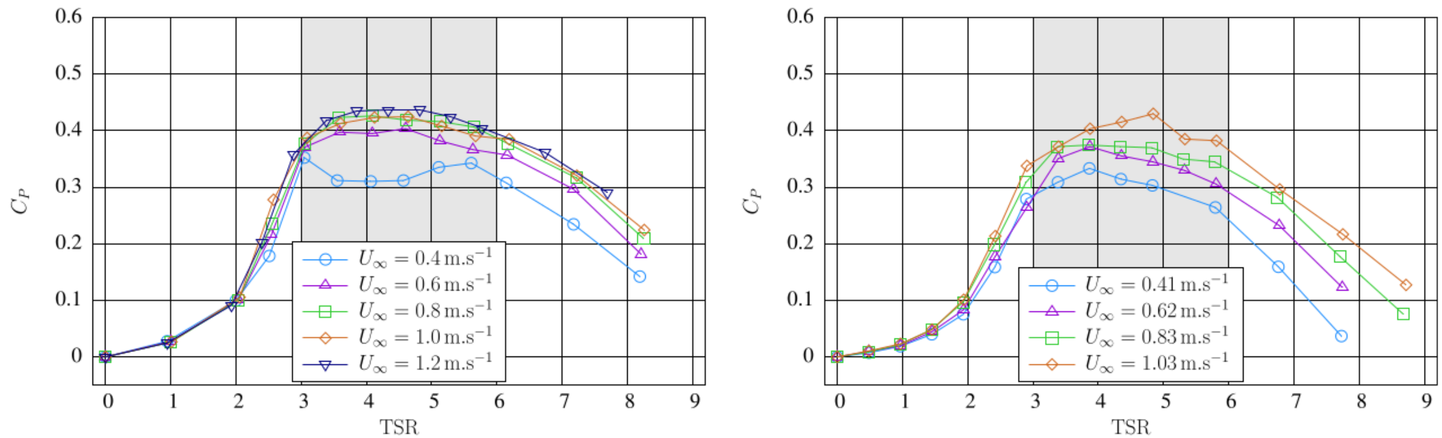
Next steps

- Validate low and high turbulence cases.
- But lift and drag characteristics change with turbulence.



(a) $I_\infty = 3\%$ (b) $I_\infty = 15\%$

Fig. 6. Evaluation of the power coefficient C_P function of the TSR, for $I_\infty = 3\%$ (left) and $I_\infty = 15\%$ (right).

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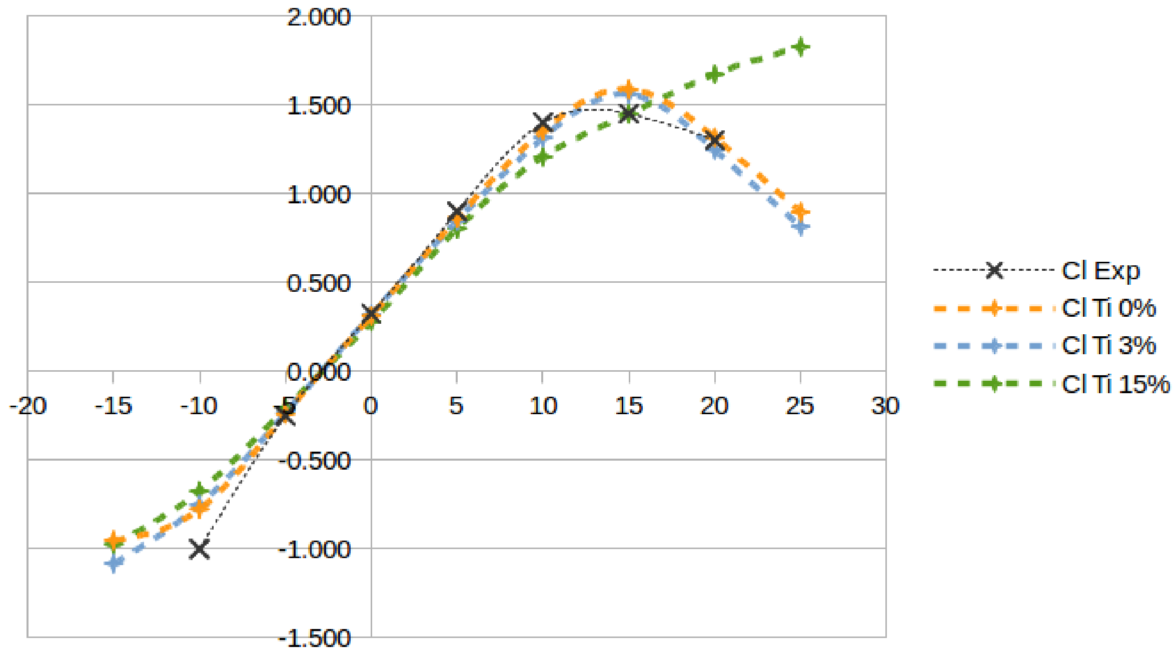
Next steps

- This can be done by using lift and drag input data obtained at the correct turbulence level.
- Initial results for this are looking promising.



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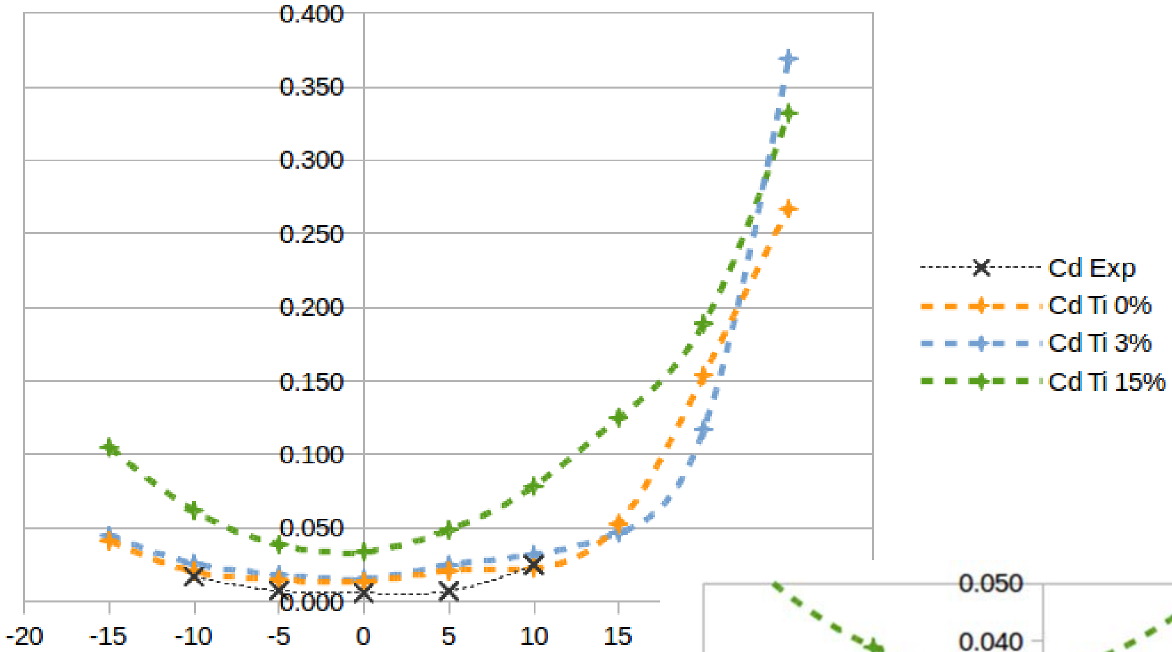
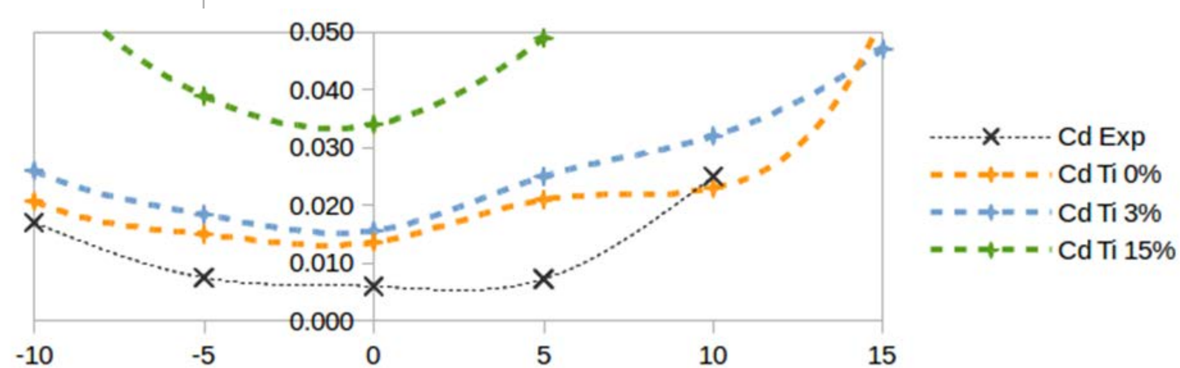
Next steps





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