From the Wind to the Tide

Using Wind Turbine Vortex Generators to enhance Tidal Turbine performance

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The original project:
From the Wind to the Tide

Engineering and Physical Sciences Research Council

Using Wind Turbine **Vortex Generators** to enhance **Tidal Turbine** Performance

EPSRC Impact Acceleration Account

Supported by Supergen Offshore Renewable Energy

Swansea University Prifysgol Abertawe

Cardiff University Prifysgol Caerdydd

SUSTAINABLE MARINE™

CATAPULT Offshore Renewable Energy

The spin-out project:
Bio-fouling effects on Tidal Turbines

hefcw

Modelling **biofouling** effects on tidal turbine blades with and without **Vortex Generators**

Higher Education Funding Council for Wales – HEFCW

Swansea University
Prifysgol Abertawe

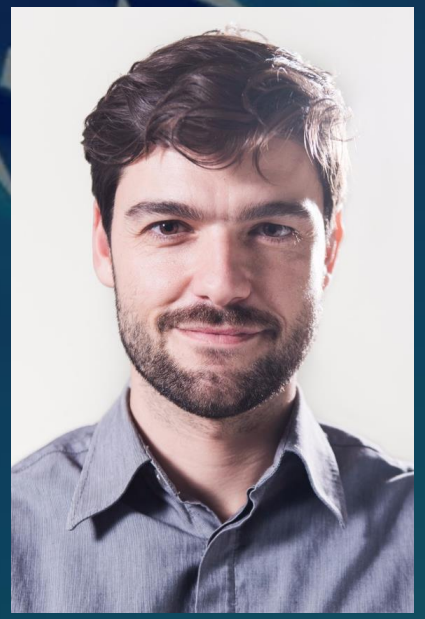
SUSTAINABLE MARINE™

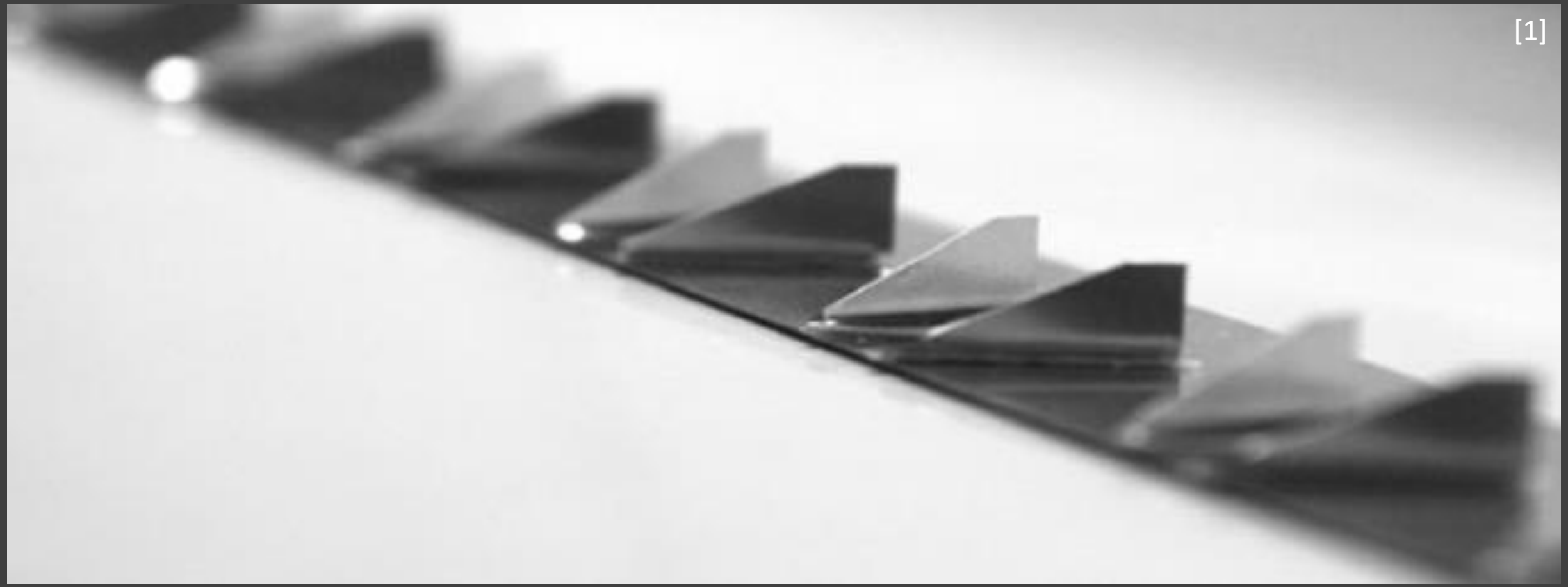
PML | Applications Ltd







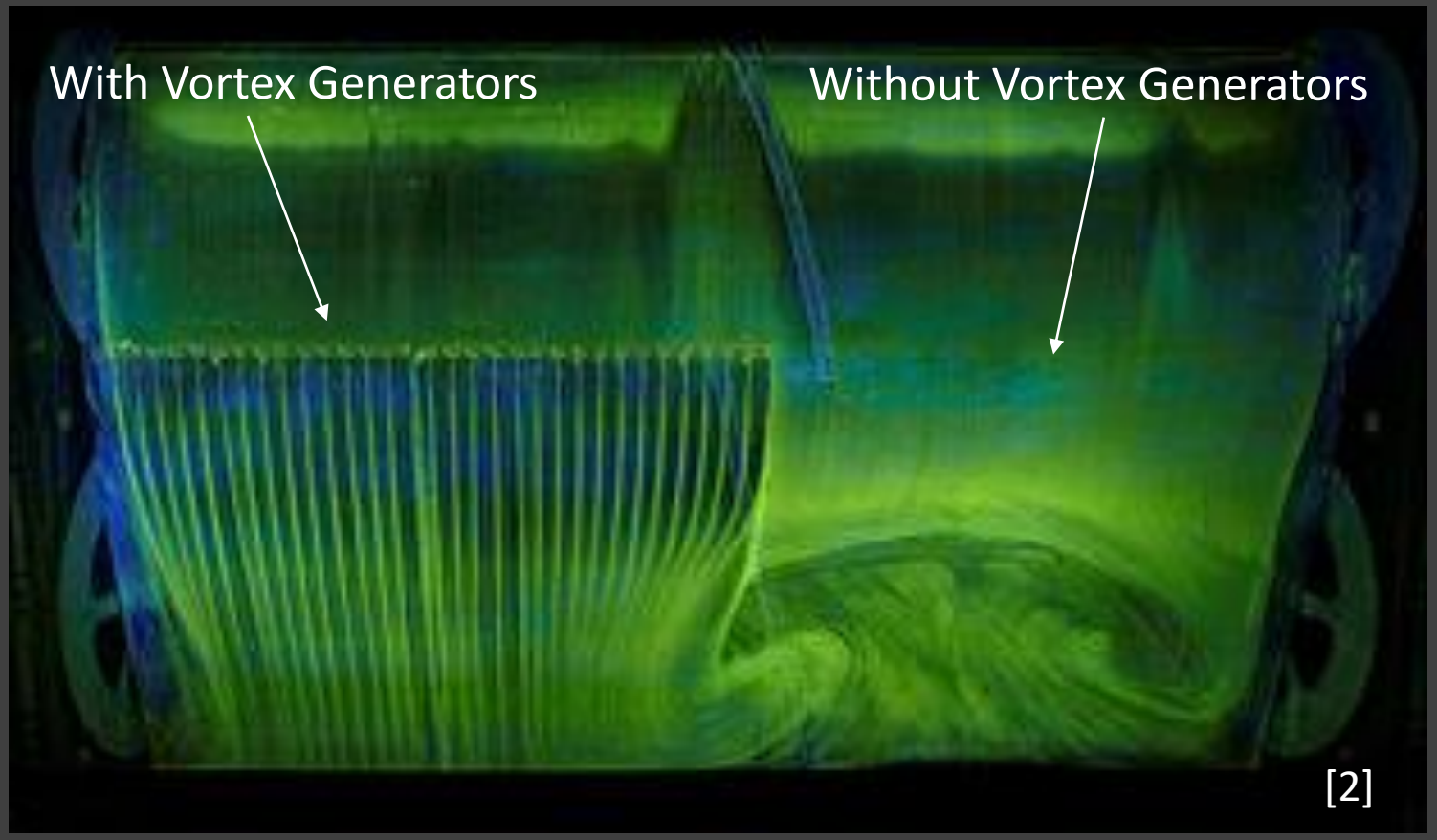




[1]

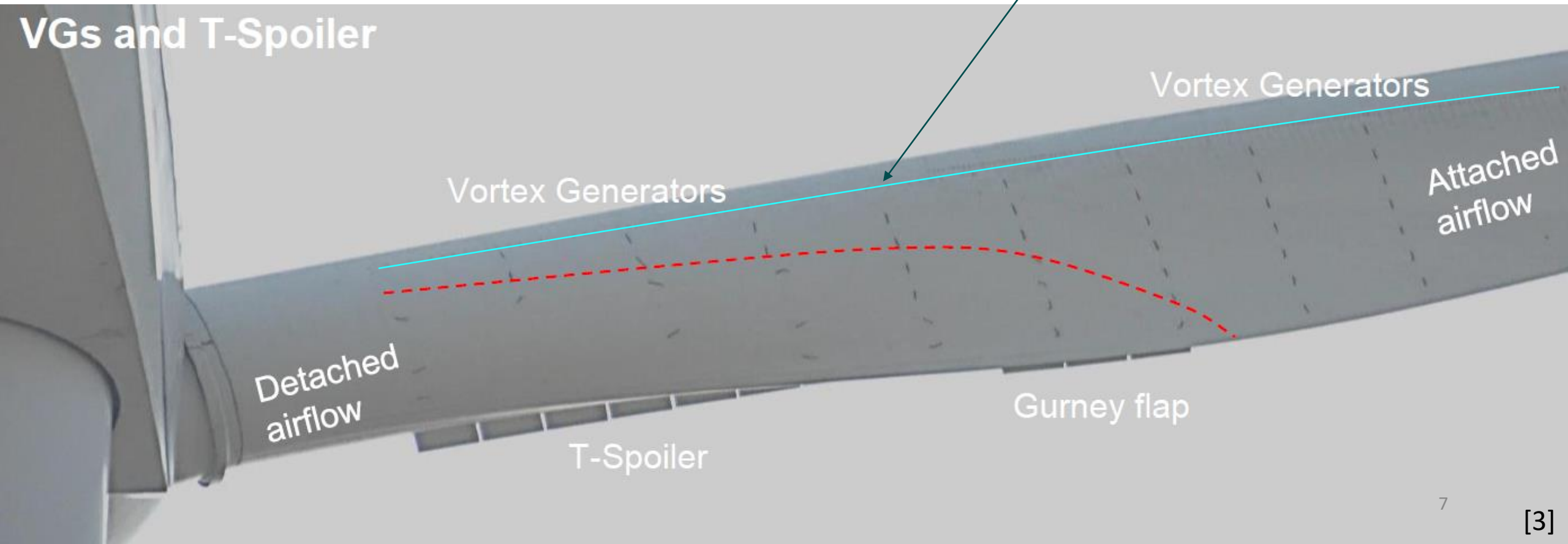
Vortex Generators

Small Vanes protruding from the blade surface
that generate streamwise vortices
to energize the local Boundary Layer and delay flow separation

How they work on an airfoil profile

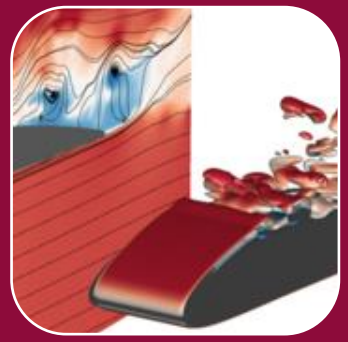


Example on Wind Turbine Blades



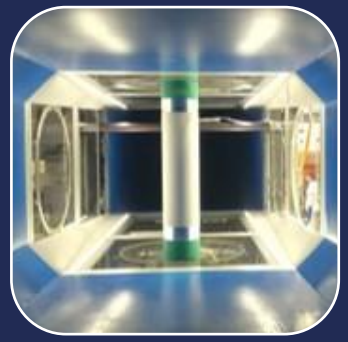
[3]

Proof of concept study – Scope

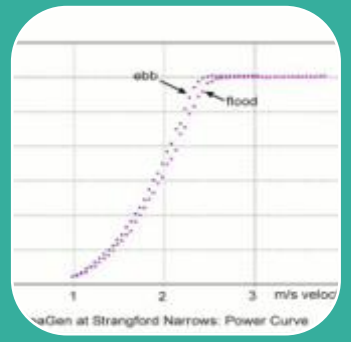


Hydrofoil CFD

[2D]

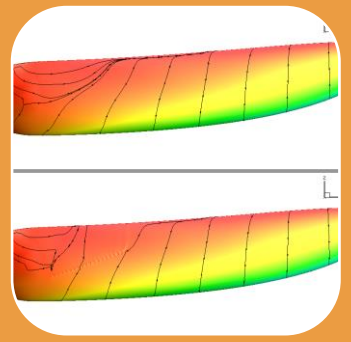


Wind Tunnel Testing



Performance Simulations

[BEM]

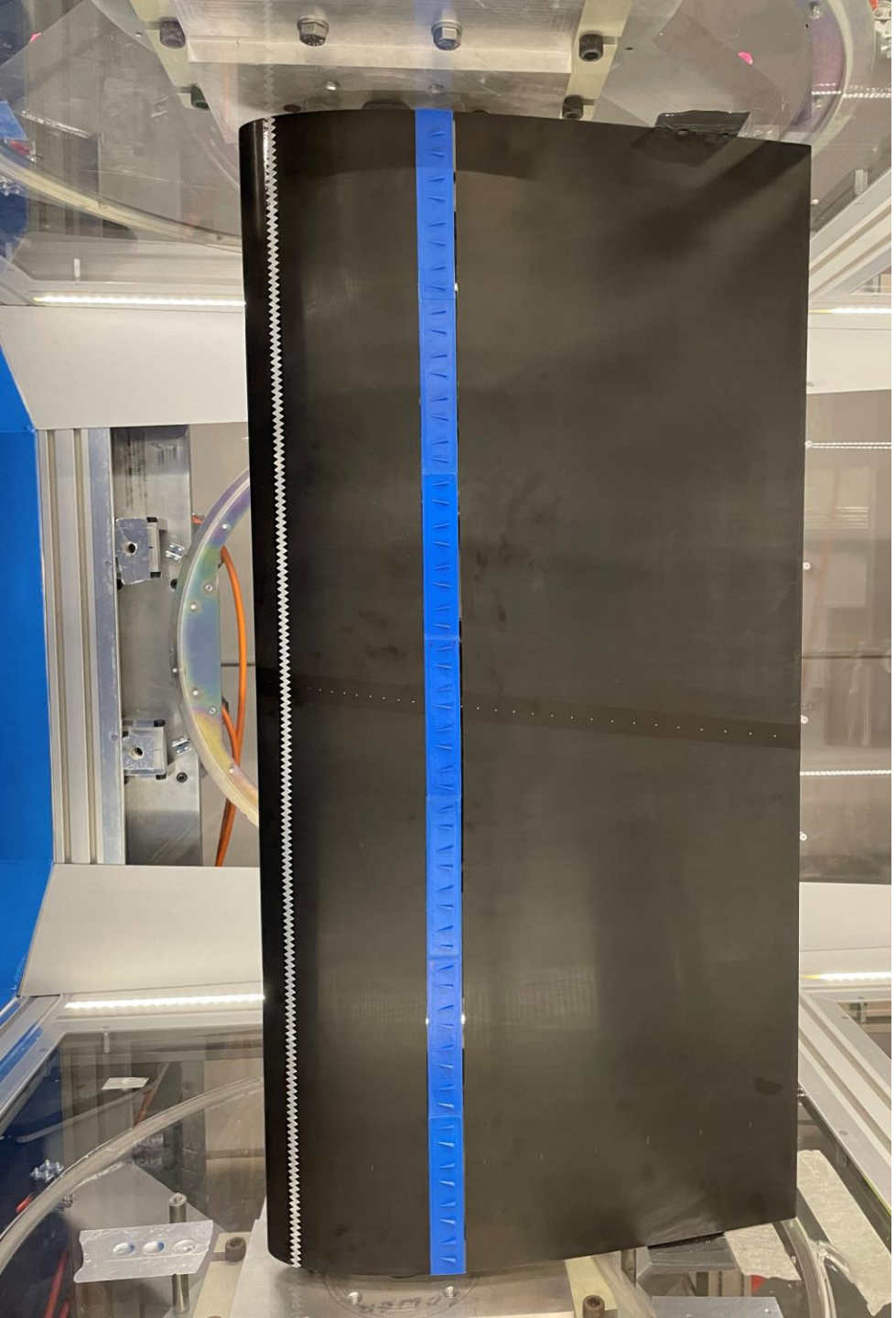


Blade Resolved CFD

[3D]

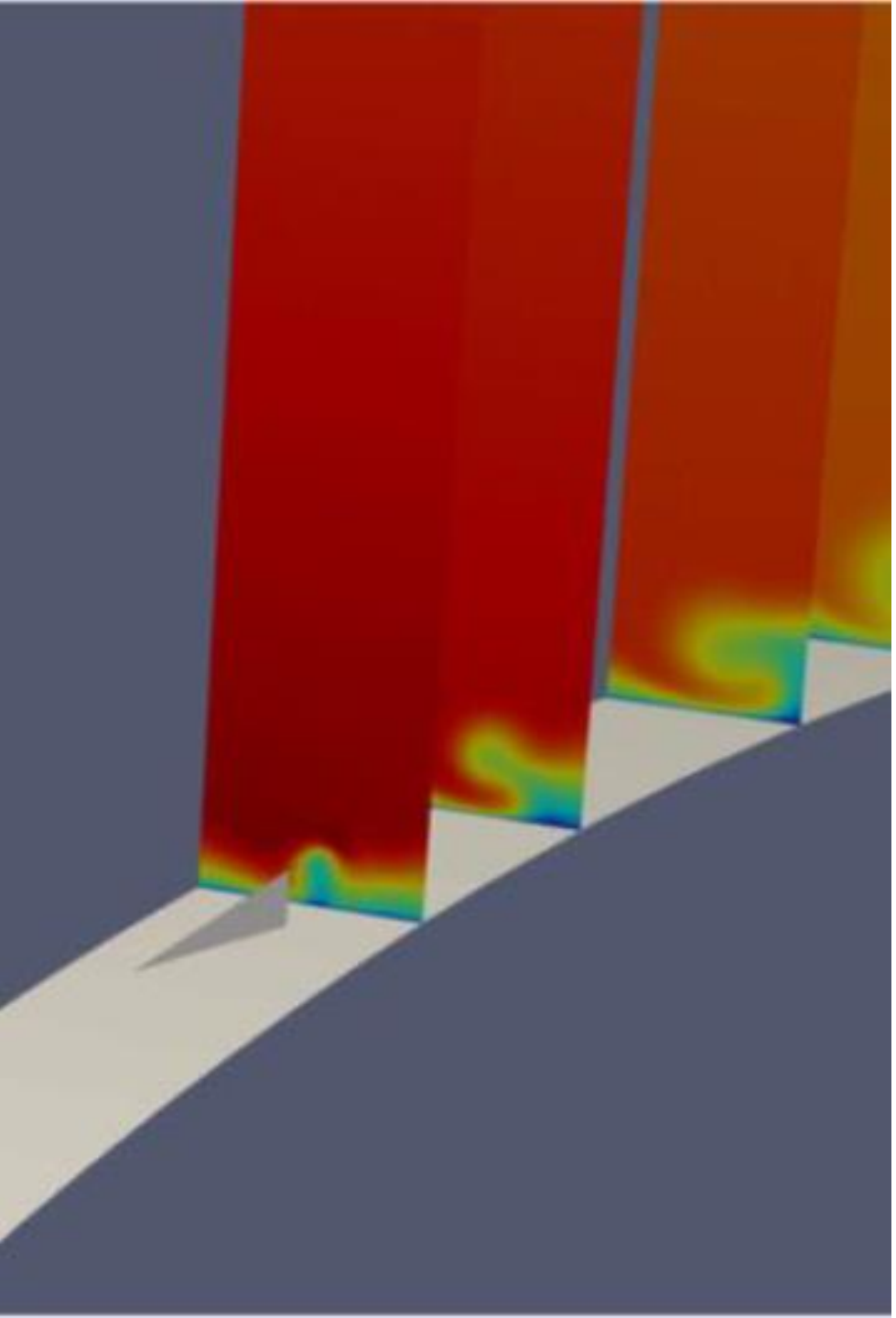
The Case

- 2D CFD on the 20% and 30% thick blade profiles
- Wind Tunnel testing on the 20% thick blade profile
- 3D CFD on the 0.5m Diameter scaled model of the SCHOTTEL HYDRO SIT250 turbine
- 85kW rotor power



Wind Tunnel set up

- Experiments at realistic Reynolds number
  - $0.5 \cdot 10^6 \leq Re \leq 1.5 \cdot 10^6$
- Force, Pressure, Stereo PIV measurements
- Free and Fixed transition
- 3D printed Vortex Generators

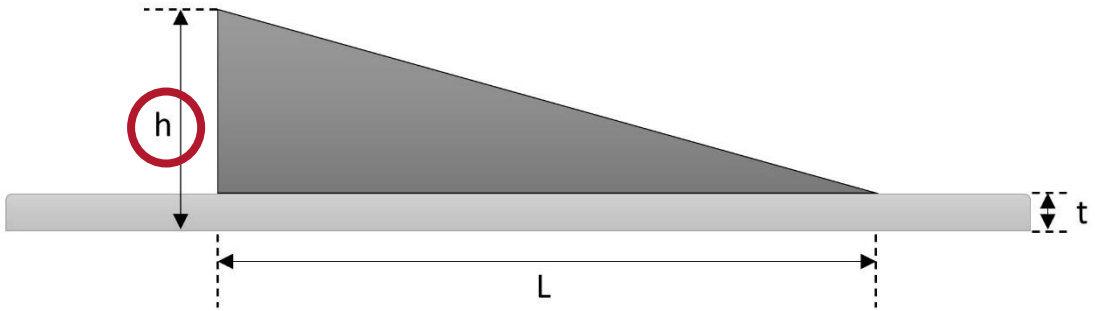


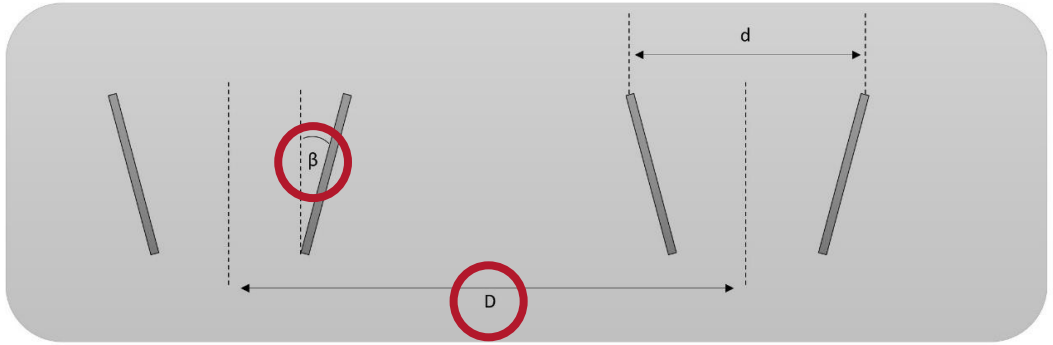
Numerical set up

- MaPFlow Unsteady RANS Solver
- BAY model for Vortex Generator modelling
- Small AR simulations for the hydrofoil
- Full Size blade simulations

Results

Parametric Study – 20% thick profile



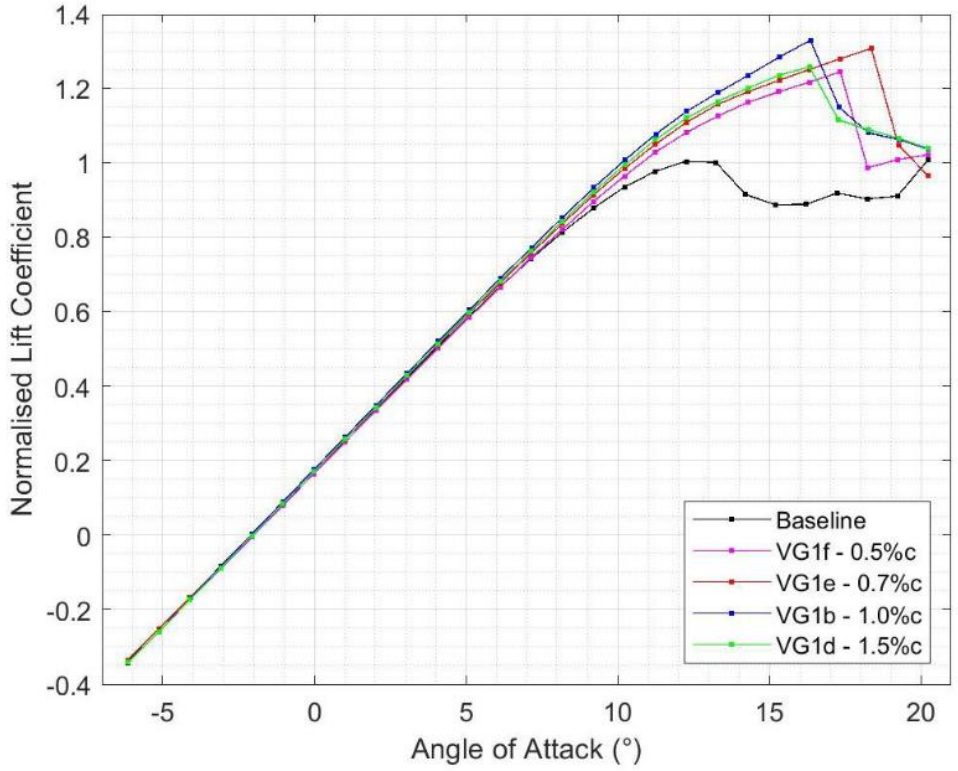


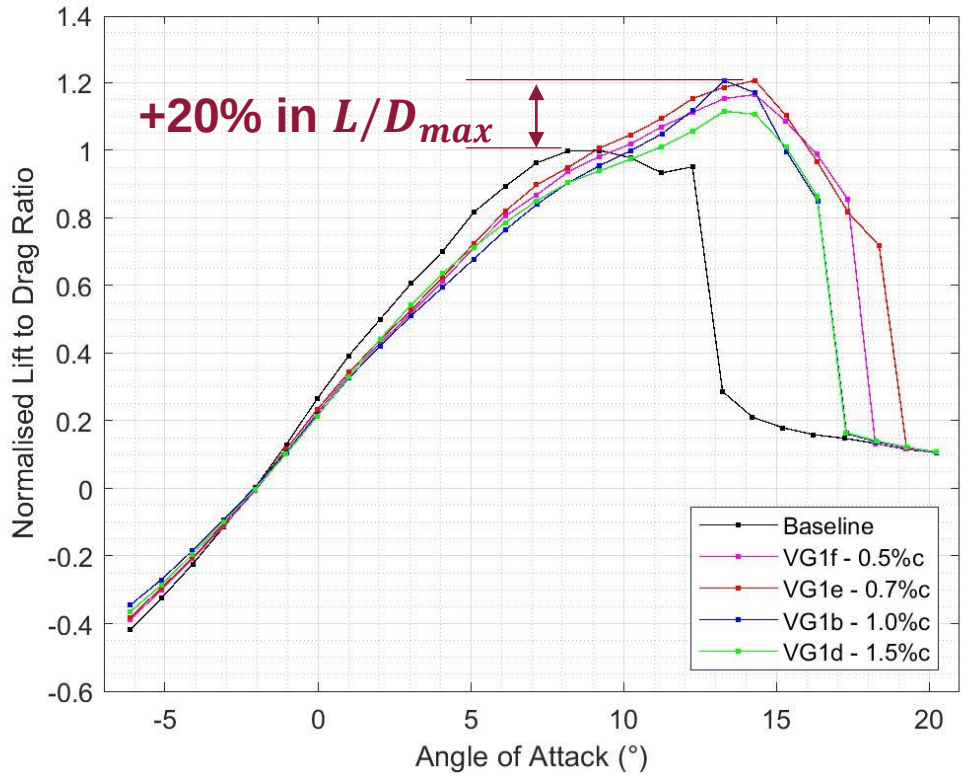
h, Vortex Generator Height
β, Vortex Generator Angle
D, Distance between VG pairs

Results

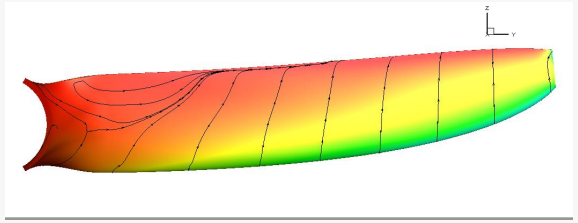
$h = 0.7\%c$
$\beta = 15°$
$D = 7h$

Parametric Study – 20% thick profile – Wind Tunnel results

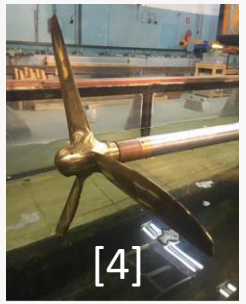




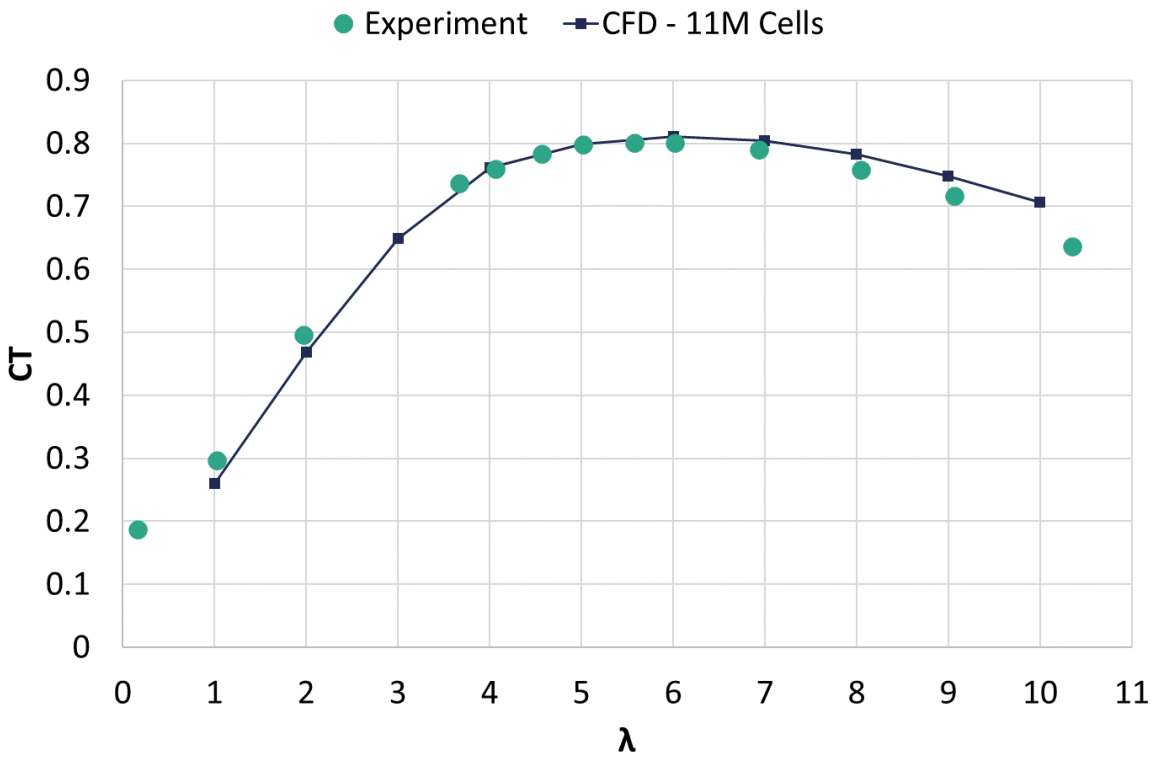
Results

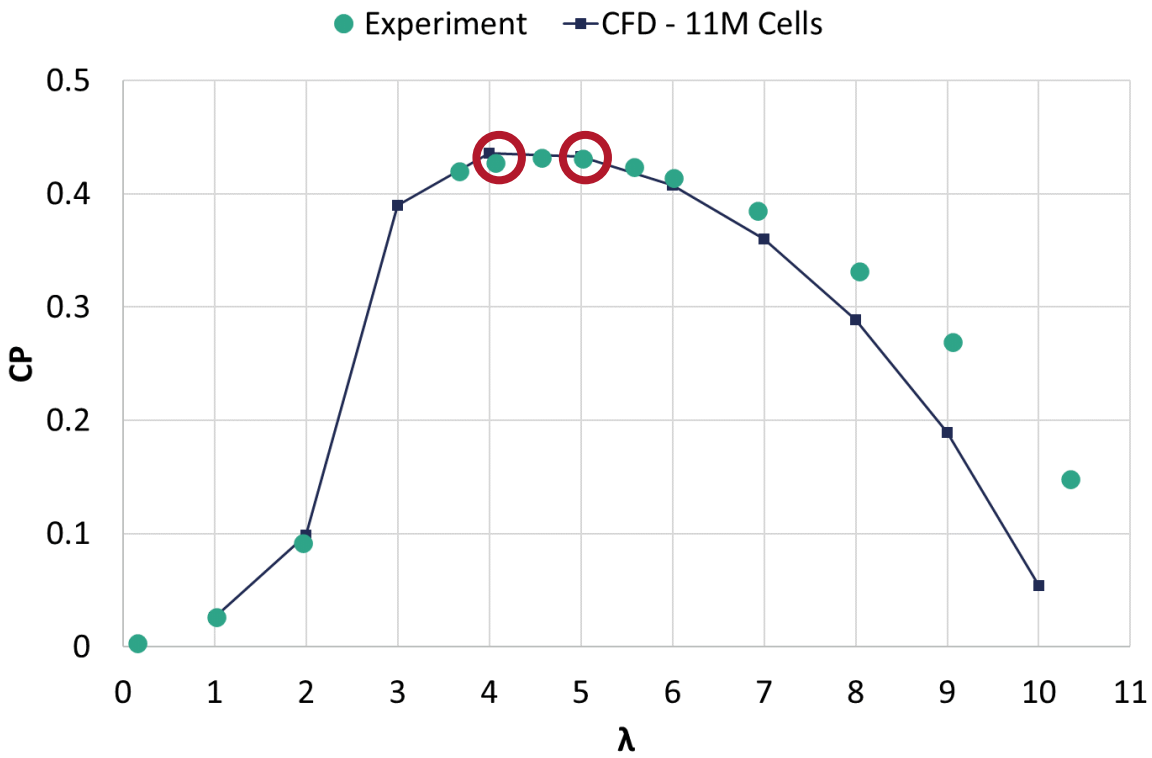


vs.



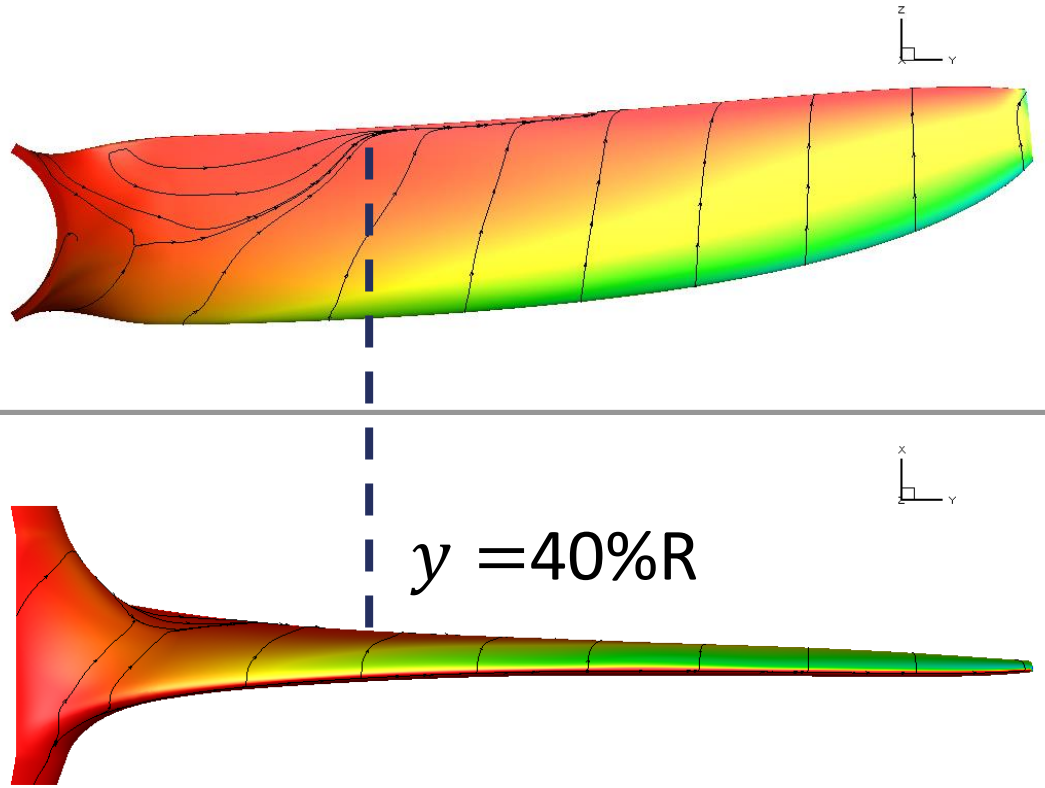
Validation of **3D blade simulations**



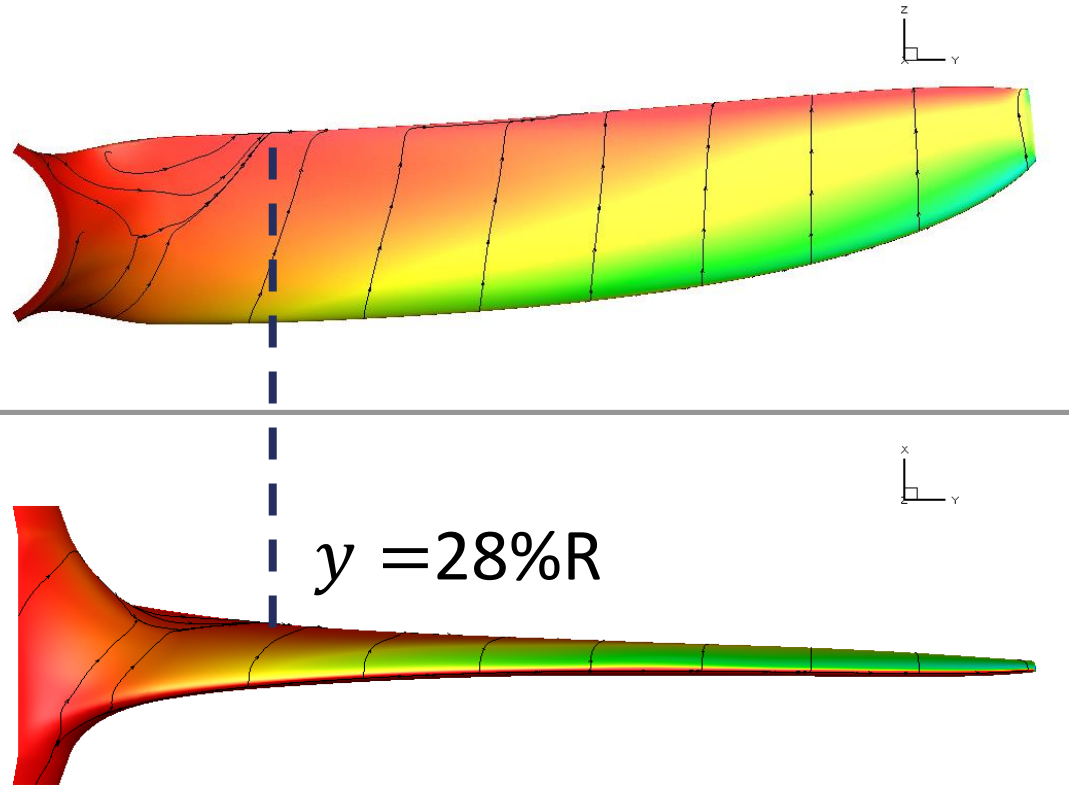


Results – Baseline

$\lambda = 4$



$\lambda = 5$



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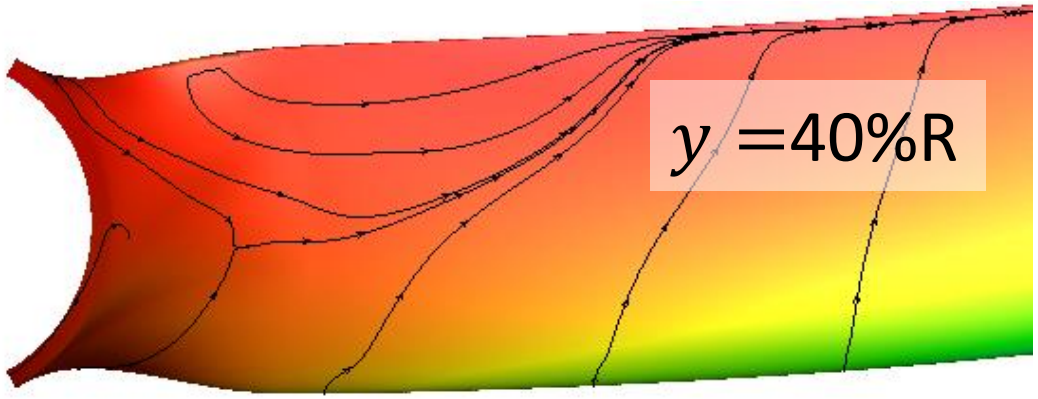

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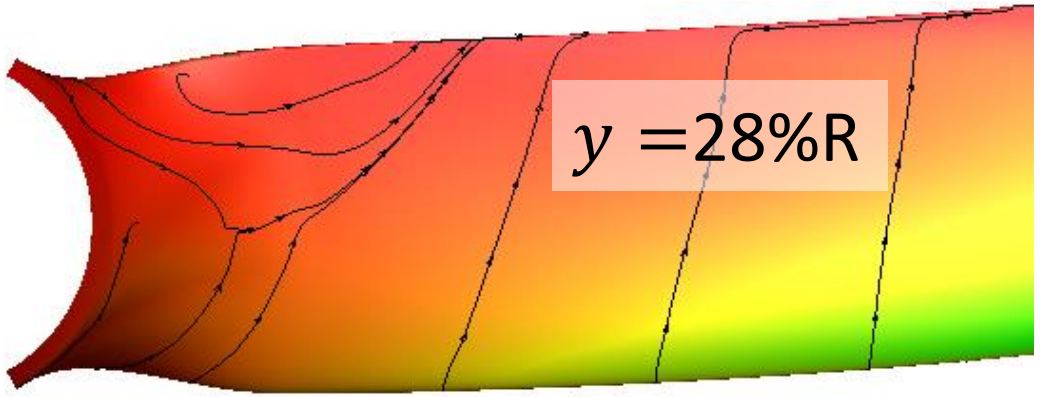
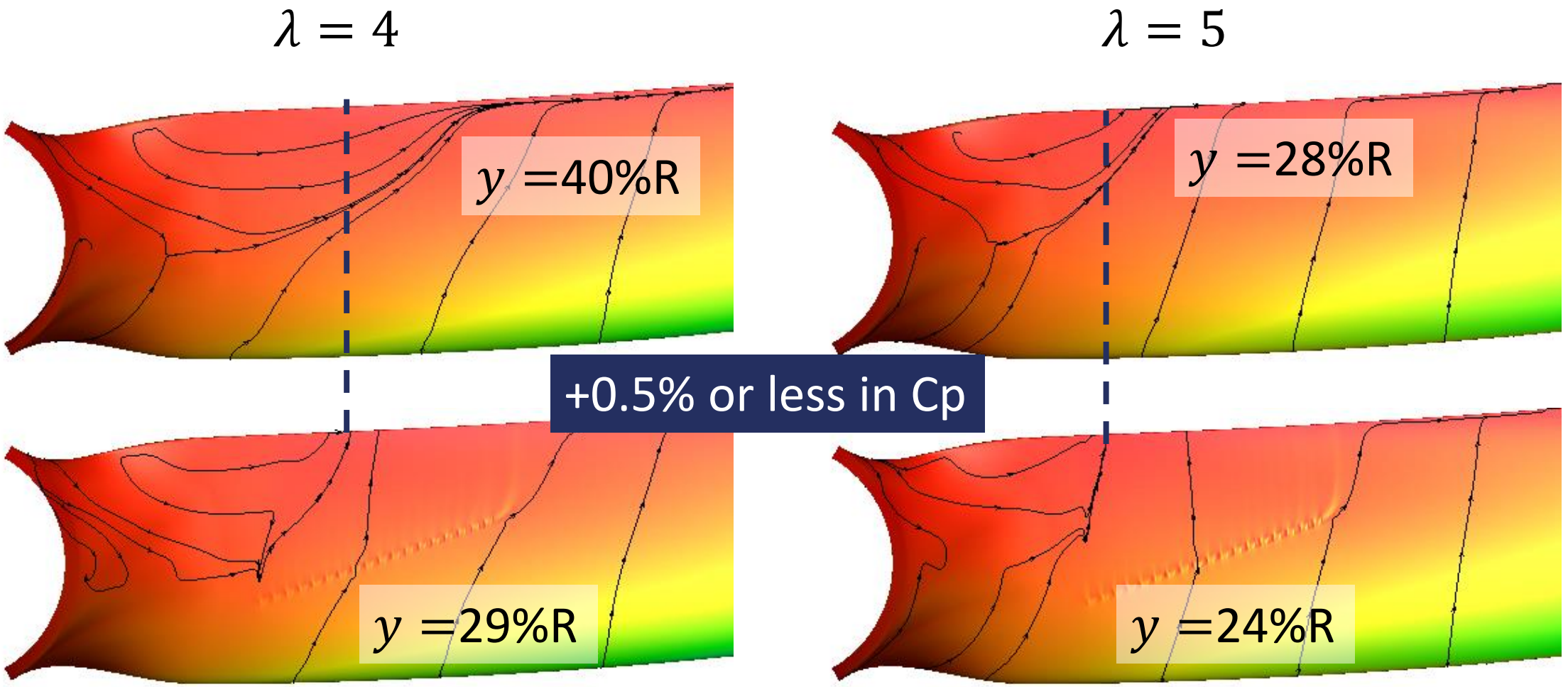
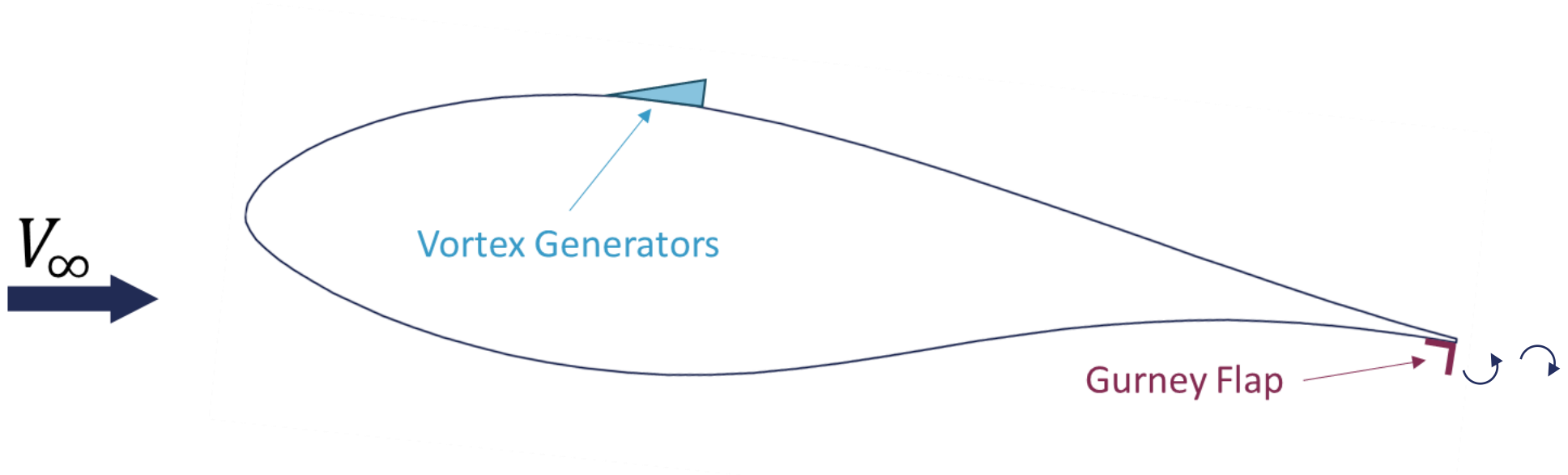


Results – Vortex Generator Effect



Bonus – What about VGs + Gurney Flaps?



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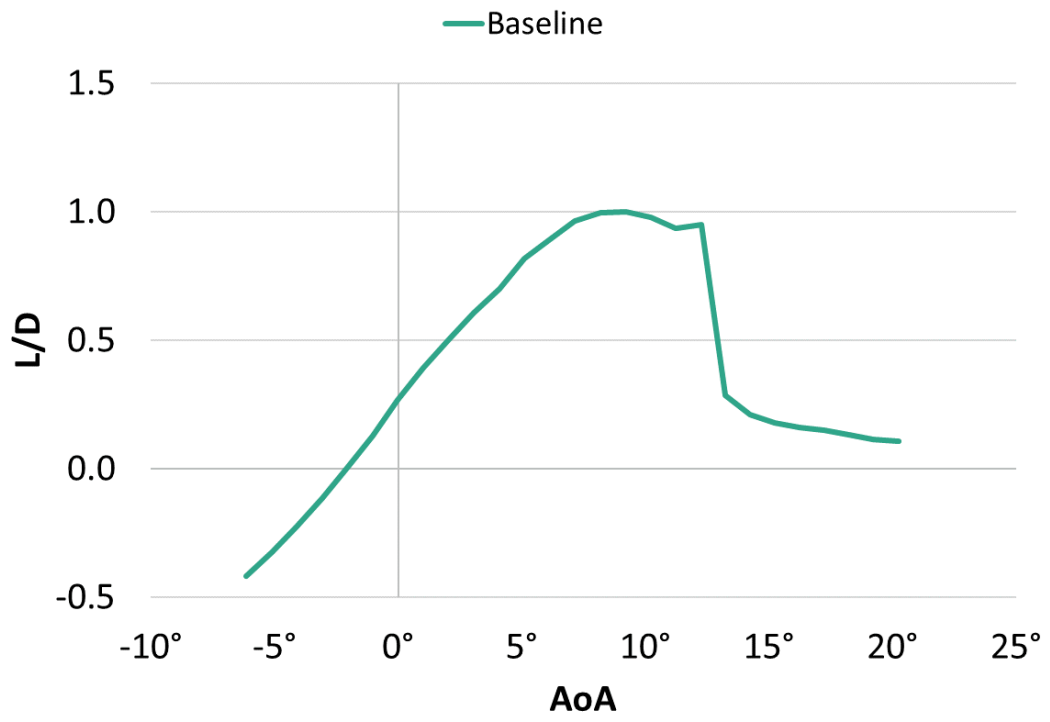

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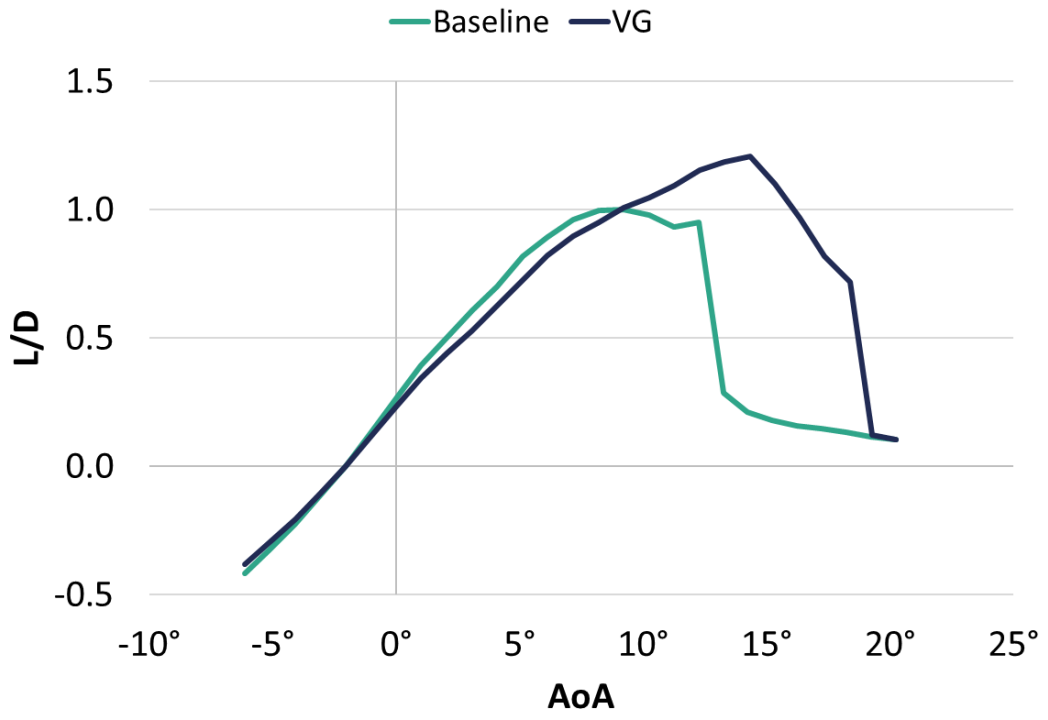

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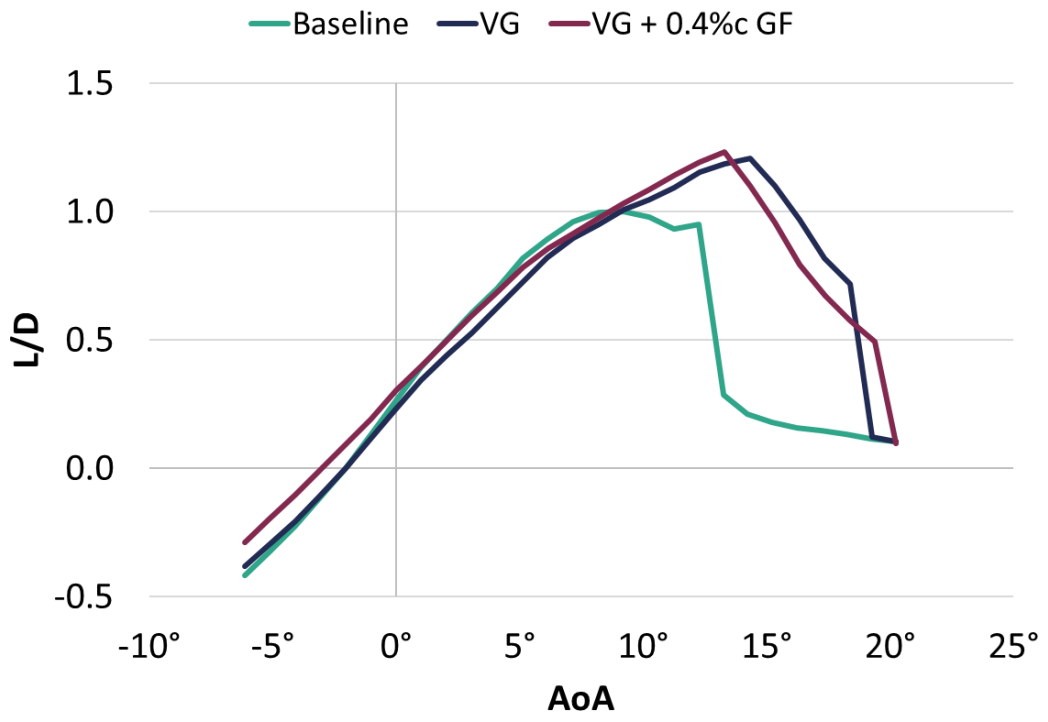
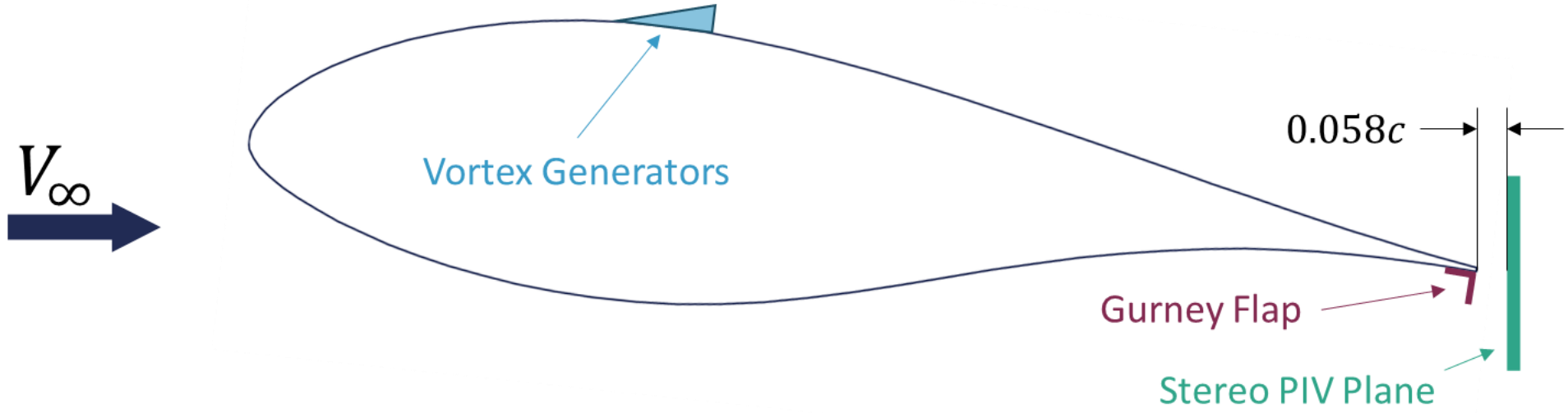


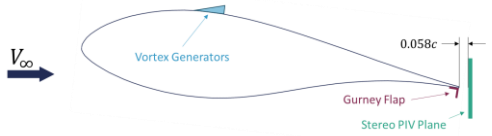
Combination of VGs + GF

- 20% increase in maximum L/D
- Lift increase due to the GF at low AoA counteracts the drag increase due to the two devices
- Could lead to new blade designs

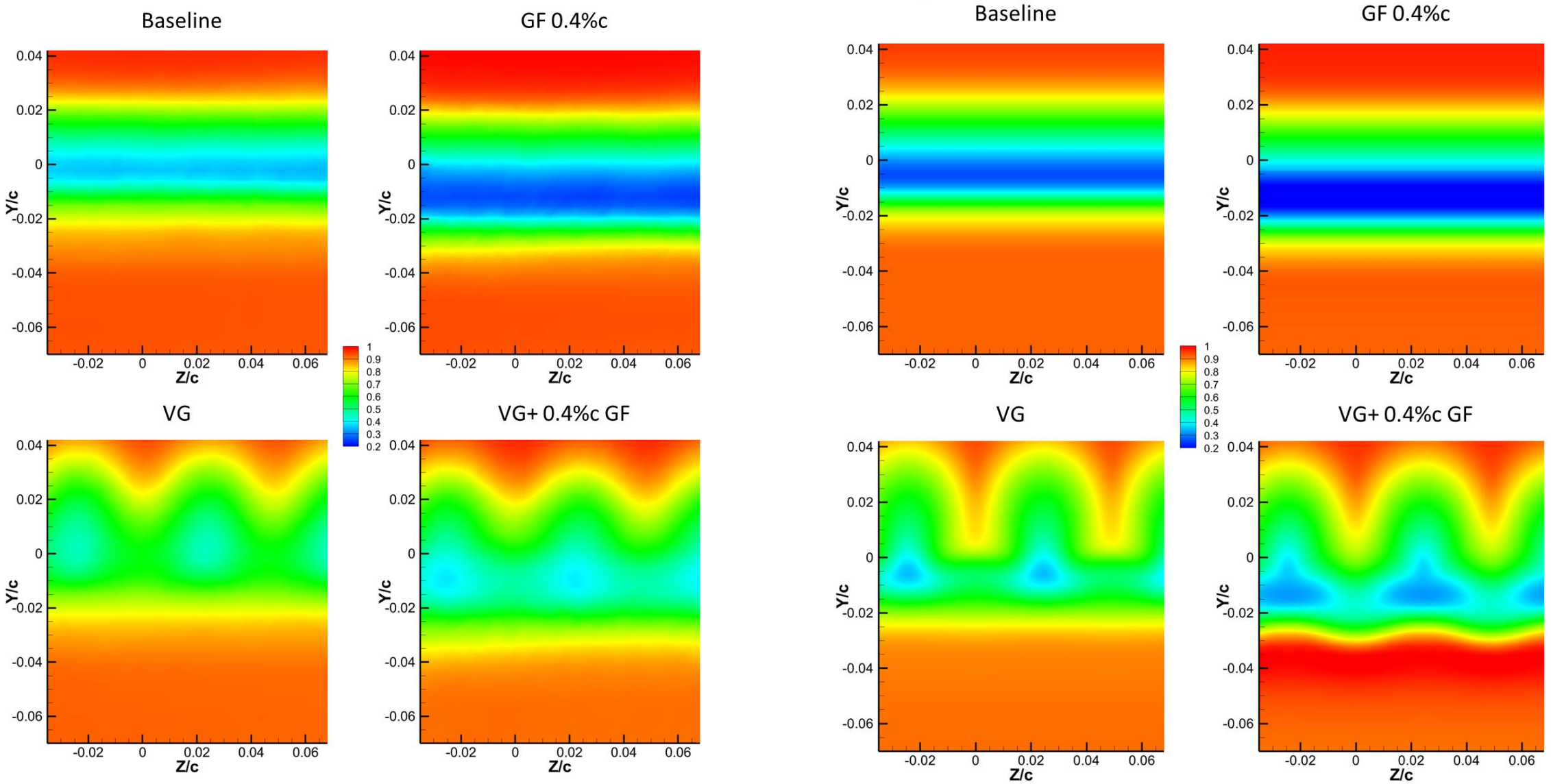
Bonus – What about VGs + Gurney Flaps?



Experiment



CFD



Conclusions

- Vortex Generators work on tidal turbine hydrofoils and blades
- 3D blade resolved CFD shows the effectiveness of vortex generators on reducing separated flow
- 20% increase in L/D max and 0.5% increase in Power
- Higher gains if Vortex Generator placement is optimised
- Vortex Generators and Gurney Flaps like each other!

Outputs

- 1x Spin-out project
- 2x MSc theses (Swansea, Cranfield)
- 2x Student placements
  (Sustainable Marine, Cardiff)
- 3x Conference Presentations
  (EWTEC 2021, TORQUE 2022, PRIMaRE 2022)
- 1x Journal Publication
  (at least)

References

1. Baldacchino, D., Ferreira, C., Tavernier, D. D., Timmer, W. A., & Van Bussel, G. J. W. (2018). Experimental parameter study for passive vortex generators on a 30% thick airfoil. Wind Energy, 21(9), 745-765, https://doi.org/10.1002/we.2191
2. Hansen, Martin Otto Laver, Clara Marika Velte, Stig Øye, R. Hansen, Niels N. Sørensen, J. Madsen, and R. Mikkelsen. "Aerodynamically shaped vortex generators." Wind Energy 19, no. 3 (2016): 563-567.
3. Performance and validation of BAY model on wind turbine airfoils, Arun Kumar, Jesper Madsen, Sudhakar Piragalathalwar, Kiran Kumar, VoxGen17, Delft, October 2017
4. Kaufmann, N., Carolus, T. H., & Starzmann, R. (2017). An enhanced and validated performance and cavitation prediction model for horizontal axis tidal turbines. International journal of marine energy, 19, 145-163.


Thank you
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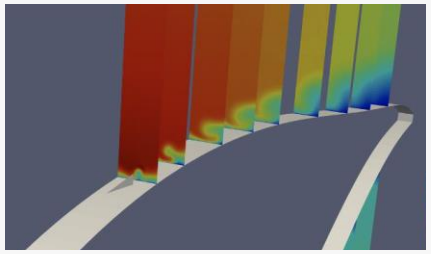
Additional Slides

Results



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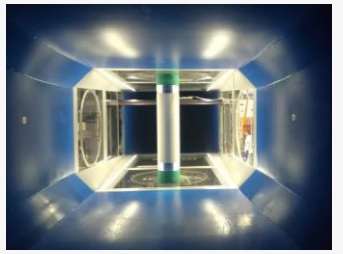
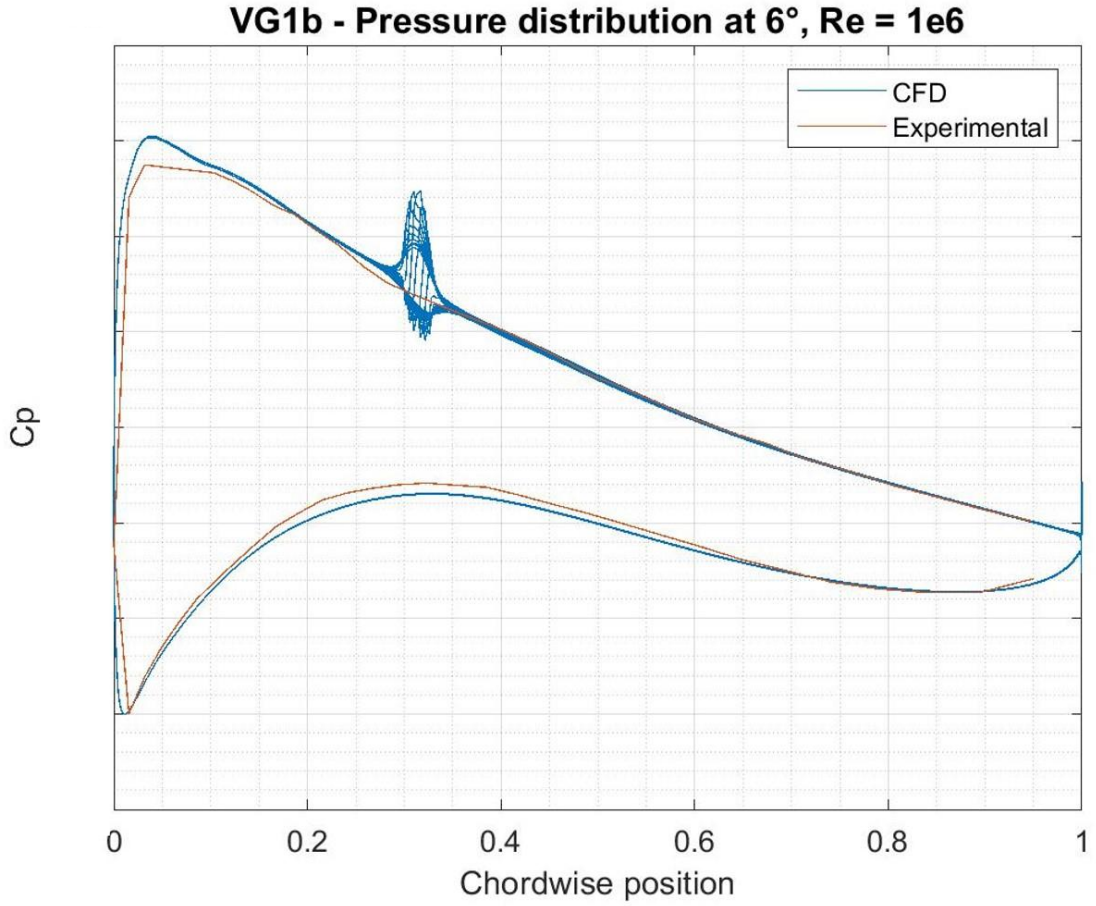
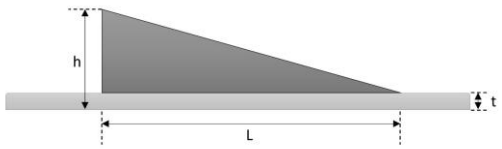


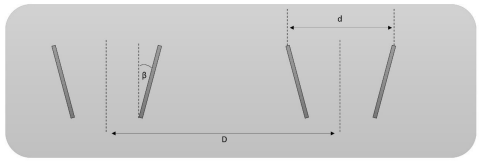
Validation of **2D VG simulations**



Results

Parametric Study – 20% thick profile – Wind Tunnel results





$h = 0.7\%c$

$\beta = 15°$

$D = 7h$

+20% in L/D_{max}