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Analysis of the performances of hydrokinetic cross-flow turbines with splitter plates

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Context

Cross-flow turbine

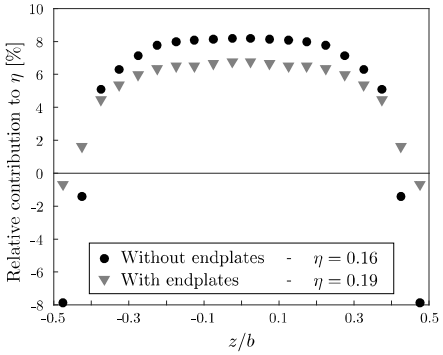
*Source: Windgenerator Antarktis, Hannes Grobe (AWI), 2007 / CC-BY-NC.

Typically, the end effects are found to be very detrimental to the efficiency (η) of a cross-flow turbine.

In order to limit this negative effect, endplates can be added at the tip of the turbines' blades.

Important parameters:
- b/c: blade aspect ratio,
- σ: solidity,
- λ: tip speed ratio,
- Re: Reynolds number.

Relative contribution of different sections of the blade in the span direction (z) to the efficiency.
($b/c = 7$, $\sigma = 0.2857$, $\lambda = 4.25$ and $Re_c = 2.5 \times 10^5$)



*Adapted from: Parametric study of H-Darrieus vertical-axis turbines using CFD simulations, Gosselin & al., 2016.

Observations:
- The endplates reduce the tip losses,
- However, they do not significantly increase the efficiency because of their **drag**,
- The drag of large endplates can even cancel out the energy extraction potential.

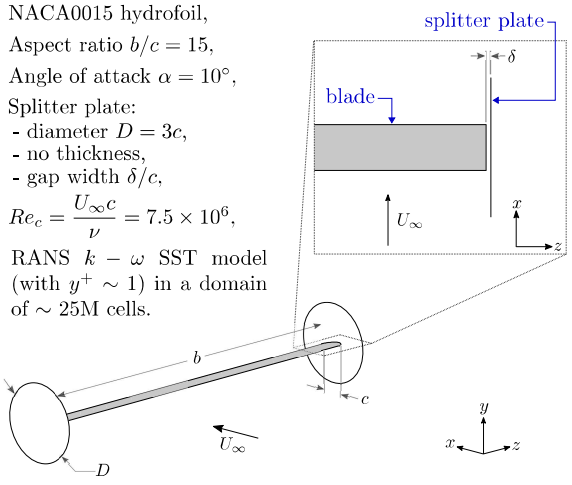
Possible alternative:
- Use fixed splitter plates which would be close enough so that the tip losses could be reduced without an added drag for the moving blades.

Main objectives of the study:
- Investigate the effect of splitter plates on the performances of a cross-flow turbine,
- Investigate the effect of the splitter plates on the wake of the turbine.

Simplified case: stationnary blade

In order to understand the physics in the small gap between the tip of a turbine's blade and a splitter plate, a simplified case which only consists of a single stationnary blade is first investigated.

Governing parameters:
- NACA0015 hydrofoil,
- Aspect ratio $b/c = 15$,
- Angle of attack $\alpha = 10°$,
- Splitter plate:
  - diameter $D = 3c$,
  - no thickness,
  - gap width δ/c,
- $Re_c = \dfrac{U_\infty c}{\nu} = 7.5 \times 10^6$,
- RANS $k-\omega$ SST model (with $y^+ \sim 1$) in a domain of $\sim$ 25M cells.

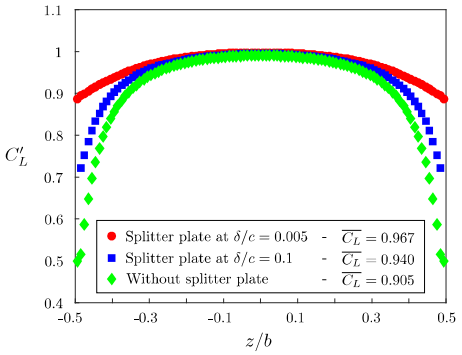


As the gap width (δ/c) is reduced, the lift coefficient of the blade ($\overline{C_L}$) increases.

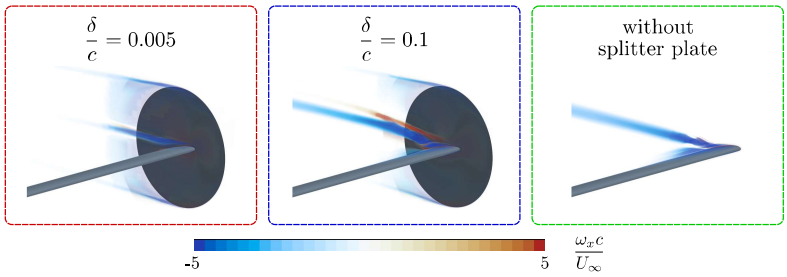
	$\dfrac{\overline{C_{L,3D}}}{\overline{C_{L,2D}}}$
Without splitter plate	0.855
With splitter plate ($\delta/c = 0.005$)	0.913

The splitter plate at $\delta/c = 0.005$ reduces the 3D effects by **40%**.

Lift coefficient distribution accross the span of the blade.

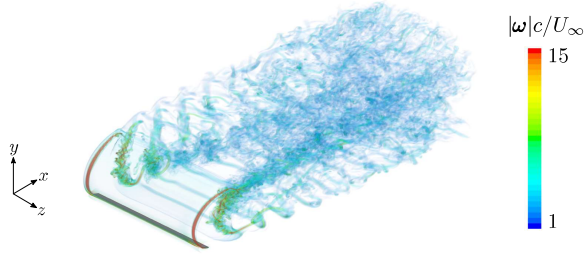


- The wing-tip vortex is deflected upward in the presence of the splitter plate and a counter-rotating vortex is created due to the interaction between the wing-tip vortex and the splitter plate.

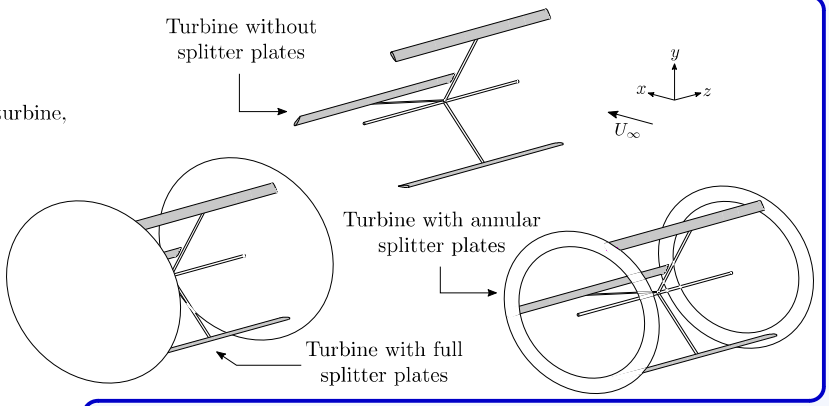


Real case: complete turbine

Next steps of the study:
- Analyze the effect of the gap width (δ/c) on the efficiency of a turbine,
- Analyze the effect of various shapes of splitter plates,
- Compare the wakes of turbines with or without splitter plates.



*Boudreau & Dumas, Vortex Dynamics in the Wake of Three Generic Types of Free-Stream Turbines, Proc. of ISROMAC 2016, Hawaii, USA.



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