INORE North American Symposium, 1-3 Nov. 2014, Halifax, Canada

UNIVERSITÉ LAVAL

Turning structure interference into improved power output for cross-flow hydrokinetic turbines

E. Gauthier, T. Kinsey, G. Dumas
Department of Mechanical Engineering, Laval University, Quebec City (Qc), Canada
Contact: etienne.gauthier.4@ulaval.ca

LMFN
www.lmfn.ulaval.ca

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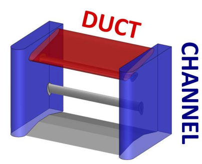
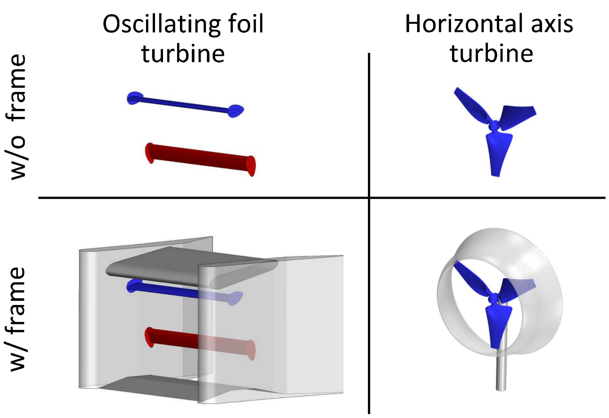
Context

The growing demand in energy coupled with the existing environmental concerns motivate the development of alternative power-generation systems using renewable energies. A novel prototype of hydrokinetic turbine based on oscillating hydrofoils (Hydrolienne à ailes oscillantes, a.k.a HAO) has been under development for several years at the Laboratoire de Mécanique des Fluides Numérique (LMFN) of Laval University.

In computational fluid dynamic (CFD), it is of common use to simulate hydrokinetic turbines with simplified geometries. However, if we want to study the impact of the frame structure on the turbine performance, a more complete representation of the turbine is needed. In this study, an optimization of the frame (Duct and channel) is made in order to increase the power extracted.





Methodology

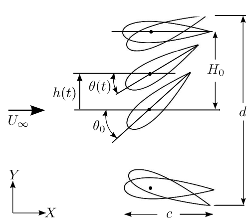
The hydrofoil motion is defined as a combination of a heaving and a pitching motion.

Pitching motion

$$\theta(t) = \theta_0 \sin(\omega t)$$

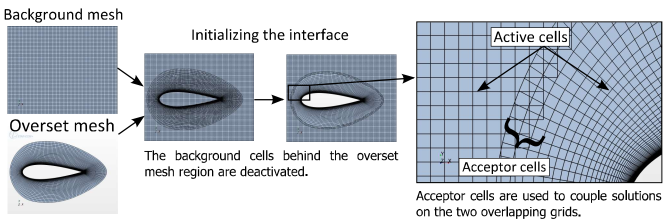
Heaving motion

$$h(t) = H_0 \sin(\omega t + \phi)$$



Hydrodynamic power = **Heaving velocity** × **Vertical hydrodynamic force** + **Pitching velocity** × **Moment at pitching axis**

3D URANS simulations are performed using CD-Adapco Star-CCM+ commercial code with overset mesh capabilities. The overset mesh approach, also known as chimera mesh technique, is an efficient tool to simulate multiple bodies in relative motions. This approach can be used to simulate complex motions with close proximity or intersecting paths.



Project website: http://www.hydrolienne.fsg.ulaval.ca/en

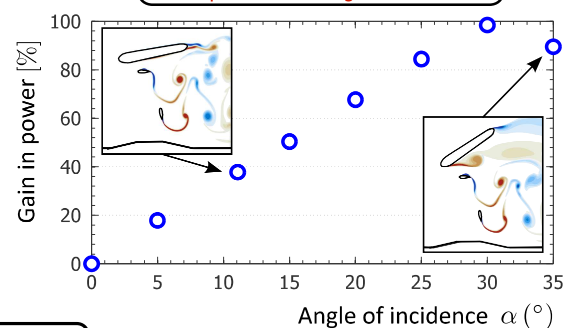
Financial support from the Natural Sciences and Engineering Research Council of Canada (NSERC), Les Fonds Québécois de la Recherche sur la Nature et les Technologie (FQRNT) and the Leadership and Sustainable Development Scholarships program of Laval University is gratefully acknowledged. Computations were made on the supercomputers Colosse at Laval University and Guillimin in Montreal, managed by CalculQuébec and Compute Canada.

Optimization of the frame

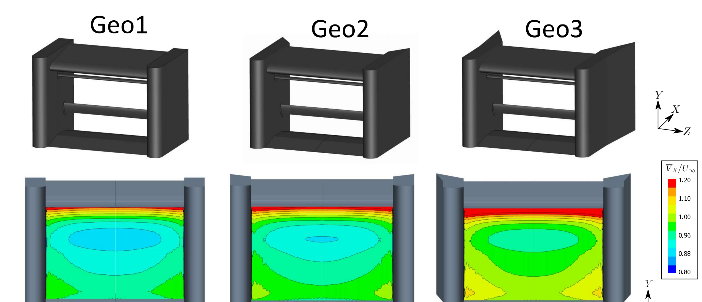
Increasing the angle of incidence tends to increase the mass flow through the turbine and thereby the power output until flow separation occurs on the duct.

Duct

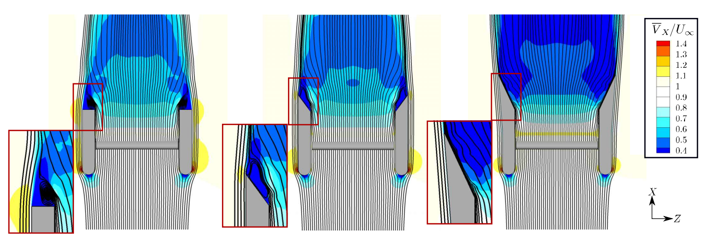
Potential to double the power extracted as compared to a straight duct.



Channel



Contours of cycle-averaged streamwise velocity entering the turbine.



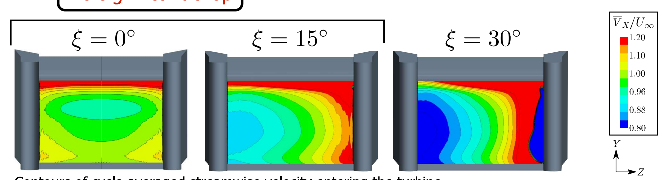
Contours of cycle-averaged streamwise velocity with streaklines in a plane at the mid height of the turbine

- Gain in power of 26% from the basic Geo1 to the optimized Geo3.
- Importance of a moderate outlet angle to avoid flow separation.

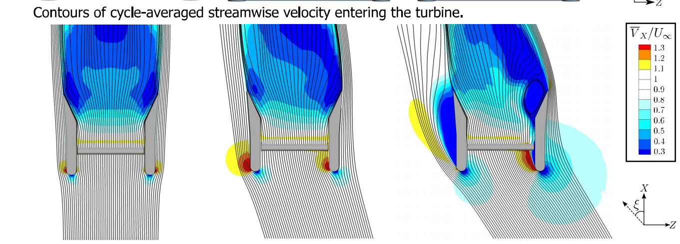
Flow misalignment

In the reality of river and tidal flow, perfectly-aligned flows are not expected. It is thus important to evaluate the sensitivity of the turbine to an upstream flow misalignment.

No significant drop



Contours of cycle-averaged streamwise velocity entering the turbine.



Contours of cycle-averaged streamwise velocity with streaklines in a plane at the mid height of the turbine