Development of the fully-passive flapping-foil turbine concept

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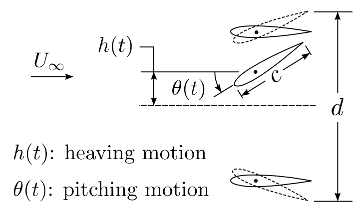
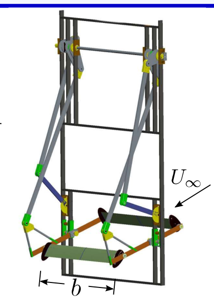
Context

Kinematically-constrained:





(Kinsey et al., 2011)

Best 2D numerical predictions:

- $\eta = \dfrac{\overline{P}}{\frac{1}{2}\rho U_\infty^3\, b\, d} = 43\%\,;$
- $\overline{C}_p = \dfrac{\overline{P}}{\frac{1}{2}\rho U_\infty^3\, b\, c} = 1.17;$

$\overline{P}$: cycle-averaged power.

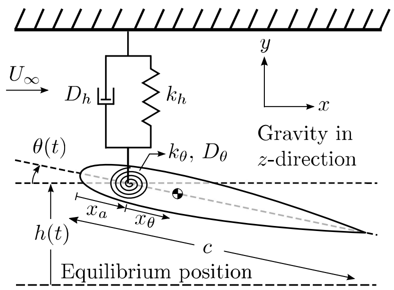
(Kinsey and Dumas, 2014)

Drawbacks:
The complexity of the mechanisms leads to:

- Losses in the power transmission;
- Increased risks of failure;
- Increased costs.

Fully-passive:

- Elastically-mounted in heave and in pitch;
- Self-induced and self-sustained motions;
- Different types of motions can be observed: damped, diverging, periodic, irregular, . . . ;
- The linear damper in heave models the presence of an electrical generator;



Best 2D numerical predictions:

- $\eta = \dfrac{\overline{P}}{\frac{1}{2}\rho U_\infty^3\, b\, d} = 29\%\,;$
- $\overline{C}_p = \dfrac{\overline{P}}{\frac{1}{2}\rho U_\infty^3\, b\, c} = 0.94;$

$$\overline{P} = \int_{t=0}^{T} D_h\, \dot{h}(t)^2\, dt\,.$$

(Veilleux and Dumas, 2016)

Objectives:

- Prove the feasibility and the potential of the fully-passive concept through experiments since only numerical simulations have been done so far;
- Optimize the concept using both experiments and numerical simulations;

Equations of motion

$$F_h = m_h\,\ddot{h} + S\left(\ddot{\theta}\cos\theta - \dot{\theta}^2\,\sin\theta\right) + D_h\,\dot{h} + k_h\,h$$
$$M_a = I_\theta\,\ddot{\theta} + S\,(\ddot{y}\,\cos\theta) + D_\theta\,\dot{\theta} + k_\theta\,\theta$$

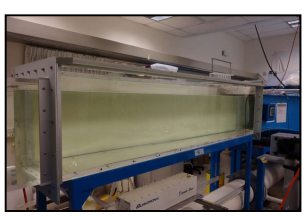
where $S = m_\theta x_\theta$

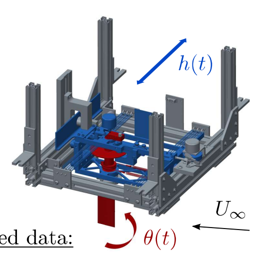
Blue: Inertia Red: Inertial coupling Green: Elastic supports

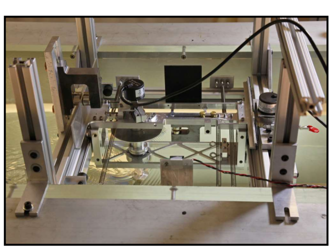
- F_h: Hydrodynamic heaving force;
- M_a: Hydrodynamic moment about the elastic axis;
- m_h, m_θ: Heaving and pitching masses;
- I_θ: Moment of inertia about the elastic axis;
- S: Static imbalance;
- D_h, D_θ: Heaving and pitching damping coefficients;
- k_h, k_θ: Heaving and pitching stiffness coefficients;
- x_θ: Distance between the elastic axis and the center of mass;
- x_a: Distance between the elastic axis and the leading edge.

Experimental setup

- Water channel with a test section of 0.45 m × 0.45 m × 2.5 m at the University of Victoria;
- NACA0015, $c = 0.05$ m and $b = 0.38$ m;
- $\mathrm{Re}_c \approx 2 \times 10^4$, $\mathrm{Fr} \approx 0.25$;
- Eddy current dampers for D_h and D_θ;







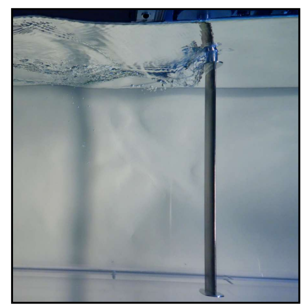
Collected data:

- $h(t)$ and $\theta(t)$ are measured with encoders;
- Velocity measurements in the wake using PIV.

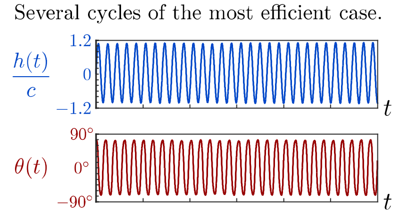
Experiments

The values of each of the following parameters have been varied independently:

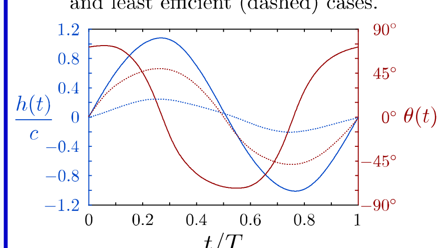
- 7 values of m_h;
- 2 values of I_θ;
- 3 values of S;
- 7 values of D_h;
- 10 values of k_h;
- 4 values of k_θ.



Several cycles of the most efficient case.



One cycle of the most efficient (solid) and least efficient (dashed) cases.



Experimental results:

	Range
$f^* = \dfrac{f\,c}{U_\infty}$	0.07 – 0.15
$\theta_{\max}$	27.7° – 96.3°
$h_{\max}/c$	0.22 – 1.66
η	1.7% – 26.5%
$\overline{C}_p$	0.03 – 0.96

Conclusion and future work

- The experiments conducted with this first fully-passive flapping-foil turbine prototype have confirmed the great potential of this technology.
- A fluid-structure coupling algorithm is currently being developed in order to carry out numerical simulations of this turbine concept.

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