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UNIVERSITÉ LAVAL

LMFN
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Oscillating-wings hydrokinetic turbine

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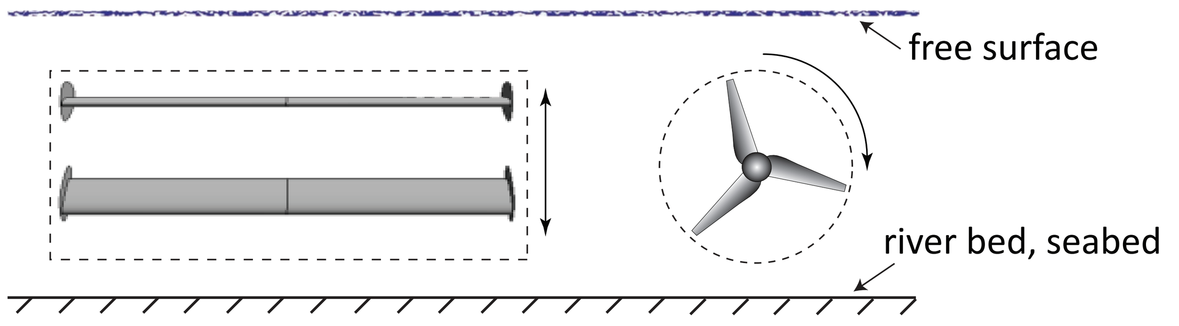
1 - Overview

A new concept of **hydrokinetic turbine** using **oscillating hydrofoils** to extract energy from water currents (tidal or gravitational) has been tested and analyzed.

Due to its **rectangular extraction plane**, this technology is particularly **well suited for river beds** and **shallow waters** near the coasts. Its **untwisted hydrofoils** are also **cheaper** and **easier to build** than conventional rotor blades.



Field tests on a 2kW turbine prototype were successfully completed in October 2009. This turbine is composed of two rectangular **oscillating hydrofoils in a tandem spatial configuration**. The hydrofoils harmonically oscillate in a combined pitch-heave motion. ☞ 2

The pitching motion of each hydrofoil is coupled to their cyclic heaving motion through four-link mechanisms which effectively yield a **one-degree-of-freedom** system driving a speed-controlled electric generator. ☞ 3

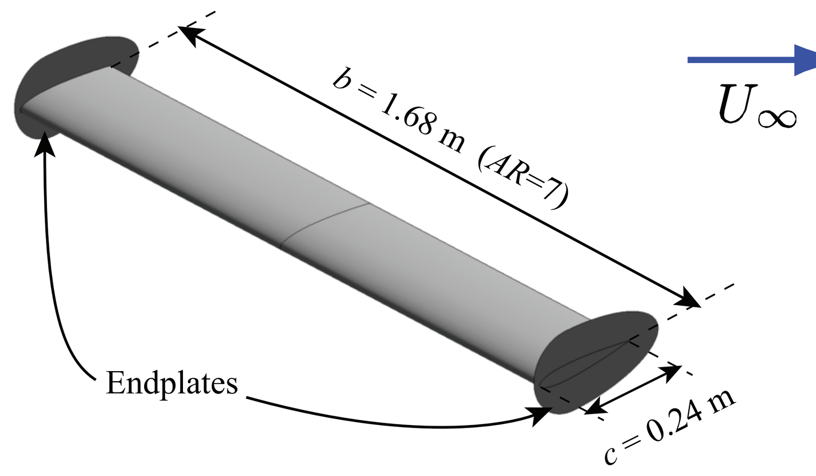
The **turbine** has been **mounted on a custom-made pontoon boat and dragged on a lake**. Instantaneous extracted power has been measured and cycle-averaged for several water flow velocities and hydrofoil oscillation frequencies. ☞ 4 Very good flow conditions and repeatability have been confirmed.

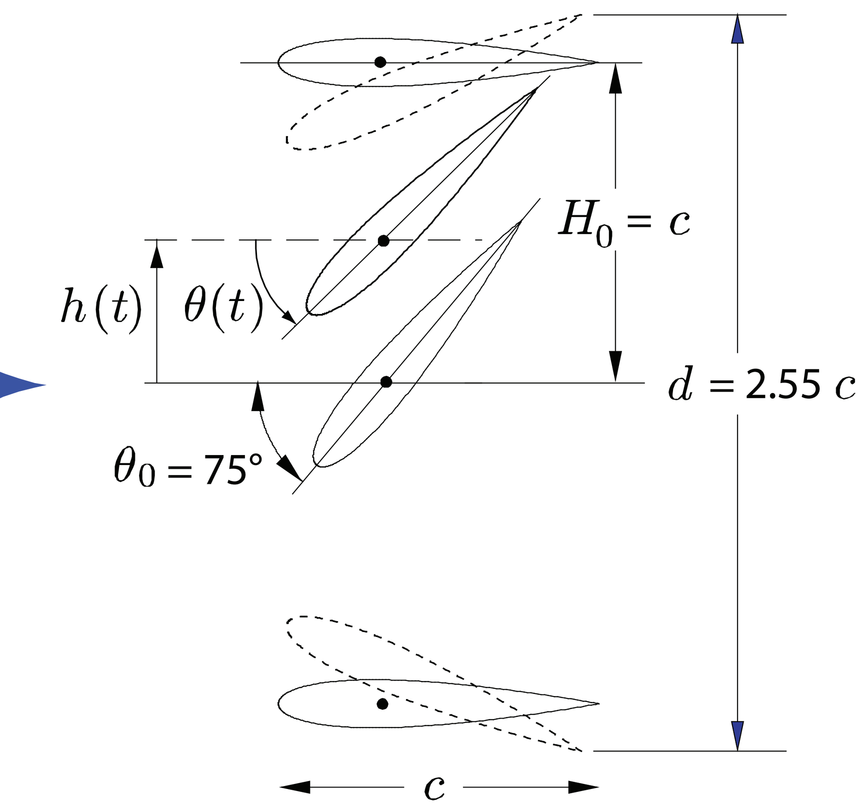
The **40% hydrodynamic efficiency** ☞ 5 of this first prototype exceeds expectation and reaches levels **comparable to the best performances achievable with modern rotor-blades turbines**. It thus demonstrates the **promising potential** of the oscillating hydrofoils technology to efficiently extract power from an incoming water flow.

2 - Hydrofoil motion

Each hydrofoil is harmonically pitching and heaving in an upstream water flow with amplitudes of 75 degrees and 1 chord respectively.

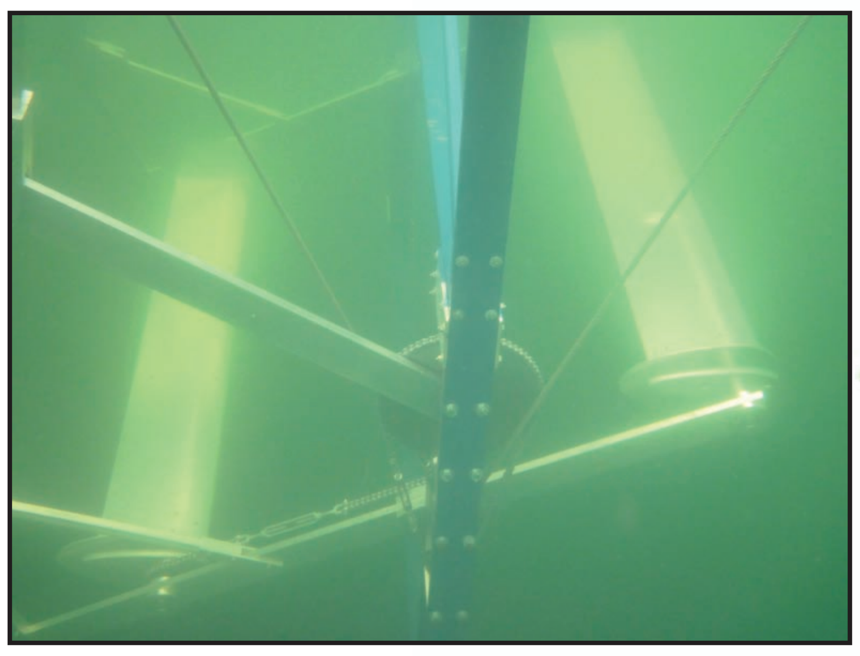
$$\theta(t) = \theta_0 \sin(\omega t)$$
$$h(t) = H_0 \sin(\omega t + \pi/2)$$
$$\omega = 2\pi f$$

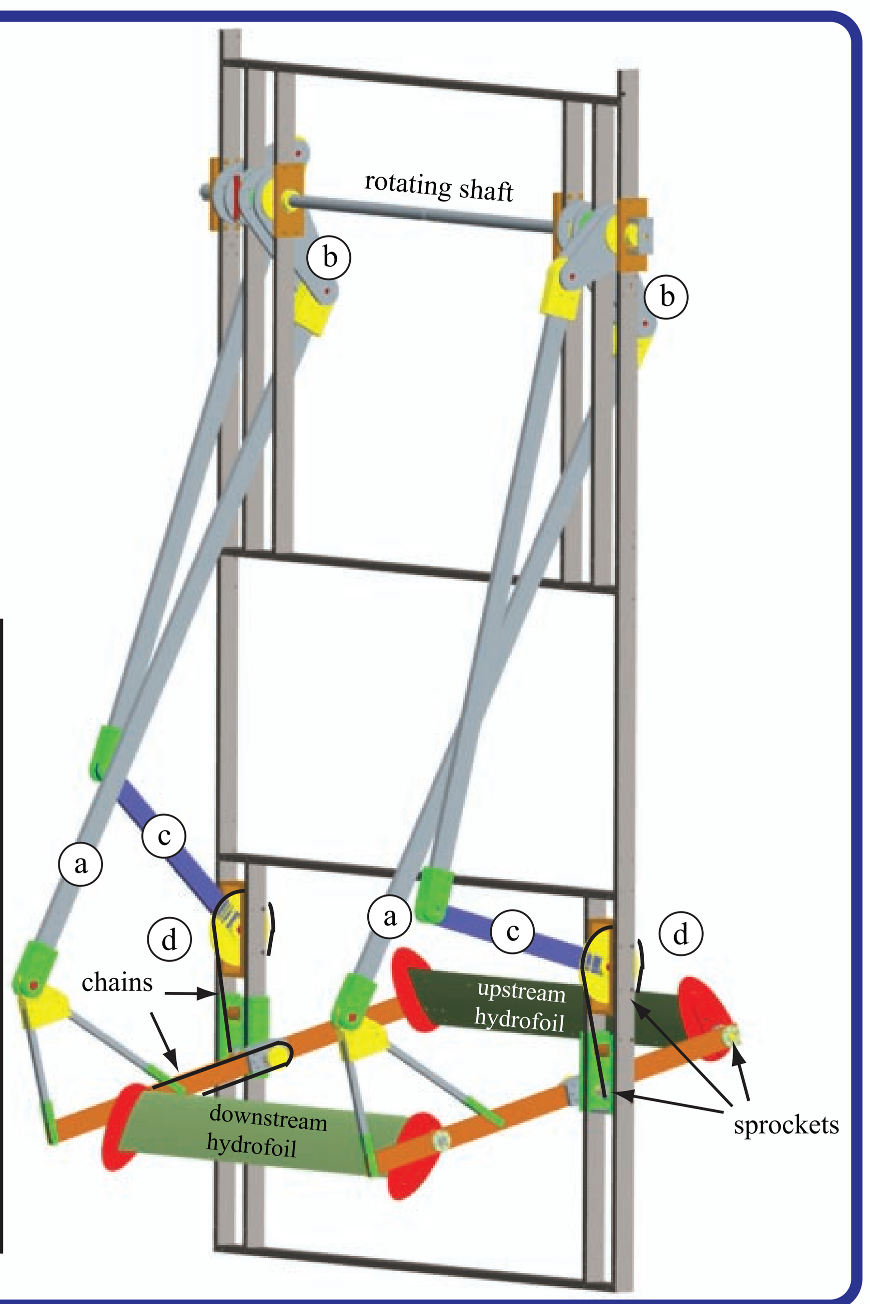




3 - Mechanism

The hydrofoils are mechanically coupled to a rotating shaft via a duplicated four-link mechanism — rod (a) and crankshaft (b) — to allow the hydrofoils to heave (approximating the actual circle arc motion to a straight vertical displacement). One additional four-link mechanism (c) is required together with two chains and three sprockets (d) per hydrofoil for the pitching part. The tandem hydrofoil motions are 180° phase-shifted.





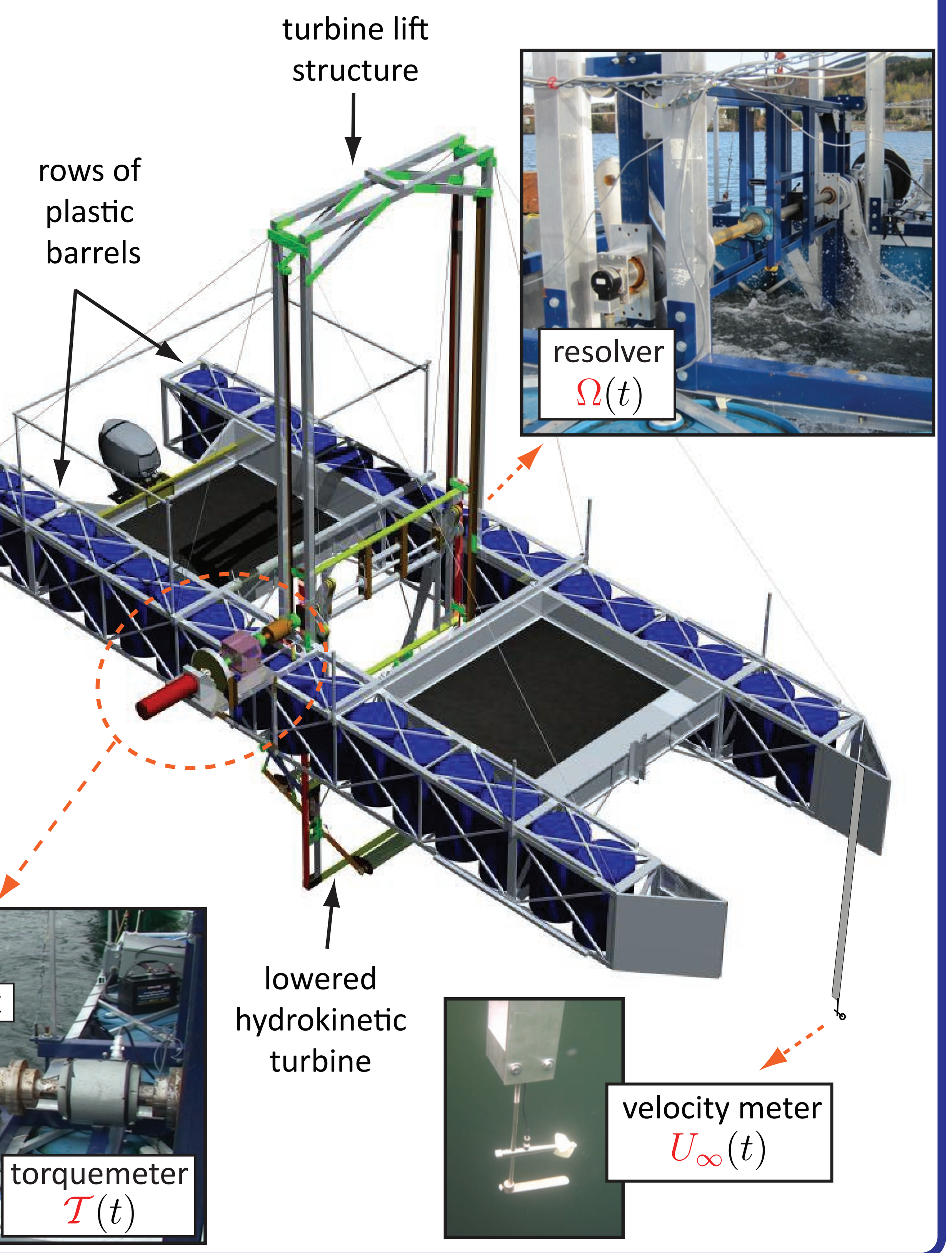
4 - Pontoon setup

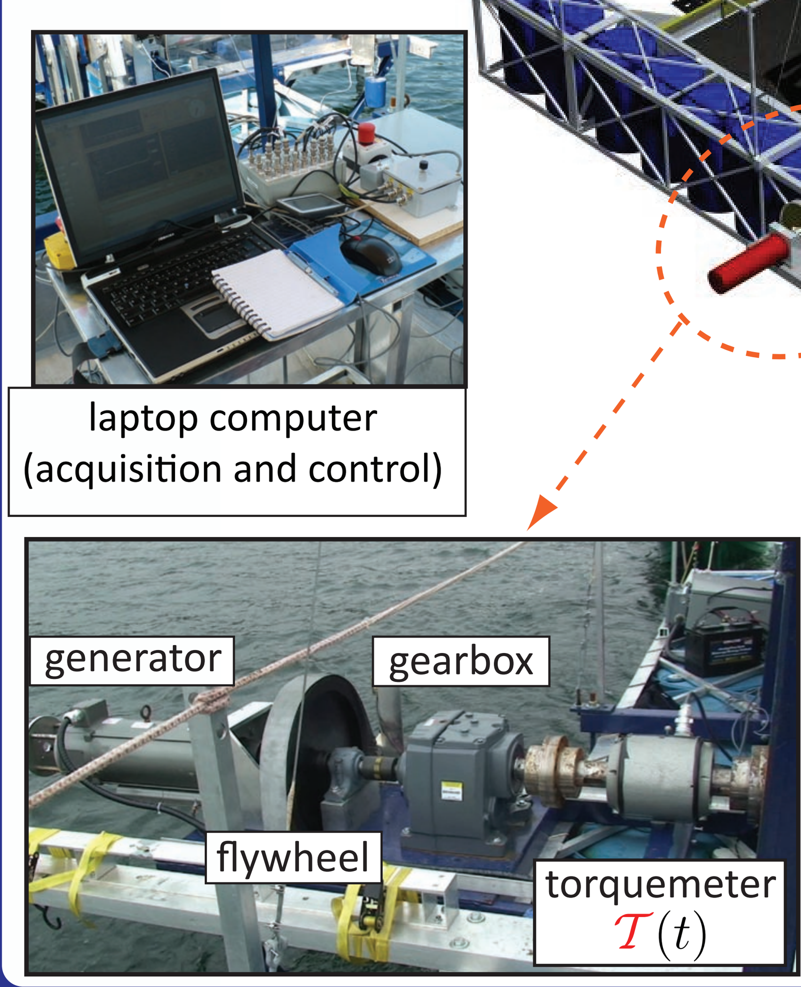
The turbine is mounted on a custom-made pontoon boat and dragged on a lake (Lac Beauport). The boat has an open center dedicated to the turbine. A lift structure allows to raise the turbine for transit or to lower it down 2m deep for operation. The rotating shaft is connected to the mechanical- electrical conversion group. Instantaneous power is measured as the product of torque on the rotating shaft and its angular velocity:

$$P(t) = \mathcal{T}(t)\ \Omega(t)$$

From the velocity meter measurements and cycle-averaged power, one gets the power extraction efficiency:

$$\eta = \frac{\overline{P}}{P_a} = \frac{\overline{\mathcal{T}\Omega}}{1/2\,\rho\,U_\infty^{\;3}\,b\,d}$$

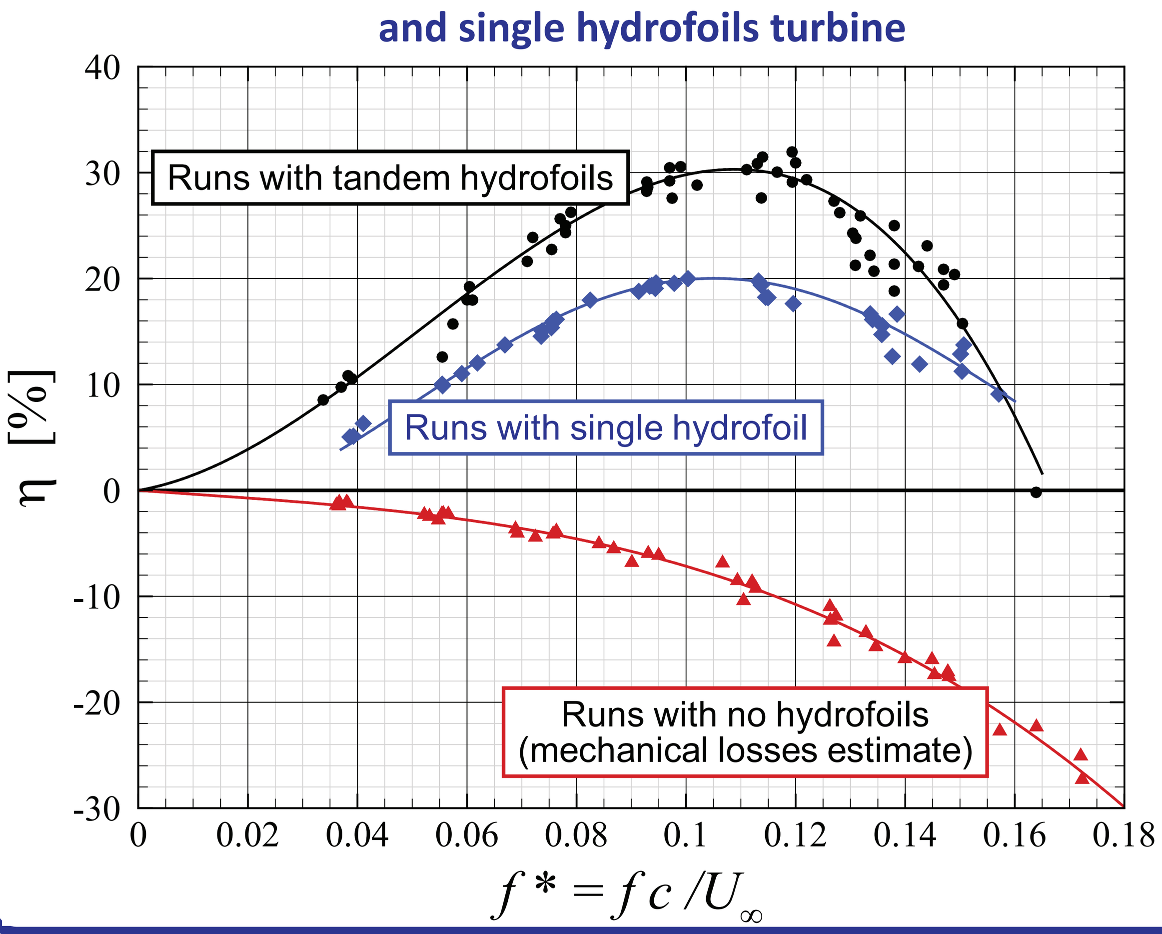




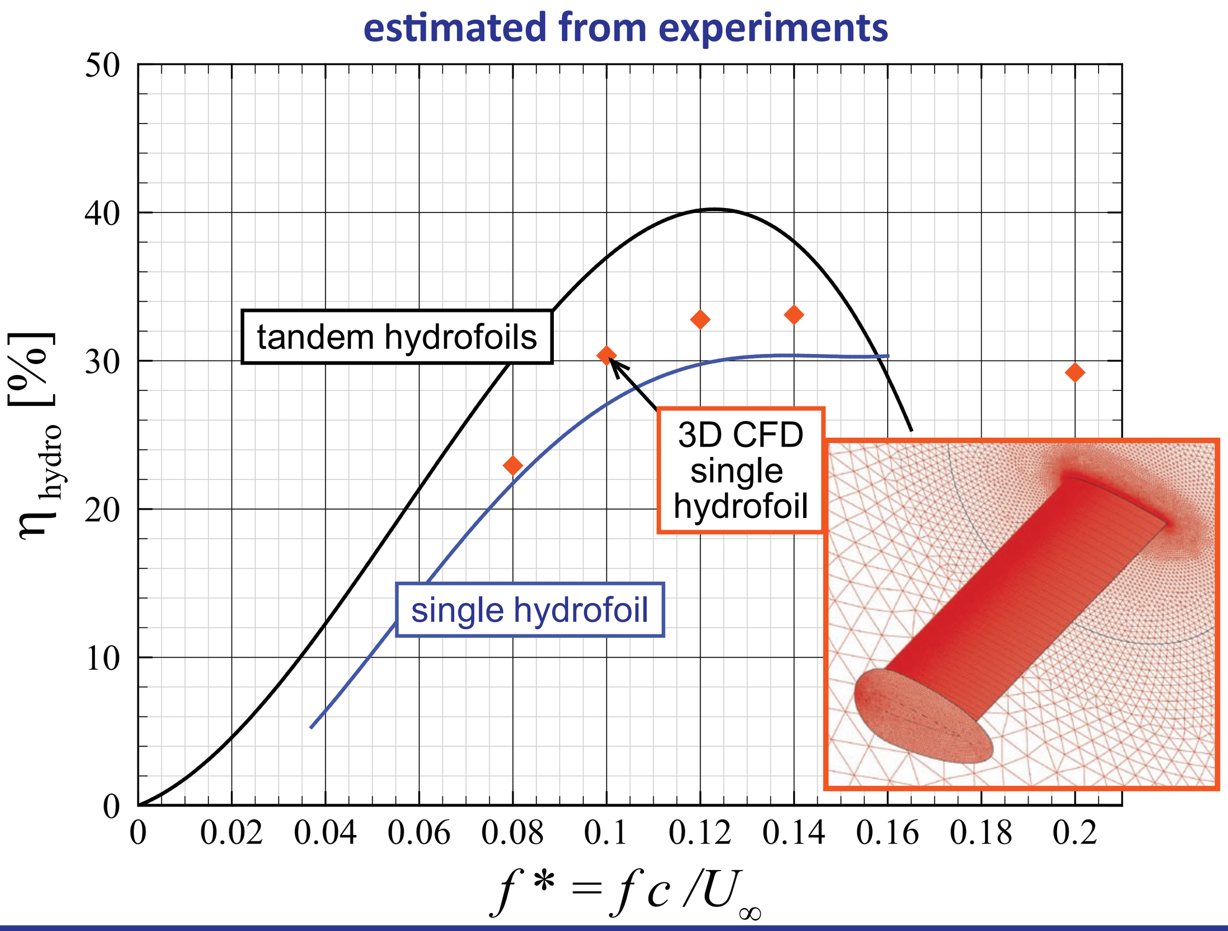
5 - Results

Experimental data show optimal performances at a reduced frequency of about 0.12, at which condition the measured power extraction efficiency reaches 40% once the overall losses in the mechanical system are taken into account. Further measurements of power extraction with a single oscillating hydrofoil have also been performed by taking out the downstream hydrofoil of the tandem pair. Those measurements favorably compare with the 3D CFD predictions.

Actual efficiency measurements for tandem and single hydrofoils turbine



Minimal bound for hydrodynamic efficiency estimated from experiments



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

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