# An Experimental and Numerical Analysis of the Structural Response of Cantilevered Flexible Hydrofoils in various flows

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## Abstract for ISROMAC2016, forum F29 - Fluid Structure Interactions

The perspective of using structures with a certain degree of flexibility in hydraulic rotating machines give rise to new questions about the hydro-elastic response of lifting structures together with the impact of the structural response on the flow. This includes points that need to be well understood as the static deformation of the structure and its impact on the flow as well as the dynamic response implicating added-mass effects, added-damping effects, stiffness, and possible flow-structure instabilities in turbulent high Reynolds and potentially cavitating flows in a high density fluid. The present paper deals with an original experiment to analyse the hydro-elastic response of cantilevered flexible hydrofoils in various flow conditions including cavitating flows. Simultaneously a numerical analysis is performed in some cases for nearly the same experimental configurations based on a CSD/CFD code.

The experiments were performed in the cavitation tunnel of the Naval Academy fitted with a 1m long and 0.2x0.2 $m^2$ test section. They are based on the measurements of the structural stress by means of strain gauges embedded in the hydrofoil structure (Figure 1) and the vibration analysis performed by means of a scanning vibrometer laser that allows us to analyse the structural modal response in flowing conditions particularly for the bending and twisting modes (Figure 2). The deflection of the hydrofoil is also investigated by means of a laser that allows us to measure the foil deformation in the vertical direction. In some cases, hydrodynamic forces measurements were performed using an hydrodynamic balance to be compared to rigid hydrofoils. Moreover for cavitating flow, a high speed camera was used in order to analyse unsteady features of partial cavitating.

Based on the experiments several observations were made and comparisons with numerical could be performed.

Specially, it was shown that the twisting mode’s frequency tends to increase as the flow velocity increases in a fully wetted flow. A strong fluid structure coupling was also observed at moderate angles of incidence and velocities that should be related to the unsteadiness of a Laminar Separation Bubble induced transition interacting strongly with the structure. In cavitating flow, the twisting mode's frequency increases as the cavitation develops suggesting the decrease of the added-mass in partially cavitating flow. The possibility of a lock-in of the flexion mode in interaction with the cavity oscillation, or its harmonics or sub-harmonics, was found for cavity length larger than about 0.4 the chord length. Finally it was found that the mean stresses slightly increase at the first stage of cavity development. As the cavity length increases the mean stress tended to decrease together with a strong increase of stress fluctuations related to cavity unsteadiness. Several physical observations will be reported in the paper that should be very beneficial for rotating machinery designers and FSI calculations.

**Figure 1. Cantilevered flexible hydrofoils used for vibration and strain measurements.**

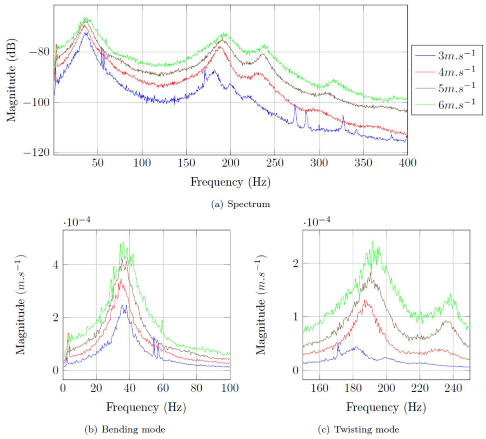


**Figure 2 Vibration response of the flexible foil for different flow velocities, α = 8°. a) full frequency range, b) bending mode c) twisting mode.**