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Hydro-dynamic damping theory in flowing water

Christine Monette, Bernd Nennemann, Charles Seeley, André Coutu, Hugues Marmont

Abstract

Fluid-structure interaction (FSI) has a major impact on the dynamic response of the structural components of hydroelectric turbines. On mid-head to high-head Francis runners, the rotor-stator interaction (RSI) phenomenon always has to be considered carefully during the design phase to avoid operational issues later on. The RSI dynamic response amplitudes are driven by three main factors: (1) pressure forcing amplitudes, (2) excitation frequencies in relation to natural frequencies and (3) damping. The prediction of the two first factors has been largely documented in the literature. However, the prediction of fluid damping has received less attention in spite of being critical when the runner is close to resonance. Experimental damping measurements in flowing water on hydrofoils were presented previously. Those results showed that the hydro-dynamic damping increased linearly with the flow. This paper presents development and validation of a mathematical model, based on momentum exchange, to predict damping due to fluid structure interaction in flowing water. The model is implemented as an analytical procedure for simple structures, such as cantilever beams, but is also implemented in more general ways using three different approaches for more complex structures such as runner blades: a finite element procedure, a CFD modal work based approach and a CFD 1DOF approach. The mathematical model and all three implementation approaches are shown to agree well with experimental results.