Acoustic-structure interaction in disk-disk configurations in water for high head pump-turbines

Raphaël Jean¹, Olivier Braun², Christine Monnette³, Bernd Nennemann³, Frédérick P. Gosselin¹
¹Laboratory for Multi-Scale Mechanics (LM2), Polytechnique Montreal, Montreal, QC, Canada
²Andritz Hydro GmbH, Ravensburg, Germany
³Andritz Hydro Canada Inc., Pointe Claire, QC, Canada
*raphael.jean@polymtl.ca

ABSTRACT

High head Francis or pump-turbine runners often have speed and dimension ratios that cause acoustic and structural natural frequencies to become close to each other as well as to the rotor-stator excitation frequency. This can result in the mixing of acoustic and structural modes and makes it difficult to distinguish the nature, i.e. acoustic or structural, of each mode and the associated amplification effect.

The main aim of the project is to study the behavior of a disk-disk system in water (acoustic cavity) for cases where acoustic and structural frequencies are close, as a simplified model of a pump-turbine runner in its casing. At first, nondimensional parameters that characterize the acoustic/structure interaction are identified.

The Ritz method is used to analyze the effect of water compressibility on natural frequencies using a Bessel decomposition for the structural (2-dimensional disk) and the fluid (3-dimensional cavity) domain. A global matrix system is assembled and the corresponding eigenproblem is solved. The results are verified with acoustic finite element analysis.

A parametric study is conducted to understand how structural and acoustic modes are interacting for a wide range nondimensional parameters. Ranges of interests are identified, namely when only few modes interact. In such cases very simple systems of 2, 3 and 4 degrees of freedom can represent analytically the system behaviour. This work helps to improve the understanding of turbine vibration in cases where acoustic and structural modes are potentially excited and interacting.

Keywords: Acoustic frequency, Structural frequency, Fluid structure interaction, Compressible fluid