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

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Abstract. Francis high-head pumps or pump-turbine runners often have speed and dimension ratios that make acoustic and structural natural frequencies, as well as rotor-stator excitation frequencies, approach each other. When compressibility effect becomes significant, it is not sufficient to only consider the incompressible added mass, which shifts the natural frequencies of the structure. The strong vibroacoustic coupling makes it difficult to distinguish the nature of each mode and the associated effect of the forced response amplification. The project's main aim is to study a disk-disk system behavior in an acoustic cavity filled with water when the acoustic and structural frequencies are close, as a simplified model of a pump-turbine runner in its casing. It is demonstrated here that the compressibility significantly affects vibration modes of the system, particularly when individual acoustic and structural modes have similar frequencies and spatial coherence, resulting in an increase in energy transmission and a decrease in total natural frequency. Additionally, the system's rigidity is affected by the cover's stiffness; when the vibration frequencies of the cover and runner are similar, excitation transmission is divided between them.

1. Introduction and literature review

Hydraulic turbines, during operation, are subject to various time-varying excitations. Among these, the rotor-stator interaction (RSI) is an unavoidable deterministic excitation at blade passing frequencies in hydraulic machinery [1].

For turbine manufacturers, understanding the vibration modes of turbine components and the degree of their excitation is crucial. The primary aim is to evade the proximity of excitation frequencies to natural frequencies, with consideration of the similarity in mode shapes and excitation patterns. For the most significant vibration modes, it is necessary to predict the vibration amplitudes to ensure system durability. High head turbines and pump-turbines, characterized by their large diameters and small channel heights, display disc-like vibration modes [2]. This is especially true for pump-turbines, requiring larger spaces between blades, where axial disk-like vibrations dominate over individual blade vibrations. As the head increases, necessitating adjustments in rotation speed or machine diameter, the excitation or natural frequency changes. Consequently, at higher heads, sub-critical excitation approaches natural frequencies more closely.