Modal analysis and characterization of a hydrofoil circular cascade test rig for hydrodynamic damping measurements

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Abstract. A test rig has been developed at the Waterpower Laboratory of the Norwegian University of Science and Technology to conduct an in-depth investigation of flow-related phenomena and fluid-structure interaction , with the focus towards hydrodynamic damping, for a circular hydrofoil cascade configuration. The rig's design enables the analysis of hydrodynamic damping by utilizing sensors on the structure and optical access to evaluate wake flow dynamics through advanced techniques such as Particle Image Velocimetry and Laser Doppler Velocimetry. The paper presents the rig's capabilities and a comparison of the results of both experimental and numerical modal analyses to identify the cascade's natural frequencies and main mode shapes, as preliminary step before future hydrodynamic damping measurements. This paper lays the foundation for further investigations into hydrodynamic damping measurements and contributes to the characterization of the circular hydrofoil cascade test rig. A comparative analysis of numerical modal methods as cyclical symmetry and a full-model approach has been conducted.

1. Introduction

Hydrofoils have been extensively studied in the field of fluid mechanics due to their diverse applications, ranging from maritime transportation to power generation [1]. Achieving a optimized blade design necessitates an extensive comprehension of the fluid-structure interactions (FSI) and flow-related phenomena. Understanding the interplay between hydrofoils and the surrounding fluid holds paramount importance in optimizing their performance and reducing costs associated with repairing or replacing the rotor in a turbine unit, especially when resonance damages occur. The hydrodynamic damping represents a crucial parameter that dictates the effectiveness and stability of a hydrofoil system, such as a turbine runner or a propeller, particularly under resonance conditions. As such, it has become a focal point of research in recent years [2–6]. However, despite advancements in numerical simulations and analytical models [7], the inherent complexity of the hydrodynamic problem introduces challenges when seeking accurate predictions, especially considering the uniqueness of the geometry of the system. To tackle this challenge, experimental investigations utilizing test