Investigation of the natural modes of a Pelton runner prototype

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Abstract. In the context of predictive maintenance, the development of new tools is crucial to assess the availability of power units and eventually anticipate downtime. Vibration-based condition monitoring already demonstrated efficient methods to anticipate failure and to detect changes in the vibration behaviour of structures. This numerical study focuses on the dynamic behaviour of a Pelton runner, with 22 buckets and a specific speed $n_q = 7.54\ rpm$. In a first step, a finite element method modal simulation was performed on a single bucket to capture pure-bucket modes. Then, similar simulations of the full runner demonstrated that for a given pure-bucket mode, there are 12 (11+1) occurrences of the same mode for the runner, each distinguished by their number of nodal diameter(s). Vibration modes with more than 8 nodal diameters present small variations between their natural frequencies. This can be explained by the proximity between these mode shapes and pure-bucket mode shapes. In addition, by testing two boundary conditions on the runner, it appears that preventing the displacement of the runner bores mainly impacts natural frequencies for modes with less than 4 nodal diameters.

1. Introduction

The availability of hydroelectric power units is a key element for the energy transition and has become of paramount importance, as the last winter (2022-2023) has shown. In Switzerland, energy producers had to postpone refurbishments and overhauls of power units to ensure electricity production during the winter. This situation is expected to become the norm in the next years. Thus energy producers and power plant operators need efficient monitoring tools to anticipate downtime and prevent failures. Vibration-based condition monitoring has proved to be efficient detecting incipient damages and changes in the dynamic behaviour of structures like wind turbines [1][2]. The transfer of such methods to Pelton turbines requires a deep understanding of their dynamic behaviour. Previous works have already addressed this topic with numerical and experimental approaches [3][4][5][6]. For Pelton turbines changes are expected in their dynamic behaviour in case of mass loss due to hydro-abrasive erosion or in the presence of cracks of a significant size in critical regions like buckets roots or buckets cutouts. Among all vibration modes of Pelton turbines, tangential modes, also called bending modes, are the most critical ones because they might produce high stress concentration in the root of the buckets if the excitation frequency matches the resonance frequencies of the runner. A previous study [7] reported high deflection amplitudes at a frequency corresponding to the 16th harmonic