Towards the non-intrusive detection and monitoring of cavitation in hydraulic machines

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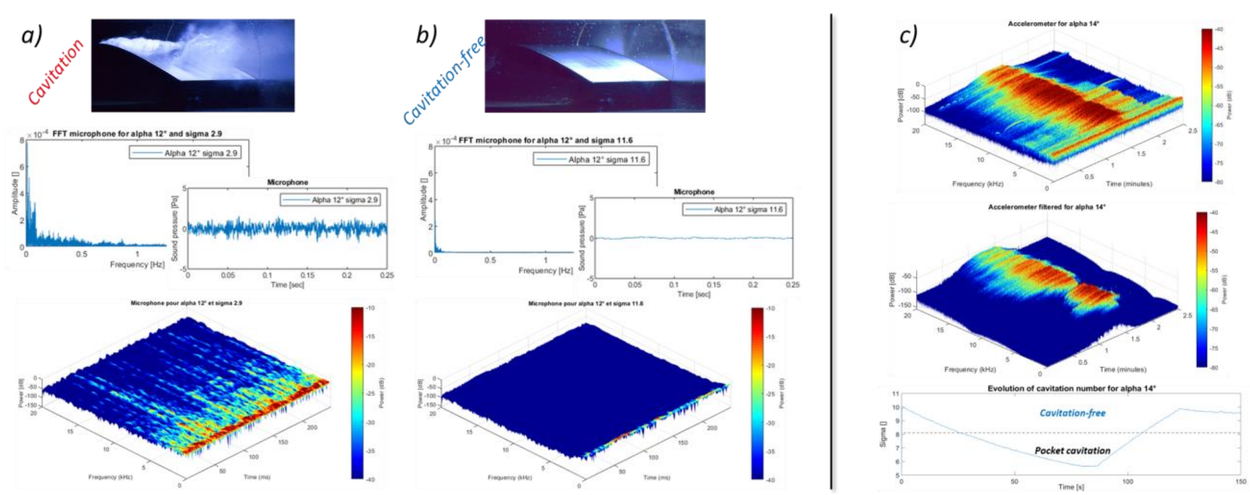
Abstract

The real-time survey of cavitation in hydraulic machines is a very real need for hydropower plant operators/owners in order to help better plan periodic inspections and maintenance. It has a direct economic benefit to business, just like the monitoring of erosion by sediments.

Today, to our knowledge, no sensor or system dedicated to the direct monitoring of the cavitation phenomenon in hydraulic machines, which affects their remaining lifespan, exists on the market. In a preliminary study, a complete non-intrusive system (sensor and measurement chain, monitoring system hardware and software) was deployed on a pump at prototype scale and measurements were taken throughout one whole season. Post-processing of the large amount of collected data proved to be non-trivial. Moreover, the presence in the signals of various signatures from the in-situ environment did not facilitate this task. The objective of this work is the development of a methodology for the post-processing of signals from non-intrusive sensors using a test bench set up for the real-time monitoring of cavitation in hydropower plants.

A comprehensive bibliographic review of existing experimental cavitation detection techniques was carried out. This was followed by an initial case study using a NACA 0015 hydrofoil mounted in the new cavitation section of the hydraulic test rig at HES-SO Valais-Wallis, Switzerland. The cavitation chart of the hydrofoil was established and several states, from cavitation-free to super-cavitation, were selected for cavitation detection and monitoring measurements. A wide range of mainly non-intrusive sensors, installed at various locations on the test rig, were used for quantitative analysis, notably: high- and low-frequency acoustic emission probes, accelerometers, an airborne noise probe, a dynamic pressure probe, a high-frequency static-pressure probe, a strain gauge and a geophone. Simultaneously, a high-speed camera was employed for qualitative visual analysis. The first post-processing efforts used standard statistical and FFT-based spectral analysis of discrete flow regimes. Then, spectrograms of stationary flow regimes and dynamic transitions from cavitation-free to super-cavitation states and vice versa, were used to detect the cavitation signature on the signal from each sensor.



First insights for the NACA 0015 case study:

- *Differences between a) cavitating and b) cavitation-free steady-flow states on waveforms and power spectra, as well as the spectrograms of airborne noise.*
- *Differences between spectrograms of c) vibration signals, original (top view) and filtered (bottom view), during a dynamic cycle from cavitation-free to pocket-cavitation states and vice versa.*

In a second case study, the set of sensors showing the most promising results were then deployed on a centrifugal multi-stage pump of the hydraulic test rig. This variable-speed pump, subject to cavitation under certain operating conditions, allowed different machinery data to be obtained in the same laboratory environment, so that the data could be compared with the NACA hydrofoil measurements.

The practical results bring us closer to the final objective of a cavitation detection toolbox deployable on a machine at prototype scale in highly-perturbed real-world environments such as the machinery area in a power plant. Moreover, correlation of the spectrograms and high-speed images presents an interesting potential avenue for further analysis with artificial intelligence algorithms.

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