Research Proposal: Passive Control of Flow-Induced Vibration of Hydrofoils

Hydrofoils are integral components in numerous maritime applications, playing a pivotal role in enhancing the efficiency and manoeuvrability of vessels and underwater vehicles. As hydrofoils navigate through water, they are susceptible to a complex phenomenon known as flow-induced vibrations. These vibrations result from the interaction between the hydrofoil and the surrounding fluid flow and can have adverse effects on both the hydrofoil and the systems it operates within. These effects include structural fatigue, reduced operational efficiency, and in some cases, safety concerns. Thus, the effective control and mitigation of flow-induced vibrations are paramount in ensuring the reliable and efficient performance of hydrofoils.

Passive vibration control refers to a set of techniques and strategies used to mitigate or reduce unwanted vibrations and oscillations in mechanical and structural systems without the need for active energy input. Piezoelectric (PZT) materials have been widely used as sensors and actuators for controlling structural vibration, and in many cases are preferred over other damping treatment methods because of their ideal properties: light weight and compactness, fast response in energy conversion, and easy integration to the host structure [1]. Typically, to mitigate structural vibrations, a piezoelectric patch is attached to or integrated into a host structure. The piezoelectric patch generates an electric field in response to the strain due to mechanical vibration. Vibration of the structure can be controlled by manipulating this energy transfer. For example, passive damping can be achieved by connecting piezoelectric patches to a resonant-shunt circuit with one resistor (R) and an inductor (L), which allows dissipation of energy as heat through the resistive components of the shunt circuit. Pernod et al. [2], for the first time, experimentally investigated the possibility of vibration control of a flat plate in flow. This project will extend their work to control vibration of a realistic hydrofoil. Through a combination of experimental work, numerical simulations, and practical case studies, this research seeks to advance our understanding of the control of flow-induced vibrations of hydrofoil and provide valuable recommendations for the implementation of this technology in hydrofoil design and operation.

[1] Thomas, O., et al. (2011). Performance of piezoelectric shunts for vibration reduction. Smart. Mater. Struct., 21(1), 015008.
[2] Pernod, L., et al. (2021). Vibration damping of marine lifting surfaces with resonant piezoelectric shunts. J. Sound Vib, 496, 115921.
[3] Karimi, M., et al. (2020). A hybrid numerical approach to predict the vibrational responses of panels excited by a turbulent boundary layer.
J Fluids Struct, 92, 102814.
[4] Karimi, M., et al. (2020). Analytical and numerical prediction of acoustic radiation from a panel under turbulent boundary layer excitation.
J Sound Vib, 479, 115372.

Project Milestones

- Comprehensively review existing literature on hydrofoil dynamics, flow-induced vibrations, and the application of smart materials such PZT patches.
- Understand the fundamental mechanisms of flow-induced vibrations in hydrofoils. This will be achieved through numerical modelling of the hydrofoil by extending the previous theoretical methods in the literature [3,4]
- Explore the potential of PZT in reducing flow-induced vibrations.
- Develop optimized shunted PZT configurations for hydrofoils through experimental and numerical analysis.
- Provide recommendations for the implementation of PZT patches for flow-induced vibration control in hydrofoils.