

## ABSTRACT

Despite serving analogous functions, the mechanical designs conceived by human engineering and those that result from natural evolution often possess fundamentally differing properties. This thesis explores the use of principles that stem from natural evolution to improve the performance of engineered mechanisms, focusing on systems whose role is to interact with a fluid environment. Two different principles are considered: the use of compliance, abundant in nature's structures, and the use of flapping propulsion, prevalent among nature's swimmers.

The first part of this thesis is dedicated to investigating the physics that govern the behavior of an inverted-flag energy harvester; an unactuated flexible cantilever plate that is clamped at its trailing edge and submerged in a flow. The resonance between solid motion and fluid forcing generates large-amplitude unsteady deformations of the structure that may be used for energy harvesting purposes. The effect of the flag's aspect ratio on its stability is first evaluated. Flags of very small aspect ratio are demonstrated to undergo a saddle-node bifurcation instead of a divergence instability. The angle of attack of the flag is then modified to reveal the existence of dynamical regimes additional to those present at zero angle of attack. A side-by-side flag configuration is finally explored, highlighting the presence of an energetically favorable symmetric flapping mode among other coupled dynamics.

The second part of this thesis delves into the analysis of underwater flapping propellers and the optimization of their three-dimensional motion to generate desired maneuvering forces, with the objective of obtaining an appendage for use in autonomous underwater vehicles that can perform both fast maneuvering and efficient propulsion. An experimental optimization procedure is employed to obtain the most efficient trajectory that generates a specified side force. The effect of increasing the fin's aspect ratio is examined, and a highly efficient trajectory, that makes use of high three-dimensionality and rotation angles, is obtained for a fin of  $AR=4$ . The use of a flexible fin is then analyzed and shown to be detrimental to the maneuvering efficiency of the system.