Influence of cavitation on the dynamic response of hydrofoils

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The dynamic response of any structure submerged in water is significantly modified by the effect of added mass. The inertia of the fluid that the body must accelerate during its vibrational motion decreases its natural frequencies. This frequency shift between the air and still water conditions must be taken into account during the design phase to foresee any resonance problems.

However, if cavitation takes place, which is a rather common phenomenon when dealing with submerged systems or machinery, the variability in the structural response remains unknown.

This thesis presents an experimental study of the influence of sheet cavitation and supercavitation on the added mass effects experienced by a 2-D NACA0009 hydrofoil. A High Speed Cavitation Tunnel was used to generate and control the cavitation, and an innovative non-intrusive excitation and measuring system based on piezoelectric patches mounted on the hydrofoil surface was used to determine the natural frequencies of the fluid-structure system. The appropriate hydrodynamic conditions were selected to generate a range of stable partial cavities of various sizes and to minimize the effects of other sources of flow-induced noise and vibrations. The main tests were performed for different sigma values under a constant flow velocity of 14 m/s and for incidence angles of both 1° and 2°.

Additionally, a series of complementary experiments and numerical simulations were performed to assure the validity of the results and to clearly separate the effects of cavitation from other factors that may also affect the hydrofoil's natural frequencies. In this context, mode shape visualization was performed under different flow conditions to guarantee the

equivalence among the tests. In addition, the effects of the lateral wall in the test section and the pressure distribution over the hydrofoil surface were also studied.

The obtained results indicate that the maximum added mass effect occurs under conditions of still water. When cavitation occurs, the added mass decreases as the cavity length is increased. Consequently, the added mass reaches a minimum under supercavitation conditions. This behavior is well characterized by the linear correlation found between the added mass coefficient and the entrained mass of fluid that accounts for the mean density of the cavity, its dimensions and its location relative to the specific mode shape deformation.

Partial sheet cavitation (above) and supercavitation (below) on a NACA0009 profile.