ACOUSTICS AND HYDRODYNAMICS OF FLUID-STRUCTURE INTERACTION IN A SUBMERGED ELASTIC DUCT

Abstract

by

Wenlong Zhang

This dissertation studied the interaction of nonuniform flows with propeller blades in a submerged elastic duct. The acoustic radiation from the duct is calculated and correlated to the flow nonuniformities and the propeller and duct characteristics. First, a benchmark problem is studied wherein the sound radiation from an infinite plate with or without ribs is examined for different excitations sources: normal single force, monopole, dipole, and vortex excitations. The investigation of the sound radiation from a plate gives us a fundamental understanding of flexure waves.

Second, the case of a cylindrical duct with or without ribs is considered and the dispersion relation of the rib-stiffened duct modes is compared with that of an unstiffened duct. The dispersion relation of the stiffened duct has a periodic structure similar to that of connected oscillators with large number of independent modes. Because of our interest in the acoustic radiation from such a system, we focus our attention on the flexure modes. The sound radiation is first tested with simple internal forces such as monopoles and dipoles. The results for un-stiffened ducts show strong directivity as the dipole radial location moves closer to the duct wall. For stiffened ducts, the magnitude of the acoustic response as well as the directivity vary strongly and show large peaks near the stiffened duct free modes.
Third, the scattering phenomena in a rigid duct and an elastic duct is investigated. The effect of the impedance on the acoustic sources is also examined. The results show that the impedance begin to have the significant effect on the unsteady lift when the magnitude of the non dimensional impedance is the order of one. The main effect of the elastic wall comes from the location of the blade and the upstream of the blade.

Finally, a model for flow-propeller interactions in a submerged elastic duct is developed. This model examines and quantifies the mechanism of flow-propeller interaction in a flexible duct. The model couples the fluid motion with the elastic duct vibration and yields the duct flexural displacement. This leads to the evaluation of the radiated sound. The coupling between the elastic duct and the flow-propeller system is studied by changing the Euler code which accounts for the rotor/stator interaction problem. The results suggests that for different combination of rotor/stator blade counts, it is possible to have low circumferential mode number, which is an efficient radiator of acoustic energy.