UNIVERSITY OF SOUTHAMPTON

ABSTRACT

FACULTY OF ENGINEERING, SCIENCE & MATHEMATICS

SCHOOL OF ENGINEERING SCIENCES

Doctor of Philosophy

A COMPUTATIONAL AND EXPERIMENTAL INVESTIGATION INTO THE AEROACOUSTICS OF LOW SPEED FLOWS

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The noise produced by low Mach number ($M \leq 0.4$) laminar and turbulent flows is studied using computational and experimental techniques. The emphasis is on the development and application of numerical methods to further the understanding of noise generation and far field radiation. Numerical simulations are performed to investigate the tonal noise radiated by two- and three-dimensional cavities submerged in low-speed turbulent and laminar flows. A numerical approach is developed that combines near field flow computations with an integral radiation model to enable the far field signal to be evaluated without the need to directly resolve the propagation of the acoustic waves to the far field. Two basic geometries are employed in these investigations: a plane rectangular cavity and a rectangular cavity with a lip. Results for the two geometries show good agreement with available experimental data, and highlight the sensitivity of the amplitude and directivity of the radiated sound to geometry, flow speed and the properties of the incoming boundary layer. The cavity with a lip is shown to behave as a Helmholtz resonator. The plane cavities are characterized by the more familiar Rossiter modes. Both geometries are characterized by intense near field oscillations and strong noise radiation. To quantify the effects of three-dimensional phenomena on the generation and radiation of sound, a fully three-dimensional simulation is performed. The Navier-Stokes equations are solved directly using an optimized prefactored compact scheme for spatial discretization. Results are compared with those from a two-dimensional simulation and the effects of the three-dimensional phenomena are discussed. Finally, wind tunnel tests are performed to quantify the effects of geometry and flow speed on the velocity and pressure fields within a plane rectangular cavity. Velocity measurements are made using the Laser Doppler Anemometry and Particle Image Velocimetry techniques. Instantaneous and statistical data are employed to probe the flows. Although coherent vortical structures are found to characterize the shear layer, their intermittent nature prevents self-sustaining oscillations developing and consequently the pressure field is broadband in nature.