Second-Year Graduate Course in Aeroacoustics

Introduction to the field of aeroacoustics for students familiar with the foundations of fluid dynamics. Fundamental theories of aeroacoustics, including Lighthill's analogy, the Ffowcs Williams Hawkings equation and Goldstein's equation. Mathematical methods needed to and apply these theories, including correlation and spectral methods for turbulent flows. Applications include the prediction of leading and trailing edge noise are taught. Relevant experimental methods, including facilities, corrections, instrumentation, signal processing and phased microphone arrays. The course assumes that students will have had a graduate level course in fluid dynamics.

Having successfully completed this course, the student will be able to:

- Model a field of ideal stationary acoustic sources
- Describe the generation and source of flow-induced noise through Lighthill's equation
- Evaluate the noise from a moving acoustic source as perceived by a stationary observer and sources and observers which are stationary in a uniform flow
- Calculate the far field sound from a source distribution on a Ffowcs Williams and Hawkings surface
- Determine leading edge noise from an impinging gust on an airfoil
- Calculate trailing edge noise from the scattering of turbulent sources by a sharp trailing edge.
- Analyze acoustic data acquired in aeroacoustic testing from single microphones and microphone arrays

Text Book: The Aeroacoustics of Low Mach Number Flows *by Stewart Glegg and William Devenport, 1st Edition*

Introduction (4%).
  1.1 Aeroacoustics of Low Mach Number Flows
  1.2 Sound waves and turbulence
  1.3 Quantifying sound levels and annoyance

Fluid dynamics and linear acoustics (13%).
  2.1 to 2.3 Equations of continuity and momentum
  2.4 Thermodynamic quantities
  2.5 The role of vorticity
  2.6 Energy and acoustic intensity
  2.7 Relevant fluid dynamic concepts
  3.1 The acoustic wave equation
  3.2 to 3.6 Plane waves and spherical waves, scattering
  3.7 Monopole, dipole and quadrupole sources
  3.8 Acoustic intensity and sound power output
  3.9 The method of Green's functions
  3.10 Fourier transforms

Lighthill's acoustic analogy (13%)
  4.1 and 4.2 Lighthill's equation and limitations
  4.3 Curle's theorem
  4.4 Monopole, dipole and quadrupole sources

4.5 Tailored Green’s functions
4.7 Wavenumber and Fourier transforms

Moving surfaces, the method of Ffowcs Williams and Hawkings (8%)
5.1 Generalized derivatives
5.2 The Ffowcs Williams Hawkings Equation
5.3 and 5.4 Moving sources and sources in a free stream
5.5 Ffowcs Williams and Hawkings Surfaces

Methods using the linearized Euler equations (12%)
6.1 Goldstein’s equation
6.2 and 6.3Drift coordinates and rapid distortion theory
6.4 and 6.5 Airfoils
7.1 Howe’s theory of vortex sound
7.2 to 7.6 Selected applications

Turbulence and stochastic processes (11%)
8.1 to 8.3 Fluid flow as a stochastic process, averaging
8.4 Time correlations and frequency spectra, spatial correlations and wavenumber spectra
9.1 and 9.2 Homogenous turbulence and some inhomogeneous flows.

Leading edge noise (8%)
14.1The blade response function and unsteady lift
14.2 Coupling to the acoustic far field, Impulsive gusts
14.3 Airfoil in a turbulent stream

Trailing edge noise (7%)
15.1 Origin and scaling
15.2 Amiet’s method
15.3 The method of Brooks, Pope and Marcolini

Aeroacoustic testing (8%)
10.1 Wind tunnels
10.2 Wind tunnel corrections
10.3 to 10.5 The measurement of sound and flow

Measurement, signal processing and uncertainty (8%)
11.1 Limitations of measured data
11.2 and 11.3 Uncertainty, averaging and convergence
11.4 and 11.5 The discrete Fourier transform
11.6 and 11.7 Numerical estimates of spectra and correlations

Phased microphone arrays (8%)
12.1 Delay and sum, beam steering, acoustic images and array shading
12.2 Generalized array processing, array design