Acoustics – overview

The understanding and control of acoustic radiation remains at the forefront of investigations in science and engineering as international agencies strive for reduced acoustic emissions from the transportation and energy conversion sectors, whereas the focus of military programs involves structure-induced vibrations from increasingly powerful powerplants as well as crew and pilot safety issues for carrier-borne aircraft. Commercial aircraft noise reduction remains one of the primary driving factors behind acoustics-related research in the United States and Europe. It is a major component in the NASA's N+2/N+3 technology roadmap in the U.S., and in the DREAM and CLEAN SKY programs in Europe, as increasingly stringent noise regulations are phased in through ICAO Stage 4 restrictions. For example, the N+3 noise objective is for a cumulative reduction of 71 dB over Stage 4 levels with the 55 dB acoustic footprint of aircraft confined within the airport boundary.

Propulsion noise reduction targets are to be taken simultaneously with the often-conflicting goals of reducing the combustion byproducts NO_x and CO and increasing the thrust specific fuel consumption (TSFC). The 'unducted fan' or 'open rotor' concept represents a viable solution to reduce emissions and increase TSFC but original designs had an acoustic penalty that effectively killed its use in the late 1980s. Advancements in noise prediction methodologies for highly loaded transonic blades has improved the situation somewhat but fundamental work remains. (Large scale wind turbines, with power output in excess of 2 MW, share similar challenges.) Traditional turbofan engines have reached their bypass ratio limit for under-wing mounted configurations so it is not expected that further acoustic benefits through reduction of the jet exit velocity will be possible, leading to a resurgence in improving the fundamental understanding of turbulence-generated noise in high-speed jets. The possibility of buried engines in commercial and military aircraft is also pushing our understanding of engine-airframe integration noise mitigation methods, such as through acoustic liners and tailored scattering.

The complexities of turbulence-generated sound continues to preclude development of a unifying theoretical framework to inform our understanding and on which to develop effective noise mitigation methodologies. However, noise reduction demands continue to increase. To this end this year's summer program saw several projects focused on either fundamental aspects of noise generation (Talei *et al.*, Parchevsky *et al.*, and Bodony) or on quantifying the uncertainty of airfoil noise predictions to variations in the noise model and free stream conditions (Christophe & Moreau).

The study of Talei *et al.* examines, in part, the dynamics of axisymmetric premixed flames in the thin reaction zone regime where flame pinch off and flame stretching are known to be dynamically important. Near flame pinch off the local time rate-of-change of heat release varies significantly, leading to a localized, intense generation of sound. Their observations that the sound amplitude was a strong function of the Lewis number illustrates the dependence of direct combustion noise on the details of the flow chemistry and inter-species diffusion. For the case of unity Lewis number they develop a theory which improves on a pre-existing one for predicting the sound radiation. (This work occurred within the Combustion group and their manuscript may be found in that group's portion of the Proceedings.)

Parchevsky *et al.* examine the generation and propagation of sound within the Sun to support helioseismic inversion techniques. By accounting for the effects of thermodynamic and magnetic field stratification, the propagation of acoustic waves is sufficiently detailed to provide a level of confidence to aid calibration of inversion techniques for the analysis of experimental data from ongoing space missions, such as SOHO/MDI. Of particular interest to the authors is the scattering of nonacoustic waves into acoustic waves by the stratification. (This work occurred within the Solar Physics group and their manuscript may be found in that group's portion of the Proceedings.)

A novel study of the effects of uncertainty is examined by Christophe & Moreau to quantify uncertainty for the trailing-edge noise of a controlled-diffusion airfoil using RANS and LES when the inlet velocity is the random variable. For the RANS calculations two different wall pressure fluctuation models were used to evaluate the efficiency of a non-intrusive stochastic Galerkin method based on a stochastic collocation expansion which was found to be superior to a more traditional, and expensive, Monte Carlo approach. When applying the method to the LES calculations, which have increased physical fidelity and introduce sensitivities not seen in the RANS calculations, the authors find a considerable increase in uncertainty of the far-field radiation as a function of the unknown inflow velocity, relative to the RANS results.

The investigation by Bodony considers the fundamental issue of why, when a high-speed jet is heated at constant velocity, it's radiated sound reduces. By examining a mixing layer, the author hypothesizes that entropy fluctuations within the layer are enhanced relative to vortical disturbances and that this structural change in the fluctuations plays a key role. Numerical simulation of the full linearized equations of motion demonstrate the expected changes and are used as a database to inform a multiscale linear theory for the growth and decay of instability waves on the spatially evolving mixing layer.

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