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Aeroacoustic computation of gust-blade interaction

by

James E. Martin
Department of Mathematics
Christopher Newport University
Newport News, VA 23666

To better understand and address the challenges faced in computing the acoustics of flow fields, test problems must be considered. In the present study, the sound radiated by the interaction of a flat plate with an oncoming gust containing a two component, mean velocity is computed. The gust has a uniform mean flow in x with Mach number M_∞ equal to 0.5. The gust's mean velocity in y is of smaller amplitude and is given by

$$v = 0.1 \sin\left[\frac{\pi}{8}\left(\frac{x}{M_\infty} - t\right)\right]$$

This problem has been posed for an upcoming ICASE/LaRC workshop on benchmark problems in computational aeroacoustics.

A plate with a length of 30 units in x is used. The plate is assumed to be infinitesimally thin and is centered at the origin. All variables are made dimensionless using the scales specified. Acoustic quantities are obtained by numerically integrating the linearized Euler equations. Integration is performed on the computational domain $-100.0 \leq x \leq 100.0$, $-100.0 \leq y \leq 100.0$, using unit length grid spacing in x and in y. An integration scheme is sought which will provide accurate solution to the small quantities of interest at a minimal computational expense. Results indicate that with the given discretization a scheme of minimal fourth order accuracy might be adequate to approximate the waves within the given flow. Thus, a variation of the MacCormack scheme with fourth order accuracy in space and second order accuracy in time was chosen. A scheme with sixth order accuracy in space has also been implemented and results compared with those of the fourth order accurate scheme.

To ensure no mass flux, zero normal velocity is assigned at the plate. This condition will induce a discontinuity in the pressure across the plate location. Values for the perturbation pressure p' along the surface of the plate are obtained using a one-sided, third order Taylor expansion, such that $p'_y = 0$. In accordance with the Kutta condition, perturbation pressure at the trailing edge is assigned to zero. In the far field, radiation boundary conditions have been implemented. The effectiveness of the far field conditions are validated by computing in a larger computational domain and comparing the results.

Early in time, sound waves begin to radiate from the plate. A Doppler effect is observed. After the initial transients disappear, the strongest waves leave the trailing edge at an approximate 45 degree angle. The intensity pattern of pressure fluctuations shows five lobes (of increasing magnitude with increasing downstream direction) emerging from the plate. Undesirable short wave contaminants are observed in the computed pressure distribution along the plate surface. For a more accurate solution at small scales, a more refined discretization will be required.