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Abstract

INVESTIGATION OF COMPUTATIONAL AND SPECTRAL ANALYSIS METHODS FOR AEROACOUSTIC WAVE PROPAGATION

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Most computational fluid dynamics (CFD) schemes are not adequately accurate for solving aeroacoustics problems, which have wave amplitudes several orders of magnitude smaller yet with frequencies larger than the flow field variations generating the sound. Hence, a computational aeroacoustics (CAA) algorithm should have minimal dispersion and dissipation features. A dispersion relation preserving (DRP) scheme is, therefore, applied to solve the linearized Euler equations in order to simulate the propagation of three types of waves, namely: acoustic, vorticity, and entropy waves. The scheme is derived using an optimization procedure to ensure that the numerical derivatives preserve the wave number and angular frequency of the partial differential equations being discretized. Consequently, simulated waves propagate with the correct wave speeds and exhibit their appropriate properties. A set of radiation and outflow boundary conditions, compatible with the DRP scheme and derived from the asymptotic solutions of the governing equations, are also implemented.

Numerical simulations are performed to test the effectiveness of the DRP scheme and its boundary conditions. The computed solutions are shown to agree favorably with the exact solutions. The major restriction appear to be that the dispersion relations can be

preserved only for waves with wave lengths longer than four or five mesh spacings. The boundary conditions are found to be transparent to the outgoing disturbances. However, when the disturbance source is placed closer to a boundary, small acoustic reflections start appearing.

CAA generates enormous amount of temporal data which need to be reduced to understand the physical problem being simulated. Spectral analysis is one approach that helps us in extracting information which often can not be easily interpreted in the time domain. Thus, three different methods for the spectral analysis of numerically generated aeroacoustic data are studied. First, the capabilities of two traditional methods for spectral analysis, namely, the Blackman-Tukey method and the periodogram method, are compared in estimating the spectra of simple-periodic process. The periodogram is then applied to analyze transitory-deterministic processes. Finally, these two methods are compared with a more recent method, referred as the Weighted-Overlapped-Segment-Averaging (WOSA) method, in estimating the spectra of a chaotic (random-like) process.

From the demonstrative case for the spectral analyses of data generated by simple-periodic process, the periodogram method is found to give better estimate of *steep-sloped* spectra than the Blackman-Tukey method. Also, for this problem, the Hanning window is found to perform better with the periodogram method than with the Blackman-Tukey method. Finally, for the spectral analysis of data generated by the chaotic process, the periodogram method does not perform well, whereas, the WOSA and Blackman-Tukey methods give equivalently good results.