First Principles Based Studies of Rotorcraft Aeroacoustics

Annual Progress Report

for the period

September 1 , 1996 - December 31, 1996

prepared by

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INTRODUCTION

The objective of this research task is to develop computational aeroacoustics (CAA) tools that may be used in conjunction with computational fluid dynamics (CFD) analyses to predict the aeroacoustic characteristics of helicopter rotor blades. The noise sources of interest to the U. S. helicopter industry include shock noise, blade-vortex interaction noise, and broad band noise. At this time, these sources are modeled by first studying the underlying aerodynamics problem using computational fluid dynamics techniques, and subsequently using the blade surface unsteady pressures in a boundary element analysis such as WOPWOP. A variant of this technique is the Kirchoff method, which uses the CFD generated pressure and flow field data at a surface away from the nonlinear flow regime surrounding the blade.

The Kirchoff method and the boundary element methods can give accurate results only if the acoustic pressure field arrives at the "Kirchoff" surface, or leaves the blade surface at the correct phase and amplitude. Many modern CFD analyses are dissipative, and dispersive. The word "dissipation" refers to the gradual decrease in the amplitude of the sound waves as they propagate through a medium or coarse computational grid. The word "dispersion" refers to the propagation of the different wave components in the acoustic field at spurious, grid dependent speeds.

As a consequence, the accuracy of the acoustic field can only be assured by using an excessively fine grid for the CFD analysis. In other words, the CFD code may need to use a far finer grid than the aerodynamics analysis requires. As may be expected, calculations on such a fine grid can be prohibitively expensive.

OBJECTIVES OF THE PRESENT STUDY

The overall objective of the present study is to develop CFD and CAA algorithms which do not have the deficiencies mentioned in the preceding section. Specifically, this task attempts to develop

a) Algorithms that will propagate sound waves through a nonlinear mean flow field,
b) Algorithms that reduce the built-in dissipation in the CFD and CAA algorithms through the use of spatially high order interpolations,
c) Algorithms that reduce the dispersion in the CFD and CAA algorithms through a minimization of the dispersion error in the scheme.

PROGRESS DURING THE REPORTING PERIOD

During the reporting period, a low dispersion finite volume scheme for solving unsteady Navier-Stokes equations, and linearized acoustic wave equations was developed. This scheme was validated by a study of several classical acoustics problems that have been proposed by a CAA Workshop Organization Committee, chaired by Prof. Chris Tam of Florida State University.

The present investigator served on the organizing committee for this workshop, and also participated in the collection and calibration of computed results by the workshop attendees.

The low dispersion finite volume scheme produced satisfactory results for the workshop problems. To improve readability, the algorithm and the validation study (as presented in an AIAA Journal article) are given at http://www.ae.gatech.edu/~lsankar/CERT . It was found that this algorithm was superior to third order upwind schemes currently in use in many of the university and industry computer codes. It was also superior to the classical MacCormack scheme, and its fourth order accuracy variants.

EXTERNAL INTERACTIONS

The following external interactions resulted during the reporting period:

1. The principal investigator visited Roger Strawn, Jim McCroskey, Frank Caradonna, Yung Yu and Chee Tung of U. S. Army Aeroflightdynamics Directorate to brief them on the proposed research. Two visits were made. During one of this visit, it was suggested that this effort be directed towards improving the algorithms which may be retrofitted into existing industry standard codes such as TURNS and OVERFLOW, rather than towards the development of yet another stand-alone code. This suggestion will be followed during the second year.

2. The principal investigator visited McDonnell Douglas Helicopter Systems, and met with Hormoz Tadghighi, Ahmad Hassan, Bruce Charles and JanakiRam. A set of CAA codes developed at Georgia Tech prior to the initiation of the current NRTC task were made available to MDHS for their examination and comments. It was decided that the Georgia Tech algorithms will be embedded in the TURNS code as a user-selected option during the second year of the research. The modified code will subsequently be applied to high speed impulsive noise by Tadghighi of MDHS and Georgia Tech researchers.

PUBLICATIONS

The following research publications resulted during the reporting period.

1. Nance, D. V., Sankar, L. N. and Viswanathan, K., “An Improved Family of Low Dispersion Finite Volume Schemes for Aeroacoustic Applications,” Invited paper, Proceedings of the Second Asian CFD Conference, Dec. 14-18, 1996.
2. Nance, D., Sankar, L. N. and Viswananthan, K., “A Comparative Study of Low Dispersion Finite Volume Schemes for CAA Benchmark problems,” Proceedings of the Second CAA Workshop, Edited by Jay Hardin of NASA Langley research Center, In print.
3. Nance, D., Viswanathan, K. and Sankar, L. N., “Low Dispersion Finite Volume Scheme for Aeroacoustic Applications,” AIAA Journal, Vol. 35, No. 2, February 1997.

APPENDIX