PROGRESS SUMMARY

During the above period, a three-dimensional unsteady full potential solver was developed. This solver is capable of computing the unsteady, transonic flow around helicopter rotor blades in hover, and in high speed forward flight. The governing equations were cast and solved in a body-fitted coordinate system, allowing the solver to handle advanced rotor configurations, including swept and tapered tip shapes. Standard second order accurate finite difference schemes were used to discretize the governing equations in space. The time derivatives were discretized using first order accurate one-sided differences. This discretization leads to a set of highly coupled nonlinear equations for the velocity potential at every point in the body-fitted coordinate system. Linearization techniques were used at every time step to obtain a system of coupled equations for the velocity potential. Care was taken to ensure that the linearization in time preserves conservation of mass flux across moving shock waves, and that the solution accuracy remains first order in time and second order in space.

When supersonic regions are present, it is necessary to bias the above discretized equations in order that the proper upstream influence will be reflected by the numerical solution. This was accomplished by biasing the density in the upwind direction using a flux biasing technique.

The system of simultaneous equations for the velocity potential, or the change in the velocity potential from one time step to the next, were solved using a Strongly Implicit Procedure. The time marching algorithm has been constructed such that this solver may be used as a quasisteady solver, or as a fully unsteady time-accurate solver.
During the above period, this solver was vectorized for efficient performance on the CRAY-XMP computer system. This vectorized version of the solver, known as the RFS2 (Rotor Flow Solver Version 2) code has been supplied to the McDonnell Douglas Helicopter Co. on a magnetic tape, along with a brief user's guide.

The mathematical and numerical details of this solver, and a number of code validation studies have been documented in the public domain (Ref. 1). Recently, the U.S. Army Aeroflightdynamics Directorate personnel have reviewed this solver along with several other codes (Ref. 2).

REFERENCES


DEVELOPMENT OF ADVANCED COMPUTATIONAL TOOLS FOR
ROTOR AERODYNAMICS

Final Report Submitted to
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Prepared By

Lakshmi N. Sankar
Principal Investigator
School of Aerospace Engineering
Georgia Institute of Technology, Atlanta, GA
During the period January 1, 1985 - December 31, 1987, under the support of the McDonnell Douglas Helicopter Company research work was done on the development of computer codes that may be used to analyze the aerodynamics of modern high speed rotors in forward flight. As a result of this effort, the following four computer codes were developed.

1. The Rotor Flow Solver (RFS2) Code: This computer code may be used to study the unsteady subsonic and transonic flow past isolated rotor blades of arbitrary planform and shape in hover or in forward flight. This computer code solves the unsteady, compressible, full potential equation in a conservation form on a body-fitted coordinate system, using an efficient time-marching procedure.

2. The Helicopter Fuselage (FUSE1) Code: This computer code solves the steady compressible potential flow over helicopter fuselage configurations through numerical solution of the compressible full potential equation. It may be used to compute the fuselage induced upwash on the rotor blades.

3. The Dynamic Stall Solver (DSS2) Code: This computer code is a derivative of a 2-D computer code developed at Georgia Tech under the support of the U.S. Army Research Office. The basic solver was capable of computing steady, and unsteady compressible viscous flow past arbitrary airfoils undergoing small or large amplitude sinusoidal pitching motion. The MDHC version of the code, referred to as the DSS2 code in this report contains numerous enhancements to this basic flow solver, added to increase the solution efficiency and accuracy of the solver. This computer code may by used to generate static airfoil load characteristics, and dynamic stall hysteresis loops of new airfoils for use in rotorcraft performance codes.

4. The Dyamic Stall Solver (DSS3) Code: This flow solver is similar to the DSS2 code, but may be used to compute the dynamic stall
characteristics of airfoils which are at a significant cross flow angle (yaw) relative to the oncoming freestream.

The following students at Georgia Tech contributed this project:

1. Devon Prichard, a Graduate Co-Op Student, worked on the development and validation of the RFS2 code and was supported by the McDonnell Douglas Helicopter Company during the entire duration of this project.

2. Mr. Jiunn-Chi Wu, a Graduate Research Assistant, worked on the development and validation of the DSS2 and DSS3 Solver, and was supported by the McDonnell Douglas Helicopter Company during the period January 1- December 31, 1986.

3. Mr. Neep Hazarika, a Graduate Research Assistant contributed to the development of the fuselage code FUSE1, and was supported by the Georgia Institute of Technology.