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FINAL REPORT

NUMERICAL CALCULATIONS OF FLOW FIELDS

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Project 911-S
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ENGINEERING RESEARCH INSTITUTE
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INTRODUCTION

Iowa State University Engineering Research Institute Project 911-S is sponsored under NASA Grant NGR16-002-029. Major areas of study and goals of this research project are:

1) Determine the flow field generated by a finitely thick lifting three-dimensional wing with subsonic tips moving at supersonic speeds.

2) Determine the flow field produced by a lifting elliptic cone using finite difference techniques.

3) Study the problem of cross-flow instability associated with lifting delta wing configurations such as space shuttle.

The extent to which these goals have been met are summarized in the following sections. In addition, a status report of work currently in progress is included.

(1) Rectangular Wing Problem

The flow field produced by a rectangular wing moving at supersonic speeds has been determined for one particular geometry. The configuration studied was a symmetric double wedge airfoil with a tip section determined by a double cone section with the cone half angle the same as the wedge half angle.

The flow field around the wing was calculated and resolved downstream into the wake for a distance equal to about half the airfoil chord. A complete presentation and discussion of the results of this investigation is included in the thesis by J. M. Vogel listed in the thesis section of this report.

Future work planned includes evaluation of the wake flow field in more detail and a study of at least one other configuration. A comparison of computed results with recently acquired experimental data will be made.

(2) Elliptic Cone Problem

The flow field produced by a lifting elliptic cone has been studied through solutions produced using finite difference methods. Computed solutions obtained with this program show good agreement with those available in the literature. Even though good agreement with available data was obtained, the problem of correctly treating the entropy layer has not been resolved. This becomes apparent when flow variable distributions normal to the body surface are examined.

(3) Cross Flow Instability Problem

The elliptic cone program generated by Pratt was to be used to study the cross-flow instability problem. In order to make the program compatible with those in use at NASA, the program was rewritten in a new coordinate system using shock fitting. The program has been debugged and comparative cases for circular and elliptic cones have been run showing good agreement with available solutions. Future work planned includes a study of the entropy layer and its relationship to cross-flow instability. Evidence suggests that the instability problem arises solely due to incorrect treatment of the entropy layer.

(4) Shock Reflection from a Blunt Body

Progress on the problem of shock impingement on a blunt body has been slow. The time dependent blunt body program for a circular cylinder has been written and is presently being debugged. First attempts use shock capturing which will make the results difficult to interpret. After experience is gained with the shock capturing solution, shock fitting will be used.

Reports, Theses and Papers Produced through Funds Made Available by the Current Grant

Theses

Vogel, J. M., "Numerical Calculation of Flow Fields about Rectangular Wings of Finite Thickness in Supersonic Flow," PhD Dissertation, Iowa State University, Ames (1973).

Pratt, P. W., "Finite Difference Solutions to the Equations of Fluid Flow around an Elliptic Cone," MS Thesis, Iowa State University, Ames (1972).

Fattahi, B., "Application of Conservative Finite-Difference Methods to Advection Problems," ME Paper, Iowa State University, Ames (1971).

Papers Submitted for Publication

Anderson, D., and Fattahi, B., "A Comparison of Numerical Solutions of the Advection Equation," Engineering Research Institute, Iowa State University, Ames, Preprint 72118 (1972). Submitted to the Journal of Atmospheric Sciences.

Anderson, D., "A Comparison of Numerical Solutions to the Inviscid Equations of Fluid Motion," Engineering Research Institute, Iowa State University, Ames, Preprint 72247 (1972). Submitted to the Journal of Computational Physics.

Papers in Preparation

A paper based on Pratt's thesis with the elliptic cone is being prepared for submission to and presentation at the AIAA 6th Fluid and Plasma Dynamics Conference.

A paper based on Vogel's thesis is being prepared for the same meetings if abstract deadlines can be met. If not, it will be submitted for publication to the AIAA Journal.