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Final Report

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INTEGRATION OF VISCOUS EFFECTS INTO INVISCID COMPUTATIONAL METHODS

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SUMMARY

A variety of practical fluid dynamic problems related to the low-speed, high Reynolds number flow over aircraft and ground vehicles fall in a category where some simplified mathematical models become applicable. This provides the fluid dynamicists with a more economical computational tool, compared to the alternative solution of the Navier Stokes equations. For the attached flow field case the fluid can be divided into two regions: the first is a thin inner boundary layer, and the second is mainly an inviscid irrotational outer flow. Solution of the outer flow problem has evolved during the past years and at the present time the solution of the incompressible flow over fairly complex three-dimensional bodies is feasible. Results of such a computation are capable of estimating the pressure distribution and lift due to the shape of given solid boundaries. For solving the complete flow field, however, effects of the viscous flow need to be considered, too, which for attached flows will provide information such as the displacement thickness, the skin friction on the solid surface - or the drag force component due to this surface friction. Also more advanced viscous methods should be capable of indicating if the flow will have a tendency to detach (e.g predicting location of separation points, lines).

The objective of this study was to provide a brief survey of some of the viscous boundary layer solution methods and to propose a method for coupling between the inviscid outer flow and the viscous boundary layer solutions. Results of this survey and details of the viscous/inviscid flow coupling efforts are presented in the M. Sc. Thesis report of Mr. Steven K. Iguchi, which will be presented to NASA's Technical officer.

This two-year long research program was accomplished as a part of the NASA Ames Research Center Post Baccalaureate Program.

SCHEDULE

The Post Baccalaureate Program schedule was:

1. Sept. 1, 1988 - June 1, 1989 : Mr. Steven K. Iguchi completed his coursework at SDSU and began an extensive literature survey of boundary layer solution methods.

2. June 1, 1989 - Feb. 1, 1990 : Research and Thesis work at NASA Ames.

3. Feb. 1, 1990 - June 1, 1990 : Final semester at SDSU.

4. June 1, 1990 - August 30, 1990 : Concluding research at NASA Ames (which included the coupling of the PMARC code with a 3D boundary layer solver).

RESEARCH PROGRESS

Computational methods, based on the solution of the inviscid flow equations (panel codes)[1-4] are now widely used both as research and developement tools. These methods are successful in estimating the lifting properties of aircraft wings, up to moderate angles of attack. But recently, because of the need to operate aircraft at higher lift coefficient and under more severe maneuvers, where often flow separation occurs, attempts were made to include such viscous effects into some panel codes[1]. In reference 1 simple boundary layer models (e.g. flow on a flat plate) were added to the potential flow solver to allow corrections due to the boundary layer thickness. After this boundary layer calculation, an additional iteration is required with a modified set of boundary conditions, so that this displacement effect is included in the potential flow solution.

During this study Mr. Iguchi examined some of the more advanced boundary layer solution methods and incorporated one of them into an existing first-order panel code (PMARC). This allows the treatment of nonplanar and curved surfaces with more accuracy than with the previous "flat-plate" based models. Also, various criterions for estimating the location of separation lines were re-examined and their possible inclusion in the panel code were evaluated.

Technical details of this research and of the viscous/inviscid flow coupling efforts are presented in Mr. Steven K. Iguchi's M. Sc. Thesis (Report No.1) which will be presented to NASA's Technical officer. During Mr. Iguchi's research at the NASA Ames Research center he contributed to several other reports and they are listed in the next section (Reports Nos. 2 -4).

REPORTS, and PUBLICATIONS

The results of this research effort were summarized in the following publications.

1. Iguchi, S., "Integration of Viscous Effects into Inviscid Computational Methods," M. Sc. Thesis, SDSU, Dept. of Aerospace Engineering, 1990.

2. Ashby, D., Dudley M., And Iguchi, S. "Development and Validation of an Advanced Low-Order Panel Method," NASA TM 101024, 1988.

3. Ashby, D. L. Dudley, M. R. and Iguchi S. K. "Development and Validation of an Advanced Low-Order Panel Method," NASA TM 101024, Oct 1988.

4. Ashby, L. D., Dudley, M. D., Iguchi, S. K., Browne, L., and Katz, J., Potential Flow Theory and Operation Guide for the Panel Code PMARC," NASA TM (Rep. No. is not yet available), March 1990.

REFERENCES

1. Maskew B., "Program VSAERO, A Computer Program for Calculating the Nonlinear Aerodynamic Characteristics of Arbitrary Configurations, NASA CR-166476, Nov. 1982.

2. Carmichael R. L. and Ericson L. L. "PAN AIR - A Higher Order Panel Method for Predicting Subsonic or Supersonic Linear Potential Flows About Arbitrary Configurations", AIAA Paper No. 81-1255, June 1981.

3. Margason R. J., Kjelgaard S. O., Sellers W. L. 3rd., Morris C. E. K. Jr., Walkey K. B. and Shields E. W., "Subsonic Panel Methods - A Comparison of Several Production Codes", AIAA Paper 85-0280, Reno Nevada, Jan. 1985.

4. Katz J. and Maskew B. "Unsteady Low-Speed Aerodynamic Model for Complete Aircraft Configurations" AIAA Paper 86-2180 CP, Aug. 1986.