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# COMPUTATIONAL TECHNIQUE FOR COMPRESSIBLE VORTEX FLOWS USING THE INTEGRAL EQUATION SOLUTION

By

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## ABSTRACT

This report covers the achievements accomplished under this grant in the period of May 1985 to July 1986.

The steady full-potential equation is written in the form of Poisson's equation, and the solution for the velocity field is expressed in terms of an integral equation. The integral solution consists of two surface integrals and one volume integral. One of the surface integrals is a source integral term, over the wing surface, which represents the wing thickness effect while the other surface integral is a vortex integral term, over the wing and wake surfaces, which represents the lift. The volume integral term is a source distribution within a small computational volume around the wing. This term represents the total compressibility contribution of the flow.

The solution is obtained through successive iteration cycles. Each cycle of iteration consists of two sub-cycles, an inner cycle for wake relaxation and an outer cycle for the strength of the source distribution integrals representing the flow compressibility. The density gradients in the source distribution is computed by using a type-differencing scheme of the Murman-Cole type.

The method is applied to delta wings and the numerical examples show that a curved shock is captured on the wing suction side beneath the leading

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edge vortex sheet. Recently, a modified version of the scheme has been applied to rectangular wings. In this modified scheme, the surface integral terms have computed by using a bilinear distribution of vorticity on triangular vortex panels which represent the wing and its wake. The results have been compared with the available experimental data and they are in good agreement. Details of the scheme and the results are given in the attached publications.

The following list covers the papers and Ph.D. dissertation which have been produced under the full or partial support of this grant:

1. Kandil, O.A. and Yates, Jr., E.C., "Computation of Transonic Vortex Flows Past Delta Wings-Integral Equation Approach," AIAA paper No. 85-1582, Cincinnati, Ohio, July 1985.
2. Kandil, O.A. and Yates, Jr., E.C., "Transonic Vortex Flows Past Delta Wings: Integral Equation Approach," AIAA Journal, Vol. 24, No. 11, Nov. 1986, pp. 1729-1736.
3. Kandil, O.A., Chuang, A. and Chu, L-C., "Finite-Volume and Integral-Equation Techniques for Transonic and Supersonic Vortex-Dominated Flows," ICAS paper No. 86-1.5.4, 15th Congress of the International Council of the Aeronautical Sciences, London, England, Sept. 1986.
4. Chu, L-C., "Integral Equation Solution of the Full Potential Equation for Three-Dimensional, Steady, Transonic Wing Flows," Ph.D. Dissertation, Dept. of Mechanical Engineering and Mechanics, Old Dominion Univ., Norfolk, VA., March 1988; Advisor: Prof. Osama A. Kandil.