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SUBSONIC AERODYNAMIC LOADS ON MISSILES.(U)

NOV 78 A H NAYFEH, D T MOOK DAAG29-76-G-0034

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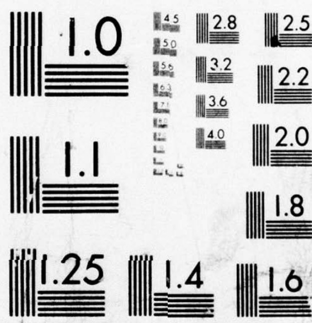


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# FINAL REPORT

# SUBSONIC AERODYNAMIC LOADS ON MISSILES

1. ARO Proposal Number: P-13164-E

2. Grant Number: DAA629-76-G-0034

3. Name of Institution: VPI & SU

4. Authors: A. H. Nayfeh and D. T. Mook

5. Summary of Most Important Results:

(a) Coupled Lifting Configurations

A nonlinear discrete-vortex method is developed to solve for the incompressible flow past wing-wing configurations. The method is exact because all the boundary conditions are exactly satisfied. Addition of an artificial viscosity to the vortex lines and utilization of the vortex-core concept ensured rapid and stable convergence of the iterative approach used to obtain the solution. The method is applied to delta and delta-like wing-wing configurations. Force-Free wake configurations, total-load coefficients and pressure distributions are calculated. These results agree closely with the experimental data of Behrbom. Long-coupled and short-coupled canard-wing configurations are handled by this approach.

(b) General Unsteady Lifting-Surface Problems

The non-linear vortex-lattice technique is developed for general unsteady motion of a thin wing in an imcompressible fluid. The problem is posed in terms of a moving frame of reference attached solutions and experimental to the wing. Hence, the elasticity of the wing surface is ignored. With the present method, there are no restrictions on the planform, aspect ratio, or angle of attack as long as separation occurs at sharp edges only. Time histories of the aerodynamic coefficients and the wake surface can be computed for a wide range of maneuvers. Loads are calculated using the unsteady Bernoulli equation. Roll and yaw motions are presented as numerical examples. The loads exhibit hysteretic-like behavior during cyclic motion. Satisfactory agreement with previous results is obtained.

(c) Flow Past Arbitrary Bodies

A numerical technique that predicts the potential flow past arbitrary bodies is presented. The technique utilizes a combination of surface distributions of vorticity, in the form of a vortex lattice, and sources to represent the body. The vortex lattice is formed by constant-strength quadrilateral as well as triangular elements. The technique features the minimum self-induced-velocity control point, which was found to be the best choice, and uses the element loop circulations as the unknowns while working with predetermined surface-source strengths. The surface-source strength of every element in the lattice is taken such that it cancels part of the freestream normal component on the element. For blunt bodies, the combination of a vortex lattice and sources appears to be slightly superior to either the vortex lattice or the sources acting alone. For slender bodies, the combination offers no apparent advantage over the vortex lattice alone, and the vortex lattice alone appears to be superior to the sources alone. The present technique was tested by comparing the predicted pressures with exact solutions and experimental data. The present method can reliably and accurately treat flows past arbitrary bodies and can be conveniently used in the analysis of wing-body combinations.

(d) Wing-Body Combinations

A method for calculating the steady nonlinear aerodynamic characteristics of wing-body combinations at low subsonic speeds is developed. The method uses a potential-flow model consisting of constant strength quadrilateral vortices distributed over the wing and body surfaces. The method accounts for separation from the lifting-surface (wing, cannard, tail) edges and for interference effects due to the presence of the body; however, it does not account for separation from the body. Total and distributed loads are predicted and compared with available experimental data as well as other theoretical models. Numerical examples are presented to demonstrate the versatility of the method for handling a variety of configurations.

(e) Dynamic-Aerodynamic Interactions

The nonlinear unsteady vortex-lattice technique in conjunction with a predictor-corrector method is used to calculate the dynamic response of a thin three-dimensional wing moving through an incompressible fluid. The problem is posed in terms of a moving reference frame attached to the wing. With the present technique, there are no restrictions on the planform, angle of attack or aspect ratio as long as separation occurs along sharp edges only and vortex bursting does not occur. The flow field, loads and motion of the wing are predicted simultaneously. The loads exhibit hysteretic behavior during cyclic motion and aerodynamic damping is observed.

6. Publications

(a) O. A. Kandil, D. T. Mook, and A. H. Nayfeh, "Application of the Nonlinear Vortex-Lattice Concept to Aircraft-Interference Problems", NASA CP-2001 (Advances in Eng. Science), 4, 1976, pp. 1321-1330.

(b) O. A. Kandil, D. T. Mook, and A. H. Nayfeh, "A Numerical Technique for Computing Subsonic Flow Past Three-Dimensional Canard-Wing Configurations with Edge Separation", AIAA Paper No. 77-1; Presented at the AIAA 15th Aerospace Sciences Meeting, January 24-26, 1977; Los Angeles, California; Accepted for Publication, J. Aircraft.

(c) D. F. Thrasher, D. T. Mook, O. A. Kandil, and A. H. Nayfeh, "Application of the Vortex-Lattice Concept to General, Unsteady Lifting-Surface Problems", AIAA Paper No. 77-1157; Presented at the AIAA 4th Atmospheric Flight Mechanics Conference, August 8-10, 1977, Hollywood, Florida.

(d) K. R. Asfar, D. T. Mook, and A. H. Nayfeh, "Application of the Vortex-Lattice Technique to Arbitrary Bodies", AIAA Paper No. 78-1205; Presented at the AIAA 11th Fluid and Plasma Dynamics Conference, July 10-12, 1978, Seattle Washington.

(e) E. Atta, and A. H. Nayfeh, "Nonlinear Aerodynamics of Wing-Body Combinations", AIAA Paper No. 78-1206; Presented at the AIAA 11th Fluid and Plasma Dynamics Conference, July 10-12 1978, Seattle, Washington.

(f) D. F. Thrasher, D. T. Mook, and A. H. Nayfeh, "Nonlinear Dynamic - Aerodynamic Interaction:, AIAA Paper No. 78-134;, Presented at the AIAA Atmospheric Flight Mechanics Conference, August 7-9, 1978, Palo Alto, California.

(g) D. F. Thrasher, D. T. Mook, and A. H. Nayfeh, "A Computer-Based Method for Analyzing the Flow Over Sails"; To be presented at the Fourth Chesapeake Sailing Yacht Symposium, January 20, 1979, Annapolis, Md.

7. Scientific Personnel Supported by This Project and Advanced Degrees Awarded During this Reporting Period:

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aerodynamics, unsteady aerodynamics, vortex lattice, wings, bodies, wing-wing combinations, wing-body combinations, nonlinear dynamics.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Five computer programs have been developed to calculate potential flows over wings, bodies, and wing-wing and wing-body conbinations. These programs are based on the vortex-lattice technique. They are not restricted by planform, aspect ratio and angle of attack as long as separation occurs from sharp edges and there is no vortex bursting. A main feature of these programs is the calculation of the shapes of the wakes. The unsteady version, which treats wing-flap systems, couples the nonlinear dynamics and aerodynamics.

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