Old Dominion University Research Foundation

DEPARTMENT OF MECHANICAL ENGINEERING & MECHANICS
COLLEGE OF ENGINEERING & TECHNOLOGY
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA 23529

VISCOUS FLOW SIMULATIONS OF INTERNAL STORE CARRIAGE AND SEPARATION

By

Oktay Baysal, Principal Investigator

Final Report
For the period ended May 15, 1991

Prepared for
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Research Grant NAG-1-664
David S. Miller, Technical Monitor
AAD-Super/Hyper Aerodynamics Branch

July 1991

DEPARTMENT OF MECHANICAL ENGINEERING & MECHANICS
COLLEGE OF ENGINEERING & TECHNOLOGY
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA 23529

VISCOUS FLOW SIMULATIONS OF INTERNAL STORE CARRIAGE AND SEPARATION

By

Oktay Baysal, Principal Investigator

Final Report
For the period ended May 15, 1991

Prepared for
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia 23665

Under
Research Grant NAG-1-664
David S. Miller, Technical Monitor
AAD-Super/Hyper Aerodynamics Branch

Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508-0369

July 1991

Final Report for the Grant NAG-1–664

VISCOUS FLOW SIMULATIONS OF INTERNAL STORE CARRIAGE AND SEPARATION

Oktay Baysal
Old Dominion University
Norfolk, Virginia

The internal carriage of stores by the military aircraft is an option for possible reductions in the aerodynamic drag and the observability. Trade studies of this option require considering the aircraft and the stores together. In an effort to develop a Computational Fluid Dynamic (CFD) code for such studies, an investigation has been conducted from 1986 to 1990 with the support of NASA Grant NAG-1–664.

The study was divided into five building-block steps. First, a full-Navier-Stokes code was developed to simulate the unsteady, three-dimensional cavity flows (a two-dimensional investigation of the cavity flows had previously been conducted in 1985–1986 under the preceding NASA Grant NAG-1–559). The open cavity flows (deep cavity), the closed cavity flows (shallow cavity), and the transitional cavity flows have been studied. The effects of a large yaw angle on the full-span cavity flow and the aeroacoustic environment of the cavities have also been investigated. Although most of the flows were supersonic, one transonic and one subsonic

flow cases have been included. An additional support for these two cases were made possible through a NASA cooperative agreement NCC-1-121.

As the second step, this code was then used to simulate the flows past various missile configurations at angles of attack up to 44°. The effects of incidence as well as the turbulence on the leeside flows were computationally captured.

The objective of this study has involved the interference flows of rather complex configurations with multiple, joint or disjoint, components of nonsimilar geometries. Hence, a hybrid domain decomposition (HDD) method was developed as the third step of the investigation. The strengths of the multiblock, zonal, and overlapped grids were judiciously combined employed for the present problem.

In the fourth step, the interference flow past a missile near a flat-plate-wing has been simulated using the HDD method. Finally, the fifth step involved the simulation of the internal store carriage and separation. Four different cases for two different configurations have been simulated. The computational results of all five steps have been successfully compared with the available wind-tunnel test data. The unsteady aerodynamic forces on the separating store have been computationally predicted.

The CFD code developed for this project is called Viscous Internal Store Carriage Code (VISCC). The code is rather general in its capability to simulate flows past complex configurations. It has been requested and used for a multitude of flow simulations by a number of branches of NASA Langley Research Center, various aerospace companies, and various research laboratories of Department of Defense.

Abstracts of the accomplishments at various stages have been reported in the 1988–1990 Research and Technology Reports of NASA Langley Research Center. Details of the project and its results have been presented in various national conferences as well as through NASA

briefings. Their written versions have been published in various national journals, conference proceedings and pamphlets, and as contractor reports. Their list is given below. Also, two Ph.D. dissertations and two Master of Science theses have been produced based on the findings of this project.

BIBLIOGRAPHY

Journal Papers:

Fouladi, K., Baysal, O., "Viscous Simulation Method for Unsteady Flows Past Multicomponent Configurations," ASME Journal of Fluids Engineering, (log. no. CJF-3047), to appear in 1992.

Srinivasan, S., Baysal, O., "Navier-Stokes Calculations of Transonic Flows Past 3-D Cavities," ASME Journal of Fluids Engineering, Vol. 113, No. 3, September 1991, pp. 300–306.

Baysal, O., Fouladi, K., Leung, R. W., Sheftic, J. S., "Interference Flows Past Cylinder-Fin-Sting-Cavity Assemblies," AIAA Journal of Aircraft (log. no. C7360), to appear in Vol. 28, No. 10, October 1991.

Baysal, O., Fouladi, K., Lessard, V. R., "Multigrid and Upwind Viscous Flow Solver on 3-D Overlapped and Embedded Grids," AIAA Journal, Vol. 29, No. 6, June 1991, pp. 903–910.

Baysal, O., Fouladi, K., Miller, D. S., "Computations of Supersonic Flows Over a Body at High Angles of Attack," AIAA Journal, Vol. 27, No. 4, April 1989, pp. 427–437.

Baysal, O., "Supercomputing of Supersonic Flows Using Upwind Relaxation and MacCormack Schemes," AIAA Journal of Fluids Engineering, Vol. 110, No. 1, March 1988, pp. 62-68.

Baysal, O. and Stallings, R. L., Jr., "Computational and Experimental Investigation of Cavity Flowfields," AIAA Journal, Vol. 26, No. 1, January 1988, pp. 6-8.

Wilcox, F. J., Jr., Baysal, O., Stallings, R. L., Jr., "Tangent, Semisubmerged, and Internal Store Carriage and Separation," Tactical Missile Aerodynamics, (Ed.: M. Hemsch), 2nd Ed., Progress in Astronautics and Aeronautics Series, Vol. 104, Ch. 15, AIAA, Washington, D.C., 1992.

Conference Papers:

Baysal, O., Fouladi, K., Lessard, V. R., Miller, D. S., "Navier-Stokes Simulations of Internal and External Store Carriage and Separation," Proceedings of Eight JOCG Aircraft/Stores Compatibility Symposium, Ft. Walton Beach, Florida, October 23–25, 1990.

Baysal, O., Fouladi, K., Leung, R.W., Sheftic, J.S., "Interference Flows Past Cylinder-Fin-Sting-Cavity Assemblies," AIAA Paper No. 90–3095 CP, Proceedings of 8th Applied Aerodynamics Conference, Portland, OR, August 20–22, 1990, pp. 884-892.

Fouladi, K. and Baysal, O., "Viscous Simulation Method for Flows Past a Configuration with Nonsimilar Multicomponents," Recent Advances in Computational Fluid Dynamics, (Ed.: O. Baysal), ASME-FED, Vol. 103, Winter Annual Meeting, Dallas, TX, November 25–30, 1990, pp. 181-190.

Baysal, O. and Yen, G-W., "Implicit and Explicit Computations of Flows Past Cavities With and Without Yaw," AIAA Paper No. 90–0049, AIAA 28th Aerospace Sciences Meeting, Reno, NV, January 8–11, 1990.

Baysal, O., "Viscous Analyses of Flows Related to Internal Store Carriage and Separation," Proceedings of Third Workshop on Weapons Internal Carriage and Release, Naval Air Development Center, Warminster, PA, April 25–26, 1989.

Baysal, O., Lessard, V. R., Fouladi, K., "A Multigrid Domain Decomposition Scheme with Embedded/Overlapped and Zonal Grids," SIAM Conference on Domain Decomposition Methods, Houston, TX, March 20–22, 1989.

Baysal, O., "Navier-Stokes Solutions for Store Separation and Related Problems," Proceedings of NASA Computational Fluid Dynamics Conference, NASA-CP-10038, Vol. 1, Moffet Field, CA, March 7–8, 1989, pp. 385–410.

Baysal, O., Fouladi, K., Lessard, V. R., "A Multigrid and Upwind Viscous Flow Solver on 3–D Embedded and Overlapped Grids," AIAA Paper No. 89–0464, AIAA 27th Aerospace Sciences Meeting, Reno, NV, January 9–12, 1989.

Srinivasan, S. and Baysal, O., "Navier-Stokes Calculations of Transonic Flows Past Open and Transitional Cavities," Advances and Applications in CFD, (Ed.: O. Baysal), ASME-FED, Vol. 66, Winter Annual Meeting, December 1988, pp. 169–180.

Baysal, O., Fouladi, K., Miller, D. S., "Computations of Vortical Supersonic Flows Over a Blunt-Nose-Cylinder at High Angles of Attack," AIAA Paper No.-88–0485, AIAA 26th Aerospace Sciences Meeting, Reno, NV, January 1988.

Baysal, O., Srinivasan, S., Stallings, R. L., "Unsteady and Viscous Calculations of Supersonic Flows Past Deep and Shallow Three-Dimensional Cavities," AIAA Paper No. 88–0101, AIAA 26th Aerospace Sciences Meeting, Reno, NV, January 1988.

Baysal, O., Fouladi, K., "Viscous Calculations of Supersonic Flows Past Cylinders at Angles of Attack," AIAA Paper No. 87–2414 CP, Proceedings of 5th AIAA Applied Aerodynamics Conference, Monterey, CA, August 17–19, 1987, pp. 338–347.

Baysal, O., Srinivasan, S., "Calculations of Wall and Free Turbulent Shear Flows at Supersonic Speeds," Turbulent Flow Symposium, (Ed.: W. Bower), ASME-FED Vol. 51, ASME Fluids Engineering Conference, Cincinnati, OH, June 14–18, 1987, pp. 55–60.

Baysal, O., Stallings, R. L., "Computational and Experimental Investigation of Cavity Flowfields," AIAA-Paper-No. 87–0114, AIAA 25th Aerospace Sciences Meeting, Reno, NV, January 1987.

Reports:

Baysal, O., Lessard, V. R., "An Overlapped Grid Method for Multigrid Finite Volume/Difference Flow Solvers," NASA-CR-182008, NASA LaRC, Hampton, VA, February 1990.

Baysal, O., Srinivasan, S., "Navier-Stokes Calculations of Transonic Flows Past Cavities," NASA-CR-4210, NASA LaRC, Hampton, VA, January 1989.

Baysal, O., Miller, D. S., "Interference Flows About Missile-Sting Assemblies Near and Inside Cavities," Research and Technology, NASA-TM-4243, Langley Research Center, pp. 84–85.

Baysal, O., Stallings, R. L., Jr., "Multigrid Solutions of Navier-Stokes Equations on Overlapped Grids," Research and Technology, NASA-TM-4150, Langley Research Center, pp. 31–32.

Stallings, R. L., Jr., "Calculation of Flow Field Over a Three-Dimensional Cavity," Research and Technology, NASA-TM-4078, Langley Research Center, pp. 26–27.