New York University
Courant Institute of Mathematical Sciences
251 Mercer Street
New York, New York 10012

(NASA-CR-158439) NUMERICAL DESIGN OF SHOCKLESS AIRFOILS Final Technical Report, 1 Sep. 1970 - 28 Feb. 1979 (New York Univ.) 8 p HC A02/MF A01 CSCL 01A

N79-20065

Unclas
G3/02 17270

Final Technical Report

NUMERICAL DESIGN OF TRANSONIC SHOCKLESS AIRFOILS

Principal Investigator: Paul R. Garabedian

NASA--Langley Research Center
Grant NGR-33-016-167

Period:
September 1, 1970 through February 28, 1979

New York University
Courant Institute of Mathematical Sciences

Final Technical Report

NUMERICAL DESIGN OF TRANSONIC SHOCKLESS AIRFOILS

NASA--Langley Research Center
Grant NGR-33-016-167

The work on the contract has been presented in considerable detail in five major publications [1 through 5]. In this final report we shall only attempt to indicate the most significant achievements.

The original goal of the contract was to develop a code that would be available to engineers to design shockless airfoils for transonic aerodynamics. This turned out to be far more difficult than was anticipated, and several early versions of the code failed to gain much acceptance by industry. However, in the last year we have brought out a final version that seems to overcome all the difficulties. It enables one to design a shockless airfoil that assumes a given pressure distribution up to a reasonable tolerance in transonic conditions. It is easy to obtain airfoils with minimal drag creep using this code. The code is now in use by several aircraft companies, including Pratt & Whitney, Lockheed and Fairchild Industries.

Perhaps the most successful contribution from the contract has been the code for two dimensional analysis of airfoils in transonic flow. This includes viscous effects through a turbulent boundary layer correction. The simulation of wind tunnel data is excellent and the code is widely used as a replacement for two dimensional testing. Predictions of performance of supercritical wing sections can be made rapidly and cheaply with this tool.

The third line of research on the contract was the development of a swept wing code and of codes that simulate the flow past wing body combinations. These codes are now in great demand by industry and are used to reduce wave drag on operational aircraft. Major contributions have been made to speed up the iterative schemes and mathematical methods involved in these calculations, which are in general far more time consuming than is the case for two dimensional flow.

At the stage of this final report it can be said that the mathematical problems in computational fluid dynamics for two dimensional transonic flow are well in hand; what remains to be done there is more in the line of development than of research. On the other hand, for three dimensional problems such as that of the swept wing, what has been achieved is rather a very promising beginning that opens up major possibilities for the future. The activities of the contract have provided a turning point for computational fluid dynamics, which now promises to become a major tool for future research in transonic aerodynamics.

The scientific personnel on the contract received a NASA Public Service Group Achievement Award in the fall of 1976.

References

1. Bauer, F., Garabedian, P., and Korn, D., A Theory of Supercritical Wing Sections, with Computer Programs and Examples, Lecture Notes in Economics and Mathematical Systems, Vol. 66, Springer-Verlag, New York, 1972.

2. Bauer, F., Garabedian, P., Jameson, A., and Korn, D., Supercritical Wing Sections II, a Handbook, Lecture Notes in Economics and Mathematical Systems, Vol. 108, Springer-Verlag, New York, 1975.

3. Bauer, F., Garabedian, P., and Korn, D., Supercritical Wing Sections III, Lecture Notes in Economics and Mathematical Systems, Vol. 150, Springer-Verlag, New York, 1977.

4. Caughey, D., and Jameson, A., "Numerical calculation of the transonic flow past a swept wing," ERDA Research and Development Report COO-3077-140, Courant Inst. Math. Sci., New York Univ., June 1977.

5. Jameson, A., "Iterative solution of transonic flow over airfoils and wings including flows at Mach 1," Comm. Pure Appl. Math., Vol. 27, 1974, pp. 283-309.

6. Bauer, F. and Garabedian, P. R., "Computer simulation of shock wave boundary layer interaction," Comm. Pure Appl. Math., Vol. XXVI, pp. 659-665, 1973.

7. Bauer, F., and Korn, D., "Computer simulation of transonic flow past airfoils with boundary layer correction," Proc. A.I.A.A. 2nd Computational Fluid Dynamics Conference, Hartford, Conn., June 19-20, 1975, pp. 184-204.

8. Jameson, A., "Transonic potential flow calculations using conservation form," Proc. A.I.A.A. 2nd Computational Fluid Dynamics Conference, Hartford, Conn., June 19-20, 1975, pp. 148-155.

9. Jameson, A., "Accelerated iteration schemes for transonic flow calculations using fast Poisson solvers," ERDA Research and Development Report COO-3077-82, Courant Inst. Math. Sci., New York Univ., March 1975.

10. Garabedian, P. R., "Transonic flow theory of airfoils and wings," 13th Annual Meeting, November 1 - 3, 1976, Soc. of Engineering Science, Hampton, Va., NASA CP-2001, pp. 1349-1355.

References - continued

11. Jameson, A., coauthored, "Relaxation solutions for inviscid axisymmetric transonic flow over blunt or pointed boxies," Proceedings AIAA Computational Fluid Dynamics Conference, Palm Springs, July 1973.

12. Jameson, A., "Numerical calculations of the three-dimensional flow over a yawed wing," Proceedings AIAA Computational Fluid Dynamics Conference, Palm Springs, July 1973.

13. Jameson, A., "Three dimensional flows around airfoils with shocks," IFIP Symposium on Computing Methods in Applied Sci. and Engr., IRIA, Paris, France, December 1973, pp. 554-571.

14. Jameson, A., and O'Malley, R. E., "Cheap control of the time invariant regulator," IREE Transactions on Automatic Control, Vol. AC-20, No. 2, April 1975.

15. Jameson, A., "Numerical solution of nonlinear partial differential equations of mixed type," SYNSPADE 1973, Academic Press.

16. Jameson, A., "Numerical computation of transonic flows with shock waves," Symposium Transsonicum II, Gottingen, September 1975, Springer-Verlag.

17. Garabedian, P. R. "Computational transonics," NASA Conference on Aerodynamic Analyses Requiring Advanced Computers, Langley Research Center, March 4, 5, and 6, 1975.

18. Jameson, A., "Accelerated iterative calculations of transonic nacelle flow fields," (with D. A. Caughey), AIAA Paper 76-100, January 1976.

19. Jameson, A., and Caughey, D. A., "Calculation of transonic potential flow fields about complex three dimensional configurations," Proceedings of Project SQUID Workshop on Transonic Flow Problems in Turbomachinery, Monterey, February 1976.

20. Garabedian, P., and Korn, D., "A systematic method for computer design of supercritical airfoils in cascades," Comm. Pure Appl. Math., Vol. 24, 1976, pp. 369-382.

21. Garabedian, P., "Computation of wave drag for transonic flow," Journal d'Analyse Mathématique, Vol. 30, 1976, pp. 164-171.

22. Garabedian, P. R., "WING supercritical," McGraw Hill Yearbook Science and Technology, 1977.

References - continued

23. Jameson, A., "Numerical calculation of transonic flow past a swept wing by a finite volume method," Third IFIP Conference on Computing Methods in Applied Science and Engineering, Versailles, France, 1977.

24. Jameson, A., and O'Malley, R. E., "Singular perturbation and singular arcs, Part II" IEEE Transactions on Automatic Control, Vol. AC 22, No. 2, April 1977.

25. Jameson, A., Balhaus, W. F., and Albert J., "Implicit approximate factorization schemes for the efficient solution of steady transonic flow problems," Proceedings of Third AIAA Computational Fluid Dynamics Conference, Albuquerque, June 1977.

26. Jameson, A., and Caughey, D. A., "A finite volume method for transonic potential flow calculations," Proceedings of Third AIAA Computational Fluid Dynamics Conference, Albuquerque, June 1977.

27. Jameson, A., and Caughey, D. A., "Numerical calculation of transonic potential flow about wing-body combinations," AIAA Paper 77-677, June 1977.

28. Sanz, José M., "A well posed boundary value problem in transonic gas dynamics," DOE Research and Development Report COO-3077-149, Courant Inst. Math. Sci., New York University, February 1978.

29. Sanz, José M., "A well posed boundary value problem in transonic gas dynamics," Comm. Pure Appl. Math., Vol. XXXI, 671-679 (1978).

30. Jameson, A., and Keller, J. D., "Preliminary study of the use of the STAR-100 computer for transonic flow calculations," AIAA Paper 78-12, January 1978.

31. Jameson, A., Caughey, D. A., and Newman, P. A., "Recent experiences with three dimensional transonic potential flow calculations," Proceedings of CTOL Transport Technology Conference, NASA Langley, February 1978, NASA CP-2036.

32. Jameson, A., "Transonic flow calculations," in Numerical Methods in Fluid Dynamics, (edited by M. J. Wirz and J. J. Smolderen), McGraw-Hill, New York, 1978.

References - continued

Status Reports for Numerical Design of Transonic Shockless Airfoils:

Summary of Progess and Proposed Research, 1971.

Summary of Progress and Proposed Research, submitted February 4, 1972.

Letter dated April 12, 1973 to J. South, NASA Langley.

Summary of Progress and Proposed Research, submitted August 1, 1972.

Summary of Progress in 1972-1973 and Proposed Research for 1973-1974 submitted March 26, 1973.

Letter dated September 17, 1973 to J. South, NASA Langley.

Report of Progress and Proposal for Future Research, submitted April 9, 1974.

Semi-Annual Progress Report for period ending August 31, 1974.

Semi-Annual Progress Report for period ending February 28, 1975.

Semi-Annual Progress Report for period ending August 31, 1975.

Semi-Annual Progress Report for period ending February 28, 1976.

Semi-Annual Progress Report for period ending August 31, 1976.

Semi-Annual Progress Report for period ending November 30, 1977.

Semi-Annual Progress Report for period ending May 31, 1978.

Final Technical Report for period: September 1, 1970 through February 28, 1979.