Viscous-inviscid interaction with the quasi-simultaneous method for 2D and 3D aerodynamic flow

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Bibliography

[1] Abbott, I.H. and Von Doenhoff, A.E. *Theory of Wing Sections*. Dover, New York, 1959.

[2] Arnal, D., Habiballah, M. and Coustols, E. Laminar Instability Theory and Transition Criteria in Two and Three-Dimensional Flow. *La Recherche Aérospatiale*, 2:45–63, 1984.

[3] Arnold, F. and Thiele, F. A Laplace Interaction Law for the Computation of Viscous Airfoil Flow in Low and High Speed Aerodynamics. AIAA 93-3462-CP, 1993.

[4] Arthur, M.T. A Method for Calculating Subsonic and Transonic Flows over Wings or Wing-Fuselage Combinations with an Allowance for Viscous Effects. RAE TM Aero 1996, 1984.

[5] Ashill, P.R. and Smith, P.D. An Integral Method for Calculating the Effects on Turbulent Boundary-Layer Development of Sweep and Taper. RAE TR 83053, 1983.

[6] Ashill, P.R., Wood, R.F. and Weeks, D.J. An Improved, Semi-Inverse Version of the Viscous Garabedian and Korn Method (VGK). RAE TR 87002, 1987.

[7] Brebner, G.G. and Wyatt, L.A. Boundary Layer Measurements at Low Speed on Two Wings of 45° and 55° Sweep. ARC CP 554, 1961.

[8] Carter, J.E. Solutions for Laminar Boundary Layers with Separation and Reattachment. AIAA 74-583, 1974.

[9] Carter, J.E. Viscous-Inviscid Interaction Analysis of Turbulent Separated Flow. AIAA 81-1241, 1981.

[10] Carter, J.E. and Wornom, S.F. Solutions for Incompressible Separated Boundary Layers Including Viscous-Inviscid Interaction, *Aerodynamic Analysis Requiring Advanced Computers*. NASA SP-347, 1975.

[11] Catherall, D. and Mangler, K.W. The Integration of the Two-Dimensional Laminar Boundary-Layer Equations past the Point of Vanishing Skin Friction. *Journal of Fluid Mechanics*, 26(1):163–182, 1966.

[12] Cebeci, T., Hefazi, H., and Roknaldin, F. Predicting Stall and Post-Stall Behaviour of Airfoils at Low Mach Numbers. *AIAA Journal*, 33(4):595–602, 1995.

[13] Coenen, E.G.M. Modifications to the DERA VFP Code to Include Quasi-Simultaneous Coupling (QS-VFP). Technical Report 98-01, University of Bristol, 1998.

[14] Coenen, E.G.M. Quasi-Simultaneous Coupling for Wing and Aerofoil Flow. In Lai, C.-H., Björstad, P.E., Cross, M. and Widlund, O.B., editor, *Domain Decomposition Methods in Sciences and Engineering*, pages 197–205, Bergen, Domain Decomposition Press, 1999.

[15] Coenen, E.G.M. Quasi-Simultaneous Viscous-Inviscid Interaction for Swept Tapered Wings. In 7th *Annual Conference of the Association for Computational Mechanics in Engineering, ACME 1999*, Durham, United Kingdom, 1999.

[16] Coenen, E.G.M., Veldman, A.E.P. and Patrianakos, G. Quasi-Simultaneous Viscous-Inviscid Interaction for Three-Dimensional Turbulent Wing Flow. In 22nd *International Congress of Aeronautical Sciences, ICAS 2000*, Harrogate, United Kingdom, 2000.

[17] Coenen, E.G.M., Veldman, A.E.P. and Patrianakos, G. Viscous-Inviscid Interaction Method for Wing Calculations. In *European Congress on Computational Methods in Applied Sciences and Engineering, ECCOMAS 2000*, Barcelona, Spain, 2000.

[18] Cousteix J. Three-Dimensional and Unsteady Boundary-Layer Computations. *Annual Review Fluid Mechanics*, 18:173–196, 1986.

[19] Cousteix, J. *Couche Limite Laminaire*. Cepadeus Editions, 1988.

[20] Cousteix, J. and Houdeville, R. Singularities in Three-Dimensional Turbulent Boundary-Layer Calculations and Separation Phenomena. AIAA 81-4201, 1981.

[21] Cross, A.G.T. Calculation of Compressible Three Dimensional Turbulent Boundary Layers with Particular Reference to Wings and Bodies. BAe Brough, YAD Note 3379, 1979.

[22] Cumpsty, N.A. and Mead, M.R. The Calculation of Three-Dimensional Turbulent Boundary Layers Part II: Attachment-Line Flow on an Infinite Wing. *Aeronautical Quarterly*, 18:150–164, 1967.

[23] Dargel, G. and Thiede, P. Viscous Transonic Airfoil Flow Simulation by an Efficient Viscous-Inviscid Interaction Method. AIAA 87-0412, 1987.

[24] Delery, J.M. and Formery, M.J. A Finite Difference Method for Inverse Solutions of Three-Dimensional Turbulent Boundary Layer Flow. AIAA 83-0301, 1983.

[25] Drela, M. *Two-Dimensional Aerodynamic Design and Analysis Using the Euler Equations*. PhD thesis, MIT, 1985.

[26] Drela, M. XFOIL: An Analysis and Design System for Low Reynolds Number Airfoils. Low Reynolds Number Aerodynamics, 1989.

[27] Drela, M. and Giles, M.B. Viscous-Inviscid Analysis of Transonic and Low Reynolds Number Airfoils. *AIAA Journal*, 25:1347–1355, 1987.

[28] Duck, P.W. and Burggraf, O.R. Spectral Solutions for Three-Dimensional Triple-Deck Flow over Surface Topography. *Journal of Fluid Mechanics*, 162:1–22, 1986.

[29] East, L.F., Smith, P.D. and Merryman, P.J. Prediction of the Development of Separated Turbulent Boundary Layers by the Lag-Entrainment Method. RAE TR 77046, 1977.

[30] Edwards, D.E. Analysis of Three-Dimensional Flow Using Interacting Boundary-Layer Theory. In Smith, F.T. and Brown, S.N., editor, *IUTAM Symposium on Boundary-Layer Separation*, pages 163–178. Springer-Verlag, 1987.

[31] Edwards, D.E. and Carter, J.E. Analysis of Three-Dimensional Separated Flow with the Boundary-Layer Equations. AIAA 85-1499, 1985.

[32] Edwards, D.E., Carter, J.E. and Smith, F.T. Analysis of Three-Dimensional Separated Flow with the Boundary-Layer Equations. *AIAA Journal*, 25(3):380–387, 1987.

[33] Firmin, M.C.P. Calculations of Transonic Flow over Wing/Body Combinations with an Allowance for Viscous Effects. RAE TM Aero 1861, 1980.

[34] Firmin, M.C.P. Applications of RAE Viscous Flow Methods near Separation Boundaries for Three-Dimensional Wings in Transonic Flow. RAE TM Aero 2065, 1986.

[35] Fluid Dynamics Panel Working Group 10. Calculation of 3D Separated Turbulent Flows in Boundary Layer Limit. AGARD-AR-255, 1990.

[36] Forsey, C.R. and Carr, M.P. The Calculation of Transonic Flow over Three-Dimensional Swept Wings Using the Exact Potential Equation. DGLR Symposium Transonic Configurations, Bad Harzburg, DGLR Paper 78-064, 1978.

[37] Goldstein, S. On Laminar Boundary Layer-Flow near a Position of Separation. *Quarterly Journal of Mechanics and Applied Mathematics*, 1:43–69, 1948.

[38] Granvill, P.S. The Calculation of the Viscous Drag on Bodies of Revolution. David Taylor Model Basin Report 849, 1953.

[39] Green, J.E. Application of Head's Entrainment Method to the Prediction of Turbulent Boundary Layers and Wakes in Compressible Flow. RAE TR 72079, 1972.

[40] Green, J.E., Weeks, D.J. and Brooman, J.W.F. Prediction of Turbulent Boundary Layers and Wakes in Compressible Flow by a Lag-Entrainment Method. RAE TR 72231, 1973.

[41] Hastings, R.C. and Williams, B.R. Studies of the Flow Field near a NACA 4412 Aerofoil at Nearly Maximum Lift. *Aeronautical Journal*, 91(901):29–44, 1987.

[42] Head, M.R. Entrainment in the Turbulent Boundary Layer. ARC R&M 3152, 1960.

[43] Henkes, R.A.W.M. and Veldman, A.E.P. On the Breakdown of the Steady and Unsteady Interacting Boundary-Layer Description. *Journal of Fluid Mechanics*, 179:513–529, 1987.

[44] Hess, J.L. and Smith, A.M.O. Calculation of Potential Flow about Arbitrary Bodies. *Progress in Aeronautical Sciences*, 8:1–138, 1966.

[45] Horn, R.A. and Johnson C.R. *Topics in Matrix Analysis*. Cambridge University Press, 1991.

[46] Horton, H.P. A Semi-Empirical Theory for the Growth and Bursting of Laminar Separation Bubbles. ARC CP 1073, 1967.

[47] Horton, H.P. Numerical Investigation of Regular Laminar Boundary Layer Separation. AGARD-CP-168, 1975.

[48] Houwink, R. and Veldman, A.E.P. Steady and Unsteady Flow Computations for Transonic Airfoils. AIAA 84-1618, 1984.

[49] Jobe, C.E. and Burggraf, O.R. The Numerical Solution of the Asymptotic Equations of Trailing Edge Flow. *Proceedings Royal Society*, A 340:91–111, 1974.

[50] Katz, J. and Plotkin, A. *Low-Speed Aerodynamics; From Wing Theory to Panel Method*. McGraw-Hill, 1991.

[51] Kerwin, J.E., Kinnas, S.A., Lee, J.-T. and Shih, W.-Z. A Surface Panel Method for the Hydrodynamic Analysis of Ducted Propellers. *SNAME Transactions*, 95:93–122, 1987.

[52] King, D.A. and Williams, B.R. Developments in Computational Methods for High-Lift Aerodynamics. *Aeronautical Journal*, pages 265–288, 1988.

[53] Kusunose, K., Wigton, L. and Meredith, P. A Rapidly Converging Viscous/Inviscid Coupling Code for Multi-Element Airfoil Configurations. AIAA 91-0177, 1991.

[54] Lagerstrom, P.A. Solutions of the Navier-Stokes Equations at Large Reynolds Number. *SIAM Journal of Applied Mathemtics*, 28(1):202–214, 1975.

[55] Lazareff, M. and Le Balleur, J.C. Computation of Three-Dimensional Flows by Viscous-Inviscid Interaction Using the 'MZM' Method. AGARD CP-412, 1986.

[56] Le Balleur, J.C. Couplage Visqueux-Non Visqueux: Analyse du Problème Incluant Décollements et Ondes de Choc. *La Recherche Aérospatiale*, 6:349–358, 1977.

[57] Le Balleur, J.C. Couplage Visqueux-Non Visqueux: Méthode Numérique et Applications aux Écoulements Bidimensionnels Transsoniques et Supersoniques. *La Recherche Aérospatiale*, 2:65–76, 1978.

[58] Le Balleur, J.C.and Girodroux-Lavigne, P. Calculation of Fully Three-Dimensional Separated Flows with an Unsteady Viscous-Inviscid Interaction Method. In Cebeci, T., editor, *Numerical and Physical Aspects of Aerodynamic Flows V*, 1992.

[59] Lees, L. and Reeves, B. L. Supersonic Separated and Reattaching Laminar Flows: I. General Theory and Application to Adiabatic Boundary-Layer Shock-Wave Interactions. *AIAA Journal*, 2:1907–1920, 1964.

[60] Lighthill, M.J. On Displacement Thickness. *Journal of Fluid Mechanics*, 4:383–392, 1958.

[61] Lock, R.C. and Williams, B.R. Viscous-Inviscid Interactions in External Aerodynamics. *Progress Aerospace Sciences*, 24:51–171, 1987.

[62] Mager, A. Generalization of Boundary-Layer Momentum-Integral Equations to Three-Dimensional Flows Including those of Rotating System. NACA R 1067, 1952.

[63] Mellor, G.L. The Large Reynolds Number Asymptotic Theory of Turbulent Boundary Layers. *International Journal of Engineering Science*, 10:851–873, 1972.

[64] Melnik, R.E. Some Applications of Asymptotic Theory to Turbulent Flow. AIAA 91-0220, 1991.

[65] Melnik, R.E. and Chow, R. Asymptotic Theory of Two Dimensional Trailing Edge Flows. NASA SP-347 (also Grumman Research Dept. Report RE-510J), 1975.

[66] Melnik, R.E. and Grossman, B. On the Turbulent Viscid-Inviscid Interaction at a Wedge-Shaped Trailing Edge. In Cebeci, T., editor, *Numerical and Physical Aspects of Aerodynamic Flows I*, pages 211–235, 1982.

[67] Melnik, R.E., Chow, R. and Mead, H.R. Theory of Viscous-Inviscid Transonic Flow over Airfoils at High Reynolds Number. AIAA 77-680, 1977.

[68] Messiter, A.F. Boundary Layer Flow near the Trailing Edge of a Flat Plate. *SIAM Journal on Applied Mathematics*, 18:241–257, 1970.

[69] Milewski, W.M. *Three-Dimensional Viscous Flow Computations Using the Integral Boundary Layer Equations Simultaneously Coupled with a Low Order Panel Method*. PhD thesis, Department of Ocean Engineering, MIT, 1997.

[70] Moran, J. *An Introduction to Theoretical and Computational Aerodynamics*. John Wiley and Sons, 1984.

[71] Morino, L. and Kuo, C.-C. Subsonic Potential Aerodynamics for Complex Configurations: A General Theory. *AIAA Journal*, 12(2):191–197, 1974.

[72] Mughal, B. and Drela, M. A Calculation Method for the Three-Dimensional Boundary-Layer Equations in Integral Form. AIAA 93-0786, 1993.

[73] Myring, D.F. An Integral Prediction Method for Three-Dimensional Turbulent Boundary-Layers in Incompressible Flow. RAE TR 70147, 1970.

[74] Neiland, V.Ya. Theory of Laminar Boundary Layer Separation in Supersonic Flow. *Fluid Dynamics*, 4:33–35, 1970.

[75] Nishida, B. and Drela, M. Fully Simultaneous Coupling for Three-Dimensional Viscous/Inviscid Flows. AIAA 95-1806-C, 1995.

[76] Prandtl, L. Uber Flüssigkeitsbewegung bei sehr kleiner Reibung. *Proceedings International Mathematical Congress*, pages 484–491, 1904.

[77] Roberts, W.B. Calculation of Laminar Separation Bubbles and their Effect on Airfoil Performance. *AIAA Journal*, 18(1):25–31, 1980.

[78] Roget, C., Brazier, J.Ph., Cousteix, J. and Mauss, J. A Contribution to the Physical Analysis of Separated Flows past Three-Dimensional Humps. *European Journal of Mechanics B/Fluids*, 17(3):307–329, 1998.

[79] Schlichting, H. *Boundary Layer Theory*. McGraw-Hill, 1979.

[80] Smith, F.T. Theoretical Aspects of Steady and Unsteady Laminar Separation. AIAA 84-1582, 1984.

[81] Smith, F.T. Steady and Unsteady 3-D Interactive Boundary Layers. *Computers and Fluids*, 20(3):243–268, 1991.

[82] Smith, P.D. Calculation Methods for Three-Dimensional Turbulent Boundary Layers. ARC R&M 3523, 1966.

[83] Smith, P.D. An Integral Method for Three-Dimensional Compressible Turbulent Boundary Layer. ARC R&M 3739, 1972.

[84] Smith, P.D. The Numerical Computation of Three-Dimensional Boundary Layers. In Fernhoh, H.M. and Krause, E., editor, *IUTAM Symposium on Three-Dimensional Turbulent Boundary Layers*, pages 266–285. Springer-Verlag, 1982.

[85] Smith, P.D. A Viscous Package for Attached and Separated Flows on Swept and Tapered Wings. RAE TR 89027, 1989.

[86] Somers, M.A.M. and Veldman, A.E.P. The Inclusion of Streamline Curvature in a Quasi-Simultaneous Viscous-Inviscid Interaction Method for Transonic Airfoil Flow. Preprint available at `http://www.math.rug.nl/~veldman/preprints.html`, 1999.

[87] Stewartson, K. Multistructured Boundary Layers on Flat Plates and Related Bodies. *Advances in Applied Mechanics*, 14:145–239, 1974.

[88] Stewartson, K., F.R.S. and Williams, P.G. Self-Induced Separation. *Proceedings Royal Society*, A 312:181–206, 1969.

[89] Stewartson, K., Smith, F.T. and Kaups, K. Marginal Separation. *Studies in Applied Mathematics*, 67:45–61, 1982.

[90] Streett, C.L. Viscous-Inviscid Interaction for Transonic Wing-Body Configurations Including Wake Effects. *AIAA Journal*, 20(7):915–923, 1982.

[91] Sychev, V.V. and Sychev, V.V. Turbulent Separation (Russian translation). *Zhurnal Vychislitelnoi Matematiki i Matematicheskoi*, 20(6):1500–1512, 1980.

[92] Sykes, R.J. On Three-Dimensional Boundary Layer Flow over Surface Irregularities. *Proceedings Royal Society*, A 373:311–329, 1980.

[93] Van Dalsem, W.R. and Steger, J.L. Using the Boundary-Layer Equations in Three-Dimensional Viscous Flow Simulation. AGARD-CP-412, 1986.

[94] Van der Wees, A.J. and Van Muijden, J. A Robust Quasi-Simultaneous Interaction Method for a Full Potential Flow with a Boundary Layer with Application to Wing/Body Configurartions. In Cebeci, T., editor, *Numerical and Physical Aspects of Aerodynamic Flows V*, 1992.

[95] Van der Wees, A.J., Van Muijden, J. and Van der Vooren, J. A Fast and Robust Viscous-Inviscid Interaction Solver for Transonic Flow about Wing/Body Configurations on the Basis of Full Potential Theory. AIAA 93-3026, 1993.

[96] Varga, R.S. *Matrix Iterative Analysis*. Prentice-Hall, 1962.

[97] Veldman, A.E.P. Boundary Layers with Strong Interaction from Asymptotic Theory to Calculation Method. Proceedings BAIL 1 Conference, Dublin, 1980.

[98] Veldman, A.E.P. New, Quasi-Simultaneous Method to Calculate Interacting Boundary Layers. *AIAA Journal*, 19:79–85, 1981.

[99] Veldman, A.E.P. Strong Viscous-Inviscid Interaction and the Effects of Streamline Curvature. *CWI Quarterly*, 10(3&4):353–359, 1997.

[100] Veldman, A.E.P. and Van de Vooren, A.I. Drag of a Finite Plate. In R.D. Richtmyer, editor, *Proceedings 4th International Conference on Numerical Methods in Fluid Dynamics, Lecture Notes in Physics*, volume 35, pages 422–430, Springer-Verlag, Berlin, 1975.

[101] Veldman, A.E.P., Lindhout, J.P.F., De Boer, E. and Somers, M.A.M. VISTRAFS: A Simulation Method for Strongly Interacting Viscous Transonic Flow. In Cebeci, T., editor, *Numerical and Physical Aspects of Aerodynamic Flows IV*, pages 37–51, 1990.

[102] Verhoff, A., Chen, H.H., Cebeci, T. and Michal, T. An Accurate and Efficient Interactive Boundary-Layer Method for Analysis and Design of Airfoils. AIAA 96-0328, 1996.

[103] Weber, J. and Brebner, G.G. Low Speed Tests on 45º Sweptback Wings. Part I: Pressure Measurements on Wings of Aspect Ratio 5. RAE R Aero 2374, 1950.

[104] White, F.M. *Viscous Fluid Flow*. McGraw-Hill, 1991.

[105] Wigton, L. and Yoshihara, H. Viscous-Inviscid Interactions with a Three Dimensional Inverse Boundary Layer Code. Presented at Symposium on *Numerical and Physical Aspects of Aerodynamic Flows II*, 1983.

[106] Williams, B.R. The Prediction of Separated Flow Using a Viscous-Inviscid Interaction Method. *Aeronautical Journal*, 89:185–197, 1985.

[107] Williams, B.R. Viscous-Inviscid Interaction Schemes for External Aerodynamics. RAE TM Aero 2152, 1989.

[108] Yoshihara, H. and Wai, J.C. Transonic Turbulent Separation on Swept Wings - A Return to the Direct Formulation. AIAA 84-0265, 1984.

[109] Young, A.D. *Boundary Layers*. BSP Professional Books, 1989.

[110] Young, D.M. *Iterative Solution of Large Linear Systems*. Academic Press, 1971.