

Contents

Lectures on experimental results are marked with *

Problems for Analysis

Problem I: Flow over a Slender Cone	6
Problem II: Turbulent Base Flow	8
Problem III: Flow over a 2D Ramp	10
Problem IV: Flow over a 3D Obstacle	13
Problem V: Corner Flow	15
Problem VI: Double (Simple) Ellipsoid	17
Problem VII: Flow over a Delta Wing	23
Problem VIII: Non-equilibrium Flow in an Arc Jet or a Shock Tube	32
Appendix I: Non-equilibrium Model for Problem VI	38
Appendix II: Pitot Pressure and Mach Number Data at Station II, Problem II	42
Summary: Comparison Workshop Part II (April 1991) and Part I (January 1990)	43
 Inaugural Address	
By R. Pellat	47

Invited Lectures

Hypersonic Research at German Universities – First Results of the Aachen Program By E. Krause	51
Some Viscous Interactions Affecting the Design of Hypersonic Intakes and Nozzles By J.L. Stollery	68
Numerical Simulation of Scramjet Engine Flowfield By A. Kumar	89
Advances in Applied Mathematics Related to Hypersonic Flows By O. Pironneau	111
Some Real Gas Shock Tunnel Experiments at Australian Universities By R.J. Stalker	132
Reacting Viscous Flow and Gas-Surface Interaction Modelling By J. Warnatz	150

Problems I–II

A Study of the Hypersonic Laminar/Turbulent Flow over a Slender Cone by the LCNS Code By N. Qin and B.E. Richards	167
Computation of Hypersonic Flow over a Slender Cone By M.P. Netterfield	179
Synthesis of Problems 1–2 By S.M. Bogdonoff	185

Problems III–IV

2D Laminar Ramp Flows By A. Joulot	189
Viscous Flow over a 2D Ramp By A. Lafon and F. Perrel	201

Hypersonic Ramp Flow (Problem III.1–4)	
By S. Menne and W. Schröder	212
Computation of Hypersonic Flows over 2D Ramps with a Multigrid Method	
By R. Radespiel	224
Computational Study of Laminar Hypersonic Flow over a 2D Ramp	
By D.H. Rudy, J.L. Thomas, and A. Kumar	236
Hypersonic Viscous Flow Calculation over a 2D Ramp with an Implicit Centred Method Using No Artificial Viscosity	
G. Lacombe and A. Lerat	248
Numerical Solution of the Navier-Stokes Equations for Hypersonic Ramps with the NS3GR Solver	
By F. Dubois and O. Michaux	258
Contribution to Problem III Using a Galerkin Least Squares Finite Element Method	
By M. Mallet	270
Flow over a 2D Ramp	
By J. Fischer and M.A. Schmatz	288
Implicit Upwind Finite-Difference Simulations of Laminar Hypersonic Flow over 2D Ramps	
By B. Müller	298
Turbulent Compressible 2D and Axisymmetric Flows Computation with the K-Epsilon Model	
By B. Mohammadi	307
Navier-Stokes Computation over a 3D Ramp	
By C. Jouet and M. Borrel	320
Computation of Hypersonic Flow Past a Compression Corner by a Spatial Marching Scheme	
By K. Srinivas	338
A Finite Element Procedure for the Simulation of Viscous Compressible Flows	
By O. Hassan, K. Morgan, J. Peraire, and E.J. Probert	348
Problem III: 2D Ramp Flows	
By W. Haase	368

Hypersonic Viscous Flow over a 2D Ramp By J. Grawe	380
Numerical Solution of Hypersonic Flows with Zonal Mesh Enrichment By F. Grasso, M. Marini, and M. Passalacqua	392
2D Hypersonic Viscous Flow over Compression Ramps By P. Leyland	407
A Synthesis of Results for Problems III and IV: Flow over a 2D Ramp and a 3D Obstacle By J. Périaux, J. Détery, G. Durand, J.L. Stollery, and B. Wagner	421

Problem V

Hypersonic Corner Flow Detailed Experimental Study* By A. Henckels and F. Maurer	441
Simulation of Laminar Hypersonic Flow About a Longitudinal Corner By A.G. Panaras, H. Vollmers, and B. Müller	455
Laminar Navier-Stokes Calculations of the Flow in a Corner Geometry By C. Lacor, H. Stehling, and Ch. Hirsch	467
Synthesis for Problem V Longitudinal Hypersonic Corner Flow Field By F. Maurer and A. Henckels	484

Problem VI

Flow over Double Ellipsoid and Sphere – Experimental Results* By M. Vetter, H. Olivier, and H. Grönig	489
Hypersonic Double-Ellipsoid Flow Cases VI.1, VI.5 and VI.7 By W. Schröder, M. Pfitzner, and G. Hartmann	501
Hypersonic Viscous Flow in Chemical Non-equilibrium By F. Perrel and A. Lafon	520

Computation of Viscous Hypersonic Flows Using a Coupled Euler/Boundary Layer Method By M.L. Sawley and S. Wüthrich	535
2D and 3D Inviscid Hypersonic Flow Simulations Including Air Dissociation Effects By J.B. Vos and C.M. Bergman	558
Equilibrium Reactive Flow past the Double Ellipsoid at Mach = 25 By S. Riedelbauch	576
Computation of Flows Around a Double Ellipsoid By J.-P. Huot, R.-C. Molina, and H. Wong	590
Unstructured Grid Computations of Reactive Flows past Double Ellipse and Double Ellipsoid Configurations By B. Stoufflet and E. Teupootahiti	608
Non-equilibrium Double-Ellipse Flows by Adaptive Upwind Finite-Elements By M.V. Salvetti, M.C. Ciccoli, and J.A. Désidéri	629
Problems VI.1 and VI.8: Ellipsoid Euler-Boundary Layer Calculation By F. Monnoyer	647
Special Aspects of Reacting Inviscid Blunt Body Flow By M. Fey, R. Jeltsch, and P. Karmann	664
3D Inviscid Real Gas Flow over a Double-Ellipsoid By M. Gazaix	677
Hypersonic Reacting Flow past Double Ellipse By J. Argyris, I.St. Doltsinis, H. Friz, and J. Urban	687
Numerical Solution of the Navier-Stokes Equations with Non-equilibrium Chemistry By V. Bellucci, F. Grasso, P. Graziosi, and M. Passalacqua	704
Synthesis of Problem VI: Double Ellipse/Ellipsoid and Sphere By H. Hollanders, A. Kumar, F. Monnoyer, H. Olivier, and J.A. Désidéri	723

Problem VII

Hypersonic Flow Field Computations Around a Double Ellipsoid and a Blunt Nosed Delta Wing By K. Dortmann	739
Aerodynamic Forces Applied to a Delta Wing Located in Rarefied Hypersonic Flows* By J. Allegre, X. Heriard Dubreuilh, and M. Raffin	769
Force and Heat Transfer on a Delta Wing in Rarefied Flow* By H. Legge	779
Pressure Measurements and Infrared Observation on the Windward Side of a Delta Wing* By J. Niezgodka, A. Henckels, and C. Weiland	791
Hypersonic Delta Wing Flow Calculations Using a Multidomain MUSCL Euler Solver By L. Le Toullec and Ph. Guillen	807
Euler Solution over a Hypersonic Blunt Nosed Delta Wing at High Angle of Attack By E. Hettena, L. Formaggia, and V. Selmin	828
Hypersonic Delta-Wing Flow, Problem VII.4 By W. Schröder and S. Menne	846
Hypersonic Flow over a Delta Wing at High Angle of Attack By S. Riedelbauch	865
Problem VII.4: Numerical Simulation of Laminar Hypersonic Flow over the Delta Wing By S. Srinivasan, P. Eliasson, and A. Rizzi	881
Problem VII.4: Blunt Nose Delta Wing Euler Boundary Layer Calculation By F. Monnoyer	902
Flow over a Delta Wing By E. Chaput, A. Corjon, P. Tran, B. Aupoix, and R. Houdeville	918
DSMC Calculations for the Mini Delta Wing – Problem VII.6 By M. Cevdet Celenligil, J.N. Moss, and R.G. Wilmoth	933

Aerodynamic Performance of Delta Wings in the Hypersonic Rarefied Flow Regime. Comparison of 3D DSMC Simulation with Wind Tunnel Data	
By D.F.G. Rault	947
DSMC Calculation on a Delta Wing – Problem VII.5	
By J.F. Pallegoix	960
Rarefied Gas Flow Around a 3D Delta Wing	
By F. Gropengiesser, H. Neunzert, J. Struckmeier, and B. Wiesen	976
Delta Wing Flowfield Computations by Upwind and Centered TVD Techniques	
By C.P. Li and E. Ma	987
High Resolution Computation of 3D Inviscid Hypersonic Flows. Application to a Blunt Nose Delta Wing	
By M. Manna and H. Deconinck	999
Synthesis of Problem VII: Delta Wing	
By C. Weiland	1014
Synthesis of Problem VII: Rarefied Flow Test Cases	
By F. Coron, J.K. Harvey, and H. Legge	1028

Problem VIII

Chemical and Vibrational Non-equilibrium Inviscid Hypersonic Nozzle Flows	
By M.C. Druguet, D. Zeitoun, M. Imbert, and R. Brun	1035
Numerical Simulation of Hypersonic Viscous and Reactive Flows in an Axisymmetric Nozzle	
By E. Boccaccio, D. Zeitoun, and M. Imbert	1050
Non-equilibrium Viscous Flows Calculations in a Hypersonic Nozzle	
By V. Mulard and G. Moules	1061
Computation of a Non-equilibrium Flow with a Fully Coupled Implicit Solver	
By G. Mehlman, F. Thivet, S. Candel, and F. Dubois	1080
Calculation of a Hypersonic Nozzle Flow	
By R. Abgrall and A. Merlo	1097

A Contribution to the Analysis of High Enthalpy Nozzle Flows By S. Borrelli, G. Russo, and A. Schettino	1112
Numerical Solution of a Nozzle Flow By M. Fey, R. Jeltsch, and P. Karmann	1124
Problem VIII.2: Non-equilibrium Flow in a Shock Tube By L. Marraffa and D. Giordano	1133
Problem VIII.1: Non-equilibrium Flow in an Arc Jet By S. Dalsecco, C. Delalondre, and O. Simonin	1147
Non-equilibrium Flow in an Arc Jet By P. Domingo and D. Vandromme	1159
Non-equilibrium Nitrogen Plasma Flow By P.C. Sleziona, M. Auweter-Kurtz, T. Gogel, E. Messerschmid, and H.O. Schrade	1175
Non-equilibrium Flow in an Arcjet or a Shock Tube: Synthesis By D. Zeitoun	1188
General Conclusion By P. Perrier	1195
Index of Contributors	1199