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Book Review

Numerical Simulation of Viscous Shock Layer Flows

Yuri P. Golovachov, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1995, 360 pp., $173.00

This book provides an excellent, comprehensive source for the theoretical development and practical application of equation sets appropriate for the analysis of a viscous shock layer. The author employs results predominantly generated by himself and colleagues at the A.F. Ioffe Physico-Technical Institute in St. Petersburg, Russia. Additional references are mostly from Russian sources as well, though international contributions are represented. The exposition in English is well executed throughout the text. Commentary on the many sample cases flows as a single voice. It is, in fact, these many sample cases that graphically illustrate the physical aspects of the mathematical models that best commend this text.

This book is the 33rd volume in the *Fluid Mechanics and Its Application* series, a collection devoted to areas of current interest and active research in fluid mechanics encompassing many interdisciplinary domains. This volume specifically covers numerical treatment of supersonic and hypersonic flows, usually characterized by a viscous shock layer model. Applications predominantly focus on external flows over blunt bodies. The author has provided excellent organization and clear presentation of the subject matter in each of the five chapters. The first four chapters describe the numerical simulation of perfect-gas flowfields. The last chapter covers high-temperature and nonequilibrium effects.

The problem scope and governing equations are defined in Chapter 1. Development of numerical methods for solving various levels of approximations to the Navier–Stokes equations are presented in Chapter 2. Special emphasis is placed on iterative approaches for solving elliptic domains with space marching algorithms. Several treatments for the subsonic portion of the boundary layer in parabolized Navier–Stokes methods are reviewed. Sufficient detail is given in most instances so that the algorithm could be programmed by a graduate student with previous exposure to computational fluid dynamics and compressible flow theory. In some instances, algorithm developments are presented in tedious detail; in others, missing intermediate steps can be filled in by appropriately motivated students! Terminology for some algorithms differs from Western standards (e.g., "proganka" for Thomas' algorithm). Chapter 3 is devoted to planar and axisymmetric flow problems. Nonuniform inflow, mass injection, and unsteady flow problems are considered. Chapter 4 treats three-dimensional flow problems. Engineering approximations to heating distributions based on numerical analysis are presented. Experimental data are frequently used to validate numerical results. Exploitation of self-similar solutions to obtain rapid engineering solutions for heating are also discussed. Chapter 5 reviews equilibrium and nonequilibrium gas dynamics, including effects of weakly ionized flow and equilibrium and nonequilibrium radiative energy transfer. A detailed database for kinetics and transport properties appropriate for Martian and Venusian atmospheres is included.

A few suggestions are offered in case a future edition of this text is planned. More details regarding stability, computational efficiency, and limitations of the featured algorithms would be helpful in their evaluation. Listing additional sources (Western and Russian) for high-temperature gas properties and models that have appeared over the past decade would enhance the value of the text as a reference book on viscous shock layers (e.g., the computerized database for high-temperature gas properties and kinetic models at the AVOGADRO Center at Moscow State University, NASA reports, etc.). More detail on the various models for vibration-dissociation kinetics in the viscous shock layer would be appropriate, considering the level of detail budgeted for related physical modeling issues in Chapter 5. Additional discussion or references to guide the reader regarding issues of modeling electron/electronic energy relaxation within the viscous shock layer would also be welcome.

An appropriate audience for this book includes professionals involved in the design and aerothermodynamic analyses of various classes of supersonic and hypersonic flight vehicles, including missiles, planetary probes, and entry vehicles. A background in compressible flow theory and basic computational fluid dynamics and some knowledge of physical gas dynamics are recommended. The text would be an excellent supplement to a course in hypersonic flows or as a primary source in a course on computational hypersonic flow. There are no sample problems included. The text includes only brief reference to more modern numerical methods (upwind, essentially nonoscillatory or ENO schemes, spectral methods). Nevertheless, it is the most comprehensive single source we know for the application of the various forms of the viscous shock layer equations to a wide variety of interesting and practical problems in these areas.

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