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Book Reviews

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Theory and Computation in Hydrodynamic Stability

W. O. Criminale, T. L. Jackson, and R. D. Joslin, Cambridge University Press, New York, 2003, 464 pp., $90.00

The new book *Theory and Computation in Hydrodynamic Stability* is a welcome addition to the literature in the field of hydrodynamic stability. Just about the time Drazin and Reid[1] published their book *Hydrodynamic Stability* in 1981, Mark Morkovin was writing a book on shear layer transition—a subject that he mastered. However, Morkovin had many unanswered questions and I believe he wanted the book to contain answers to most, if not all, of the questions, with the result that he never finished. At least to my knowledge, the same fate met the independent efforts of Les Mack and Ali Nayfeh, who were toying with the idea of writing books on the subject in the early 1990s. I knew Mack to be a perfectionist, and this probably stood in his way; otherwise, he had in hand a treatise on compressible boundary-layer stability dated 1969 that he could have turned into a book with little effort at any time. The field of shear layer instability and laminar–turbulent transition saw tremendous advances during the last two decades of the 20th century. These include secondary instability theory, parabolized stability equations, receptivity theory, instabilities in three-dimensional boundary layers, practical methods for computation of shear layer instabilities, enhanced understanding of supersonic boundary-layer transition and the role of quiet wind tunnels, new laminar flow concepts and analysis tools, transient growth phenomena, and direct Navier–Stokes simulations of transition (both incompressible and compressible). However, two decades passed without a new book on the subject except for the treatise on the evolution of instabilities in boundary layers written in Russian by Zhigulev and Tumin in 1987.[2] Hence, the book by Schmid and Henningson (SH),[3] *Stability and Transition in Shear Flows*, in 2001 fulfilled a great need. Similarly, this new book by Criminale, Jackson, and Joslin will help fill the void that has existed in the literature on hydrodynamic stability.

The stated goals of this book are to 1) provide complete updating of all aspects of the field of hydrodynamic stability, 2) provide both analytical and numerical means for solution of any problem posed, and 3) cover the full range of the dynamics, ranging from transient to asymptotic behavior, as well as linear and nonlinear formulations, including direct numerical simulation (DNS). A book of this type is certainly called for and timely.

With the exception of geophysical flows, the topics covered by this book are similar to those in SH, albeit with a different degree of emphasis. For example, this book provides much more discussion of compressible mixing layers and contains entire chapters dealing with DNS and flow control, reflecting the expertise of the individual authors. A brief summary of the contents of the book is given next.

Chapter 1 gives a good account of the history and background of the subject and derives some fundamental equations that govern the stability of small disturbances imposed on steady basic flows. Chapter 2, which deals with temporal stability of inviscid incompressible flows, is the longest and, perhaps, the best written chapter in this book. The results presented therein are supported by detailed mathematical derivation and rigorous discussion. A student new to the field, but armed with necessary mathematical skills, should be able to understand the subject with minimal effort. However, Chapter 3, which addresses temporal stability of viscous incompressible flows, seems to be different in style and presentation and appears much less thorough.

Spatial stability of incompressible flows is discussed in Chapter 4, which contains topics such as Gaster's transformation, absolute vs convective instabilities, and discrete vs continuous spectra. Chapter 5 deals with the stability of compressible flows and gives a good discussion of mixing layers, in addition to some essential results for flat-plate boundary layers. Chapter 6 discusses centrifugal instabilities and includes the classical Taylor problem, Görtler vortices, and trailing vortices, along with some other topics. Here, I fail to understand why the stability of Poiseuille pipe flow would fall under the heading of "centrifugal stability." Similarly, only the lower-branch solution for rotating disk flow is associated with "in-plane" streamline curvature instability[4,5] (and, hence, centrifugal instability), and that is not even discussed here. Also, the upper-branch disturbances belong to the family of inviscid instability, most commonly referred to as cross-flow instability, found in three-dimensional boundary layers. No explicit reference to "cross-flow vortex modes" is given here, even though Chapter 10 refers back to this section in connection with "cross-flow vortex breakdown." Unless the references cited here are consulted, the reader comes out of this section without knowing much about cross-flow instability—a subject of great significance for three-dimensional boundary layers. Similarly, in spite of important recent developments,[6,7] the subject matter related to Görtler vortices does not go beyond what was covered in the 1967 book by Betchov and Criminale.[8] On the other hand, I found Chapter 7, which deals with geophysical flows, quite thorough; it contains a wealth of information that will be useful for a student interested in the subject although some of the recent developments are also not included here.

Chapter 8 discusses the important topic of transient dynamics in considerable detail, and it is different in scope and emphasis from the treatment given in SH. Chapter 9 on "Nonlinear stability" includes both weakly nonlinear theory and parabolized stability equations (PSE). Secondary instability theory and resonant wave interaction are also discussed. The results on various breakdown mechanisms, along with discussion on receptivity theory and practical approaches to prediction of boundary-layer transition, can be found in Chapter 10.

Chapter 11 deals with DNS and provides detailed description of a specific numerical approach for the solution of the incompressible Navier–Stokes equations. The resulting computer code is then applied to study the nonlinear evolution of Tollmien–Schlichting waves, oblique mode breakdown, and the stability of an attachment-line boundary layer. Chapter 12 is dedicated to a discussion of flow control and optimization. The forms of control considered are passive (wall compliance) as well as active (wave cancellation). A detailed discussion on the application of optimal control theory, using direct and adjoint Navier–Stokes equations, is given with numerical examples taken from the control of Tollmien–Schlichting instability. Finally, Chapter 13 gives an overview of experimental issues associated with investigation of hydrodynamic stability.

The book appears to have escaped a thorough editorial reading (cf. "Fig ??" on page 88 and 184, "Eq ??" on page 365, and "... peak-valley spitting ... " on page 268). Note that x should be outside the square root in Eq. (3.6). The sign on the right-hand side of Eq. (6.45) is not consistent with Eq. (2.31). Also, how can Eq. (7.25) be a solution to (7.21) when the dependent variable is a function of z only? This is obviously not an exhaustive list, and the book needs to be edited carefully before the second edition goes to print.

I would leave the readers to judge whether the authors have been successful in meeting the goals they set for themselves. One would like to see a certain balance in the level of detail on various topics covered in any book. I think that such balance is missing here. For example, fine details of numerical methods to solve the Navier–Stokes equations, as well as a discussion of optimal control theory, are given here, but the important topic of PSE is given much less attention. Other examples of this imbalance can be cited. However, given the vastness of the subject, it may be too much to ask for a single book on stability and transition to be complete and perfect. This pursuit for perfection, perhaps, prevented giants such as Morkovin and Mack from bringing out the books they so desired. The collaboration between Criminale, Jackson, and Joslin has resulted in this book, *Theory and Computation in Hydrodynamic Stability*, for which the authors certainly need to be congratulated.

References

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Mujeeb R. Malik
NASA Langley Research Center