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Book Reviews

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Internal Flows—Concepts and Applications

E. M. Greitzer, C. S. Tan, and M. B. Graf, Cambridge University Press, New York, 2004, 735 pp., $110.00

This is an excellent book on internal flows. It builds upon fundamental concepts and adds various complexities associated with internal flows one at a time. Although it is directed toward applications, especially complex flows in rotating machines, it provides an extensive and thorough coverage of fundamentals of fluid flows. This book would be a valuable reference for engineering graduate students interested in the field of fluid dynamics and engineering practitioners and researchers working with devices and systems that include fluid flows of external or internal nature.

Fluids books, in general, take on either a fluid dynamics or a thermodynamics flavor in the presentation of concepts and the development of the equations of motion, depending on whether the book emphasizes incompressible or compressible flows. This book maintains a good mix of both flavors in its 12 chapters. Chapter 1 provides definitions and introductory concepts leading to the derivation of the equations of motion. The chapter also includes useful information on initial and boundary conditions and similarity concepts. Chapter 2 covers some more fundamental concepts such as pressure fields, fluid accelerations, and upstream influence. It also covers a significant amount of simple compressible flow elements such as normal and oblique shock waves, quasi one-dimensional flows, flow regimes in nozzles, and ejectors.

Chapter 3 presents the kinematics and dynamics of vorticity and circulation. It has a good coverage of vorticity generation and evolution in many different configurations, preparing readers for more complex practical rotating machinery applications with unsteady and three-dimensional motions considered later. Chapter 4 provides analyses of canonical wall-bounded and free shear flows. The boundary-layer coverage includes laminar and turbulent boundary layers, as well as boundary-layer separation. Two-dimensional free shear layers, entrainment, compressibility effects, and jets and wakes under pressure gradients are all briefly covered in this chapter.

Flows in practical fluid devices are often quite complex and encounter numerous losses, the sources of which must be well understood, accounted for in any analysis, and minimized for efficient operations. Chapter 5 presents analyses of various loss elements, which include flow through a screen or porous plate, viscous layers, various mixing processes, spatially nonuniform temperature and stagnation pressure, and separation.

The materials covered in Chapters 1–5 are fundamental in nature and much could be utilized in many fluid flow applications. The remaining seven chapters address various issues associated with the varied complexities of flows in fluid devices, especially in rotating machinery. The issues include unsteady flows, rotating coordinate systems, three-dimensional and secondary flows, compressible flows, and flows with heat transfer. Chapter 6 deals with unsteady flow, which is inherent in rotating machines. The rotating speed and size of the machine and flow velocity dictate how significant the role of flow unsteadiness is. The chapter addresses this phenomenon, including waves, oscillations, and instabilities in rotating machines. Chapter 7 casts the equations of motion in a rotating coordinate system, which is noninertial, and introduces Coriolis and centrifugal accelerations and forces. Nondimensional equations are used to identify a range of Rossby and Ekman numbers for which the rotation effects become dominant and substantially change the flow properties. The chapter also shows how vorticity and circulation are modified by the presence of rotation.

Naturally induced or externally introduced swirling flows are present in various fluid devices such as combustors, rotating machinery and their components, and cyclone separators. Chapter 8 presents significant coverage of swirling flows, including the upstream influence in such flows, instabilities of vortex cores, and the effect of swirls on canonical flows such as boundary layers, jets, and mixing layers. Chapter 9 looks into three-dimensional flows with imbedded streamwise vorticity. Such flows are often generated naturally, for example, in a duct inlet, in ducts with contractions, in curved flow passages, and behind blades in rotating machinery. They are also often generated by shaping a duct for mixing enhancement or noise reduction, as in lobed nozzles and nozzles with chevrons and tabs.

Chapter 10 treats quasi-one-dimensional flows with heat and mass addition and friction, flows in variable area ducts, and flows with oblique shock and expansion waves. These are classical topics typically covered in introductory textbooks on compressible flows. Added to this foundation are the complexities that normally occur in rotating machines such as shock trains, swirling flows, interaction of streams, and spatially nonuniform stagnation conditions. Chapter 10 focuses on flows with density variations due to the changes in the Mach number, and Chapter 11 covers density changes due to bulk heat addition, as, for example, in propulsion devices such as ramjets and scramjets. Chapter 12 present flows with substantial spatial nonuniformity, which is typical of rotating machinery applications. It deals with flows in contractions, diffusers, and compressors and how flow nonuniformities affect the performance of and interaction between such fluid devices.

In summary, this is an excellent reference book and graduate students interested in fluid dynamics, as well as engineering practitioners dealing with fluid flows, especially internal flows, will find it very useful. The book covers a broad range of flows from the canonical to the very complex flows in fluid devices, but the complexities are added one at a time. Therefore, it will find a wide range of readership. It could be a good textbook for perhaps two graduate-level courses for students who have already taken a first graduate-level fluid dynamics course, if it had some examples and end-of-the-chapter problems. However, it will be a great supplement to textbooks covering mostly canonical flows, but perhaps with a little more depth, and it will provide additional materials for students of fluid dynamics who are looking for challenging problems and issues to tackle.

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