Book Review

Fluid Mechanics, Seventh Edition, by Frank M. White, McGraw-Hill Companies, Inc. 2011; ISBN-13 9780073529349

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What is Fluid Mechanics? A concise and informative answer can be stated as follows: Fluid Mechanics is a branch of mechanics of continuous media, which deals with the exploration of all fluids under static and dynamic behaviours.

The former editions of this book quickly became a basic source in courses to teach engineering fluid mechanics at technical universities, and the seventh edition will undoubtedly be successful in holding up this tradition.

The book consists of eleven chapters, four appendices, answers to selected problems, and an index. Each chapter contains many illuminating examples, and finishes with problems to be solved and a representative list of references.

Chapter 1 deals with fundamental concepts relating to fluids. Fluid properties, including molecular structure, kinematics, thermodynamics, state relations, viscosity, surface tension, and compressibility, are concisely discussed. Some historical remarks about the founders of modern fluid mechanics who made truly fundamental contributions, are also added.

Chapter 2 discusses *Pressure Distribution in a Fluid*. The material is rather classical and presents the concepts of pressure and pressure distribution in the atmosphere and the oceans, mercury barometers, manometry, hydrostatic thrust on plane and curved surfaces, hydrostatic forces on a surface plunged in layered fluids, buoyancy and stability, pressure

distribution in rigid-body motion, and pressure measurement devices divided into four groups.

Chapter 3 is devoted to *Integral Relations for a Control Volume*. The notion of the control volume is explained and the essence of the control volume method is sketched. The Reynolds transport theorem for an arbitrary fixed control volume is formulated and applied to obtain the basic laws of mechanics of fluids in integral form. In addition, the famous Bernoulli equation is discussed, mainly because of its historical importance.

Differential Relations for Fluid Flow are the subject of chapter 4. The basic differential equations of fluid motion are debated in detail. Appropriate boundary conditions for the basic equations are also discussed. Some important approximations, including incompressibility, inviscid flow, the stream function approach, and irrotationality, are explained and demonstrated. A few spectacular exact solutions of selected fluid flows (e.g. Couette and Hagen-Poiseuille flows) are also obtained and analysed.

Chapter 5 treats *Dimensional Analysis and Similarity*. This technique is traditional in fluid mechanics and illustrates how dimensional arguments can lead to remarkable results, even without a detailed study of the underlying equations. The basic system of dimensions and the way to find the relationship between variables affecting a phenomenon, are discussed first. Then, the famous Buckingham Π theorem is formulated and an alternate step-by-step method by Ipsen is described. The dimensionless form of basic equations is obtained, and important, non-dimensional numbers in fluid mechanics are defined and interpreted. The notions of kinematical and dynamical similarity are introduced and

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exemplified also. Overall, dimensional analysis and similarity is very useful for planning, presentation, and interpretation of fluid experimental data.

Viscous Flow in Ducts is the theme of chapter 6. Analysis and solving complex pipeline systems are certainly the most known problems encountered in technical fluid mechanics. This chapter concentrates on bounded, both laminar and turbulent, pipe flows.

First, the Reynolds number dependent regimes of pipe flows are described. Some turbulence modelling concepts in such flows are presented also. Then, the Moody diagram for pipe friction factor for almost any type and size of pipe is presented and discussed. Four types of pipe flow problems, namely, head loss, flow rate, sizing, and pipe length are formulated and investigated. Remaining questions refer to minor losses in pipe systems, piping networks, diffusers, and selected types of flowmeters.

Flow Past Immersed Bodies is discussed in chapter 7. It begins by outlining differences between internal and external flows. Next, the concept of boundary layer is introduced and the elements of Kármán's momentum integral approach, together with Prandtl's boundary layer theory (BLT) are concisely presented. The celebrated Blasius equation and the Blasius velocity profile are given, and the elements of turbulent flat-plate boundary layer semi-empirical theory are sketched. The pressure gradient effects in boundary layers, which lead to flow separation, are also described. Separation is the term used to describe the phenomenon in which a flow breaks down and detaches from a solid surface. For the flows with separation the BLT is not applied; they are studied experimentally and by CFD methods. The chapter ends with detailed analysis of drag coefficients of selected two- and three-dimensional bodies and a terse discussion of lift forces generated by lifting bodies. Lift forces are the crucial for propulsion, but being more subtle than drag forces, are not well understood.

In chapter 8 on *Potential Flow and Computational Fluid Dynamics*, the emphasis is placed on potential flows theory. Such flows are solutions of the Navier–Stokes equations which satisfy Laplace's equation with appropriate boundary conditions. So all the mathematical machinery of potential theory can be used.

After the short introductory remarks which recall the motivation for the study, some elementary plane flow solutions are presented. The methods employed to obtain the solution are standard, and include superposition of sources, sinks, and vortices. The other techniques presented here are the variable-strength vortex sheets, the method of conformal mapping, and the method of images. Thereafter follows the elements of the theory of flow over an airfoil and the wings of finite span. A few exemplary solutions in the case of axisymmetric potential flows are obtained and discussed also.

The final section on numerical analysis, concentrates briefly on the modern approach to description of complex flows (not necessarily potential). Presented are the finite element method, the finite difference method, and the boundary element method. Some information on the commercial CFD codes for fluid flow problems is provided also.

The study of *Compressible Flow* starts with chapter 9. The subject of compressible flows is also called gas dynamics, and these flows have features that do not occur in incompressible dynamics. These include choked flow and discontinuity (shock wave).

First, some basic facts regarding the thermodynamic properties of an ideal gas are recalled. Next, the high-speed, one-dimensional adiabatic and isentropic steady flow is analysed and some useful formulas for gas flow in a variable-area duct are obtained. This shows the phenomenon of sonic-flow choking, where the mass flow rate through a duct system is limited as a result of the Mach number being equal to 1 at some point in the throat of a nozzle.

Later on, a complex world of shock waves, that is, waves which propagate at supersonic speeds, is presented in some detail. The effect of back pressure on the efficiency of converging and diverging nozzles is elucidated, with the help of normal shock. Also, an analysis of duct flow, alone, and also with friction and with heat transfer, both of which lead to choking effects, is performed. At last, two-dimensional supersonic flow is discussed because of its aeronautical importance, together with the supersonic thin-airfoil theory.

Chapter 10 focuses on *Open-Channel Flow*. This notion refers to the flow in an open channel, or in a

closed conduit having a free surface. Such flow is often called free-surface flow. The consideration is limited to the steady, one-dimensional flow in channels of simple geometry.

After some preliminaries, the basic classification of open-channel flows is presented, including division by depth variation and Froude number. The Chézy formulas and Manning formula for flow velocity in uniform channel flow are obtained and discussed. Optimal aspects of channel shape design to find the geometry which guarantees maximum flow rate with minimum friction losses, are considered also. Other flows of engineering interest are frictionless flow over a bump and flow under a sluice gate. Some analogies to compressible gas flow in a nozzle are used.

The basic hydrodynamics of the flow inside hydraulic jumps is elucidated in the subsequent section. They belong to the most intriguing turbulent flow phenomena that occur in reality under steady, one-directional flow conditions. Classification of hydraulic jumps as well as a brief theoretical description of horizontal jump are presented. In the succeeding section, the first-order ordinary differential equation that describes the gradually varied flow is obtained, numerically solved and discussed, and, finally, the typical forms of overflow spillway, that is the sharp-crested weir and broad-crested weirs are also described.

The last chapter concerns *Turbomachinery*, a topic of great importance in a various branches of the industry (energetics, aviation, ships building, water pump, etc.).

Turbomachines may be divided into two main categories: those that deliver energy to the fluid, i.e. pumps, fans, blowers, and compressors, and those

that extract energy from the fluid, such as turbines. The chapter begins with classification of pumps, then addresses the elementary pump theory with many illuminating examples. Next, two types of turbines, reaction and impulse, are described. Some theoretical and practical aspects of wind turbine technology, with a brief analysis of several types of windmills, are presented also.

The appendices contain thermodynamic properties of common fluids, compressible flow tables, conversion factors, and equations of motion of an incompressible fluid in cylindrical coordinates.

The didactic value of the book is enhanced by an accompanying student resource DVD, which contains the Engineering Equation Solver (EES), limited academic version software. Unfortunately, in the unregistered version of ESS, the copy, paste, save, and print commands are unavailable. Also, a full book website is available only for registered users (<http://www.mhhe.com/white7e>).

In sum, this is an excellent, very well organized, carefully written, and nicely edited book. The presentation is clear, elegant, and supported with many of top quality graphs and figures. The collection of examples and problems offers a respectable view on the contemporary status of engineering fluid mechanics. Therefore, I heartily recommend this book to students, instructors, and researchers specializing in the field and related areas, including geophysical applications.

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