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Book Reviews

An Introduction to Magnetohydrodynamics

Peter A. Davidson, Cambridge University Press, New York, 2000, 425 pp., $39.95

There is considerable interest in magnetohydrodynamics (MHD) within certain sections of the readership of the *AIAA Journal*. Various forms of plasma propulsion are being used and developed for applications from satellite orbit maintenance to deep space exploration. Space propulsion engines based on MHD concepts are of particular interest in the high-power range of these devices. The principles of MHD are also being applied in the development of compact power generation technology for use on deep space vehicles that can no longer rely on solar energy. Another active area is in the possible use of weakly ionized plasmas generated around hypersonic vehicles for a variety of functions including vehicle control and drag reduction. In addition, there are significant MHD issues in many astrophysical and geophysical phenomena. Therefore, a modern introductory book on the subject is a welcome addition to the literature, and, at the price of only $39.95, this is a really good buy!

The book is divided into two distinct parts. In the first part, the fundamental theory of incompressible MHD is introduced. In the second part, the present state of the art in the use of MHD in liquid metallurgical processes is described.

The first section of the book (Part A) consists of Chapters 1–7. Chapter 1 presents an overview of MHD that provides a short summary of basic electrodynamics and uses these ideas to introduce qualitatively some of the basic MHD phenomena. Chapter 2 introduces the basic ideas of fields and the Lorentz force together with the fundamental laws of electrodynamics (due to Ohm, Ampere, and Faraday). Laced throughout the text are quotations and anecdotes from the pioneering fathers of fluid mechanics and MHD (Faraday, Maxwell, and Rayleigh, among others). These help to put the material in historical perspective and also offer temporary light relief from some of the inevitable mathematical complexity.

To introduce the fundamental phenomena of MHD, Davidson follows an approach that will appeal to many readers in the *AIAA Journal* community. Specifically, he proceeds by relating many of the important MHD concepts to well-known phenomena in fluid mechanics. In this way, the book provides a particularly appealing introduction to MHD theory for those already well-versed in theoretical fluid mechanics. Thus, in Chapter 3, a general introduction to incompressible fluid mechanics is provided, including such topics as diffusion, vorticity, boundary layers, and turbulence. Each of these phenomena is then discussed later in the book in terms of related MHD effects. Chapter 3 ends by presenting the full set of MHD equations.

Chapter 4 describes the advection, diffusion, and helicity of magnetic fields and includes some discussion of sunspots. In Chapters 5 and 6, MHD behavior is described for progressively increasing magnetic Reynolds numbers. Thus, Chapter 5 begins at a low magnetic Reynolds number and discusses such topics as magnetic damping, natural convection, fluid motion driven by magnetic fields and electric currents, and Hartman boundary layers. Chapter 6 deals with medium to high magnetic Reynolds number effects including Alfven waves, the geo-dynamo, solar MHD, and instabilities. Chapter 7 concludes Part A of the text and begins with a general introduction to conventional turbulence in fluid mechanics. The magnetic effects are then introduced to indicate their unique effects on turbulent flow phenomena.

An important omission in Davidson's book for those interested in studying almost all of the MHD application areas presently of interest in the field of aerospace engineering is the topic of compressibility effects. Most aerospace applications of MHD involve high-speed flows of plasmas (conducting gases) rather than the author's research field of low-speed liquid metal flows. This book can therefore be used only as a stepping stone toward the more complicated effects of high-speed MHD flows. However, using the analogy of incompressible and compressible fluid mechanics, mastering the material in Part A of this book is an important and necessary first step.

Although the second section of the book (Part B) is primarily aimed at the liquid metallurgical community, the various phenomena discussed offer further insight into the subtleties of several important MHD phenomena. A summary of the latest research results for the study of MHD effects in liquid metals involving theory, experimentation, and numerical simulations is presented for a range of topics including magnetic stirring, magnetic damping, current-driven flows, MHD instabilities, magnetic levitation, and induction heating.

In summary, the author has written a text that provides an excellent introduction to the theory of incompressible magnetohydrodynamics. The book is particularly well-suited for an applied mathematics course on the subject, although it will also be readable by the engineering community. With its strong interpretation of MHD phenomena from the fluid mechanics viewpoint, the book is particularly welcome for those with a strong background in this discipline. The reader should be warned, however, that this book really does only provide an introduction to the types of MHD flows described at the beginning of this review. There is a direct analogy between incompressible

and compressible flows whether gas dynamic or magnetohydrodynamic. Compressibility leads to a significant number of additional and important phenomena that, for a conducting fluid in the presence of magnetic fields, will be mastered only with considerable additional study.

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Smart Structures

A. V. Srinivasan and D. M. McFarland, Cambridge University Press, New York, 2000, 228 pp., $34.95

This book is a welcome addition to the literature on smart structures. According to the preface of the book, it grew out of senior undergraduate and graduate-level courses and a weeklong short course taught by the authors. The book is divided into nine chapters. The first chapter, entitled Introduction, defines a smart structure and gives a brief overview of general applications and natural occurrences of smartness in biological structures. The second chapter describes the strength-of-materials approach to one-dimensional problems for composite beams involving piezoceramic elements. The analysis is easily understandable and is essentially at the senior undergraduate level. After reviewing the historical developments of shape memory alloys, the authors borrow heavily from the 1990 paper of Liang and Rogers to give a one-dimensional theory of phase transformations in a shape memory alloy. Several potential and actual applications of shape memory alloy wires are subsequently described.

The chapter on electrorheological and magnetorheological fluids describes the one-dimensional deformations of such fluids enclosed between two parallel flat plates and driven either by a pressure gradient or by the motion of one of the plates. It is postulated that the mechanical response of these materials is similar to that of a Bingham solid, with the yield strength increasing monotonically with an increase in either the magnetic or the electric field. Potential applications of these materials in automobile clutches and other mechanical devices are described. The chapter on vibration absorbers analyzes in detail the vibrations of spring-mass systems connected in arrangements often taught in undergraduate courses on vibrations. A discussion of gyroscopic vibration absorbers is also included. However, the use of piezoceramic elements in either controlling or annulling the vibrations is not included.

The sixth chapter deals with the analysis of vibrations of mistuned structures. A mistuned structure is defined as a periodic structure with a slight variation in the material and/or geometric properties of different segments of the periodic structure. Various practical examples are discussed, and the modes of vibrations of mistuned beams and disks are depicted. The use of optical fibers for measuring strains is elaborated upon in Chapter 7. Practical applications of the optical fibers to measure strains of $1.0E{-}08$ and displacements of the order of 0.1 nm are described. The chapter on the control of structures is quite brief and outlines the basic strategies employed, while referring the reader to other literature for details. The reviewer found the material on biomimetics included in the last chapter quite interesting. The specific strengths of various natural materials such as bones, wood, and an insect cuticle are compared. It is indeed a challenging task for a design engineer to design structural elements that either duplicate or come close to mimicking the behavior of natural objects.

Two appendices provide some background material in the areas of structural dynamics and vibration control. The material included in the book can probably be covered in a one-semester, senior-level course. Graduate students and researchers interested in learning about the subject will need to dig through the literature either cited in the book or found through other databases. A practicing engineer will find the material useful and should be able to design a prototype of a simple smart structure by using some of the concepts discussed in the book. Depending on the complexity of the structure and the sophistication of the analysis desired, the engineer will need to rely on various other sources and concepts, some of which (e.g., constrained layer damping) have not been touched upon in the book. Doctoral students interested in pursuing research in smart structures will definitely need to study the current literature, and the material included in the book most likely will not bring them to a stage where they can comfortably understand current research work.

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