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Book review

Modelling of Mechanical Systems, Vol. 2: Structural Elements, François Axisa, Philippe Trompette. Elsevier Butterworth-Heinemann, Oxford (2005)
Modelling of Mechanical Systems, Vol. 3: Fluid–Structure Interaction, François Axisa, José Antunes. Elsevier Butterworth-Heinemann, Oxford (2007).

In the review of Vol. 1: Discrete Systems, it was said that "if the relatively dry topic of Vol. 1 could be made exciting, one can but anticipate the joys of Vols. 3 and 4" (JFS 2004, Vol. 19, 1027–1028). Indeed, now that Vol. 3 has appeared, one is anything but disappointed, while Vol. 2 contains unanticipated delights.

Vol. 2: Structural Elements

Vol. 2 deals with distributed parameter systems. It contains eight chapters and a number of appendices. Chapter 1, entitled Solid Mechanics, is concerned with establishing the fundamentals which are used in the chapters that follow: the definitions and concepts of continuum mechanics, the stress tensor, Hamilton's principle, etc. However, just as in Vol. 1, the reader is pleasantly surprised to find unexpected topics; in the case of Chapter 1, an erudite and thorough treatment of wave propagation. The chapter ends with a discussion of the transition from the continuum description to the formulation of the standard engineering structural elements, which are treated in detail in the chapters that follow: beams, plates, arches and shells.

The deformation and dynamics of beams are treated in Chapters 2–4 with unusual but welcome thoroughness, where by generalizing the type of deformation a beam may suffer, the topic of longitudinal deformation of "bars" becomes but a special case of deformation of beams; thus, the beam is viewed as a generalized 1-D structural element, whereby strings and cables are treated as limiting cases. As such, a beam can undergo longitudinal, shear, torsional (without and with warping) and bending type of deformation. In Chapter 2 the approach is Newtonian while in Chapter 3 it is Hamiltonian. Again, one finds unusual features to add to the flavour, such as thermoelastic and plastic effects; and in Chapter 3, weighted-integral formulations and finite element techniques (FEM), with a very welcome discussion of possible inaccuracies and errors *vis-à-vis* the exact solutions. Chapter 4 deals with the vibration of beams, modes of vibration and modal analysis methods, and wave propagation. A clear exposé on appropriate truncation of the modal series is illustrated with practical examples. Again, unusual, novel features are (i) the use of FEM, (ii) the substructuring method, and (iii) impacting of beams with a rigid wall or another beam; so, again, what might be considered as advanced topics are neatly integrated in an accessible manner with the more classical methods.

Chapters 5 and 6 deal, respectively, with in-plane and out-of-plane motions of plates. The equations of motion are developed in a rigorous but accessible manner based on the Kirchhoff–Love hypotheses. In Chapter 5, examples are given in elastostatics and thermoelasticity. Clear and plentiful illustrations, some in glorious colour, are very helpful in understanding modal deformations, warping, Chladni figures, and so on.

Chapters 7 and 8 are devoted to curved structures, namely arches and thin shells. Here is where the benefit of rigorous treatment in the foregoing chapters pays off: one can fairly easily understand these topics (not usually found in such books, and not taken quite so far). In Chapter 7, simplified versions of the equations are presented which allow gaining understanding and familiarity, while in Chapter 8 the full equations of motion are derived—in the case of shells based on Love's equations of equilibrium. Again the very helpful graphics, some in colour, must be mentioned, which greatly aid understanding.

The hallmark of Vol. 2, similarly to Vol. 1, is a rigorous yet not abstruse style of presentation, which allows the subject to be covered much deeper and farther than a more mathematically/physically stunted treatment would have allowed. The style and approach is practical, an engineer's approach, rather than an applied mathematician's, yet not eschewing the use of mathematical rigour when necessary.

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The contents of Vols. 1 and 2 are clearly intended to prepare the ground for the topics covered in Vols. 3 and 4, dealing with Fluid–Structure Interaction and Flow-Induced Vibration, respectively—the latter yet to come.

Vol. 3: Fluid–Structure Interaction

Vol. 3 is a thickish tome, but the additional length is very worthwhile, for it covers subjects that one might not suspect to be part of Fluid–Structure Interaction, yet clearly are. It consists of seven chapters and six appendices, as follows: 1. Introduction; 2. Inertial coupling; 3. Surface waves; 4. Plane acoustical waves in piping; 5. 3-D Sound waves; 6. Vibroacoustic coupling; 7. Energy dissipation by the fluid. Thus, at a glance, a great deal of attention is devoted to sound propagation and interaction with the fluid-containing structures. The appendices relate to thermodynamics, mechanical properties of materials and Bessel and spherical functions.

Fluid–Structure Interaction in this book deals with the coupling between fluids and structures, and acoustical effects, in the absence of a mean flow. Problems involving a mean flow are to be presented in Vol. 4. In the case of Vol. 3, the experience gained in a long and illustrious career at CEA (*Commissariat à l'Energie Atomique*), the Atomic Energy Commission of France, by the lead author shines throughout; as well as the long experience by the second author, both at CEA and at the Instituto Tecnológico e Nuclear of Portugal. The benefit of basing the book on course notes to students of the *Ecole nationale supérieure des techniques avancées* is also very obvious in the methodical and clear manner in which all topics are treated.

Chapter 1 presents the fundamentals of fluid mechanics: the Navier–Stokes equations and simplified versions thereof, e.g. the Euler equations; also, an interesting discussion of surface tension and gravity effects.

Chapter 2 deals with inertia coupling, i.e. "added-mass" effects. This is done in an entirely novel, instructive manner, starting with a "fluid column model" and a "piston–fluid system" and seismic excitation considerations, before proceeding to the more standard systems of single or coaxial cylindrical shells immersed or containing fluid (strip theory, thin fluid-layer approximation, etc.), and ending with 3-D problems (e.g. a plate immersed in liquid of finite depth).

Chapter 3 is entitled "Surface waves". The objective of the earlier parts of this chapter is to establish the fundamentals (and such interesting applications of shallow wave theory as tsunamis), so as to be able to understand sloshing and the material in the final section of the chapter, which deals with coupling between sloshing and structures, including wave–ship interactions. Both gravity- and surface-tension-dominated problems are tackled. This chapter is very useful to all concerned with nuclear power plant of certain types, but also to anyone interested in sloshing: the presentation is simple and easily comprehensible, whereas recourse to specialized texts on sloshing would be considerably more onerous.

With Chapter 4 begins the treatment of acoustical waves, plane waves in piping in this chapter, to be followed by 3-D sound waves and acoustostructural problems in the chapters that follow. This is an area in which CEA has made extraordinary, peerless contributions (see also R.J. Gibert 1988 *Vibrations des Structures*, Eyrolles; reviewed in JFS 1991, Vol. 5, pp. 729–730). Hence, these chapters are expected to be particularly strong, and the reader will be anything but disappointed! The treatment in Chapter 4 is for 1-D waves (free or forced) in rigid piping, with changes in cross-section, changes in fluid medium; including a presentation of the transfer matrix method, Helmholtz resonators, concentrated acoustical sources (monopole and dipole), and computational methods for branched systems; ending with an unexpectedly interesting section on the speed of sound, including sound propagation in bubbly liquids and in fluids contained in pipes with elastic walls.

Chapter 5 presents 3-D sound waves and guided wave modes (rectangular and cylindrical waveguides), with a nice interpretation of the guided waves of higher rank (non-plane waves). This is followed by more advanced topics, e.g. forced waves in rectangular enclosures, in waveguides and in open space. The chapter ends with weighted-integral formulations, the Kirchhoff–Helmholtz integral theorem, paralleling the weighted-integral formulations for structures, treated in Vol. 2.

Armed with the necessary understanding and tools, the reader can then tackle vibroacoustics in Chapter 6, focusing on 1-D systems. A variety of systems are considered: piston/fluid-column systems, tube and duct circuits (involving branching and bends), cylindrical vessels and toroidal shells, by means of analytical, transfer matrix and FE methods.

The last chapter deals with energy dissipation by the fluid. This chapter is excellent in that it presents the basics, builds on accumulated by rarely shared engineering experience with a sound physical/mathematical foundation. The viscous damping model is revisited in terms of dissipative waves and complex vibration modes. Then, radiation damping, a rather difficult subject, is made comprehensible. Finally, perhaps the most interesting kind of dissipation is discussed, called *fluid–structure coupling* by the authors; the kind of problems discussed are a flexibly supported plate oscillating while facing a thin liquid layer confined on the other side by a rigid wall, and the ‘‘squeeze-film’’ damping involving an annular gap, so important in multi-supported heat exchanger tubes. Finally, the chapter closes with a discussion of dissipation in acoustic waves.

In addition to profuse b&w illustrations throughout, some magnificent colour graphics on fluid-filled cylindrical shell vibrations, sloshing, acoustical modes in spheres, waveguides and vibroacoustics add immensely to the value of this book.

These two volumes represent a *tour de force* on Dynamics and Fluid–Structure Interaction that anyone interested in these subjects must want to have in his/her bookcase. They set the stage for what must be *la pièce de resistance*: Vol. 4 on Flow-Induced Vibration.

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