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Book Review

Liquid Sloshing Dynamics: Theory and Applications, Raouf Ibrahim. Cambridge University Press, Cambridge (2005), pp. xxi + 948, £160, US$275, hbk, ISBN: 0-521-83885-1

The appearance of this book is an event. Written by Professor Raouf Ibrahim, an internationally recognized expert in nonlinear vibrations and random responses of liquid-free surface and more generally liquid sloshing dynamics, this book is particularly welcome as it appears as a monumental monograph on various phenomena occurring in sloshing problems, mostly based on analytical results and discussions resulting from various particular tank geometries. As a consequence, this book will be a useful complement to computational mechanics studies of free surface sloshing effects—linear and nonlinear, periodic and random—in earthquake engineering, civil engineering (storage tanks), aerospace engineering (such as liquid propelled launchers), nuclear engineering, naval and offshore engineering, etc.

The book has 948 pages and an exhaustive list of approximately 2700 references (104 pages) in alphabetic order and is divided into four parts. Part I (202 pages) is devoted to *Linear sloshing dynamics*, Part II (269 pages) is devoted to *Nonlinear and parametric sloshing dynamics*, Part III (209 pages) is devoted to *Sloshing–structure interaction* and Part IV (140 pages) is devoted to *Rotating fluid and low gravity sloshing*.

The first part—*Linear sloshing dynamics*—is composed of 3 chapters. The first chapter introduces fluid field equations and analytical eigenfrequencies and mode shapes. Results for different tank geometries (including non-traditional shapes) are compared to measurements. The second chapter discusses hydrodynamic loads and moments generated under harmonic excitations. A noteworthy original feature of this chapter is that it includes forced excitation of magnetic fluids. The third chapter presents the influence of viscous damping and sloshing suppression devices in closed tanks. The contribution of periodic boundary layers of fluids to the inertia and damping parameters of the system, for upright cylinders experiencing roll oscillations, is very well described and finds applications to immersed pipes.

The second part—*Nonlinear and parametric sloshing dynamics*—is composed of 4 chapters. The first chapter (Chapter 4) deals with weakly nonlinear dynamics under lateral excitation. A distinctive feature is the discussion of rigid-body random excitation of containers under earthquake loading. Interaction between free surface dynamics and submerged fluid jet dynamics, also called self-induced sloshing in nuclear reactor technology, is very well described. The second chapter (Chapter 5), introducing the concept of equivalent mechanical models as a tool for nonlinear analysis, is particularly welcomed. For example, rotary sloshing is presented through a spherical pendulum analysis. At the end of this chapter an equivalent pendulum with high restoring forces is presented for strongly nonlinear motion associated with hydrodynamic pressure impacts, as detailed in Chapter 7. The third chapter (Chapter 6) is devoted to the classical Faraday wave problem (parametric sloshing induced by excitation applied perpendicularly to the free surface). The modern concepts of modal competition, quasi-periodic mixed mode, chaotic and mixed mode motions are illustrated for circular and rectangular tanks (under random parametric effects). The last chapter of this second part (Chapter 7) is devoted to hydrodynamic slamming and impact; it includes an original phenomenological approach to modelling impact and damping forces, through a high-power equivalent forces concept covering rigid and elastic impacts.

The third part—*Sloshing–structure interaction*—is composed of three chapters. The first chapter (Chapter 8) is a basic chapter on fluid–structure linear interaction, illustrated on particular configurations such as cylinders: it discusses rigid tank walls with flat elastic bottom, elastic walls with flat rigid bottom and finally a total elastic system. Various nonlinearities are then introduced in the second chapter (Chapter 9) for the

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description of interaction between free surface and cylindrical shells for storage-tank applications. Finally, the last chapter of this part (Chapter 10) presents the interaction between an elastic support structure and tuned liquid sloshing absorbers, and constitutes in itself an original contribution not described currently elsewhere.

The last part—*Rotating fluid and low gravity sloshing*—is composed of two chapters. The first one (Chapter 11) describes the basic aspects of liquid dynamics in spinning tanks and naturally leads to the last chapter (Chapter 12) for low gravity cases (surface tension phenomenon). Marangoni flow and liquid bridges are discussed in the static and dynamic cases as well as thermocapillary effects.

As stated in the first paragraph, the reviewer considers Professor Ibrahim's book as a remarkable and comprehensive contribution to sloshing dynamics, using analytical descriptions for particular tank geometries to understand very complex sloshing phenomena. The reviewer highly recommends this book for graduates and Ph.D. students in this field, as well as researchers and engineers in various industries that use storage tanks, because it contains not only original aspects but also acts as a tutorial through its discussions of how analytical results compare with measurements. It represents an important addition to the fluid–structure interaction bookshelf.

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