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BOOK REVIEW

FLUID-STRUCTURE INTERACTIONS: SLENDER STRUCTURES AND AXIAL FLOW. VOL. 1

MICHAEL P. PAIDOUSSIS

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THE DYNAMICS AND STABILITY of slender structures subjected to axial flow is a complex and a fascinating subject on several dimensions. Physically, the problem first became apparent with the fluttering of fire or garden hoses but is now known to have a diverse variety of practical applications ranging from nuclear reactor internals and marine risers to physiological ailments causing pulmonary insufficiency. Mathematically, since the flows typically do not separate from the structural boundaries, the problem lends itself to analytical modelling which can be validated using relatively simple experiments. This, together with an amazing range of stability characteristics and, sometimes, apparently paradoxical behaviours have made the problem one of great interest to applied mechanicians. The result is a dynamics problem of sufficient depth, breadth, practical interest, and, by now, maturity, that it is well worthy of a specialized monograph. No one is better qualified to undertake this task than Michael Paidoussis.

Paidoussis states that the objectives of his book are "(i) to convey an understanding of the undoubtedly fascinating (even for the layman) phenomena discussed, (ii) to give a complete bibliography of all important work in the field, and (iii) to provide some tools which the reader can use to solve other similar problems". Paidoussis delivers this and much more. The mathematical treatment is rigorous but written in an interesting style, emphasizing the physics. In fact, the clarity of the text and the ample use of thoughtfully prepared figures and graphs should make the complex physical concepts and modern mathematical methods accessible to most readers with a Bachelor's-level background and could serve as a model for future technical writers. With more than 500 references cited, the book is an illuminating synthesis of the state-of-knowledge of the subject matter. This is a significant contribution in itself since, as the complexity of these systems has been revealed with evolving research, much confusion over the effects of various parameters and discrepancies between theoretical predictions and experimental observations has arisen.

Chapters 1 and 2 provide the necessary background and review of the concepts, definitions and methods to understand the developments to come. The relevant structural and fluid mechanics are covered briefly but, more importantly, the distinct mathematical nature of non-conservative dynamical systems and the useful analysis tools are discussed. The latter includes the relevant stability analysis. A full treatment of the development of equations of motion, stability methods of nonlinear systems and even experimental methods are given in 11 Appendices.

Chapter 3 deals with the linear dynamics of straight pipes conveying fluid. The chapter is divided into subsections, covering the effects of different boundary conditions, or other

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physical modifications. Each subsection proceeds logically from theoretical development, through physical explanation, to experimental verification whenever possible. In the process, numerous misconceptions, perplexing predictions and apparent paradoxes which have characterized the historical development of this subject are resolved. Significant amongst these are the effect of pipe boundary conditions on the work done by non-conservative forces, the destabilizing effect of damping on these systems, and the apparently paradoxical differences between the stability behaviour of continuous cantilevered pipes conveying fluid and that of articulated cantilever pipes with finite degrees of freedom.

Chapter 4 extends the linear theory of pipes conveying fluid to pipes of non-uniform cross-section, aspirating pipes, short pipes, refined flow modelling and pipes with harmonically perturbed flow. This discussion of linear dynamics finishes with a number of practical applications, including useful ones such as Coriolis flow meters and hydroelastic ichthyoid propulsion. This chapter also includes a particularly interesting account of various efforts to resolve the difference between theoretical predictions and experiments for aspirating pipes. While the theory apparently predicted flutter instability at infinitessimally small velocities, experiments showed no indication of this behaviour and both Paidoussis and Nobel Prize winning Richard Feynman blew up experiments in their attempts to study the phenomenon.

The nonlinear behaviour and chaotic dynamics of fluid conveying pipes is covered in Chapter 5. The nonlinearities considered are mainly due to the significant curvatures associated with large amplitude motions, and the tension in fixed-ended pipes induced by lateral motions. Indeed, extensibility effects in the latter case create important differences between the stability behaviour of fixed-ended pipes and that of cantilevered pipes which can be considered inextensible. Inevitably, the mathematical tools required are fairly sophisticated but, as with previous chapters, the required methodologies are explained, useful references for further reading are provided, and emphasis is placed on a physical understanding of the mathematical models and predicted stability behaviour. The introduction of nonlinearities not only permits analysis of the post-stable behaviour of these systems but demonstrates that pipes conveying fluid is an ideal problem for applying and further developing modern methods of nonlinear dynamics. This is abundantly clear in the remaining sections of this chapter which deal with chaotic dynamics and nonlinear parametric resonances.

The final chapter of Volume 1 covers the dynamics of initially planar curved pipes conveying fluid. Curved pipes with fixed ends, a free end, and the intermediate case of a cantilevered pipe with various sliding restraints at its "free" end are considered. The historic confusion regarding the contradictory stability productions of 'inextensible' and 'extensible' theories is resolved by showing that the curvature produces steady flow-induced forces which eliminate static instability.

The book is replete with historical notes, interesting anecdotes, critical and insightful analyses and useful guidance. I consider Paidoussis' book to be a must read for researchers in the field of flow-induced vibration, an essential reference for practitioners working on related problems, and a fascinating and useful guide for anyone interested in the dynamics and stability of non-conservative systems. The appearance of Vol. 2 is eagerly awaited.

Prof. D. S. Weaver
Department of Mechanical Engineering
McMaster University
Hamilton, Ontario, Canada