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Book review

Fluid–Structure Interactions: Slender Structures and Axial Flow, vol. 2. M.P. Païdoussis. London: Elsevier Academic Press; 2004.

This is the ‘‘eagerly awaited’’ Volume 2 of Michael Païdoussis’ *magnum opus* as referred to by this reviewer in his enthusiastic review of Volume 1.[1] The two volumes are, in every sense, parts of a single comprehensive and integrated coverage of the subject. Volume 1 provides important background material and a detailed treatment of the dynamics and stability of fluid-conveying pipes in 6 chapters. Volume 2 begins with Chapter 7, p. 573. Numerous references are made in Volume 2 to the material in Volume 1 and it might have been appropriate to include the contents of Volume 1 in the table of Contents for Volume 2. However, this is a minor point. As *the* major contributor to this field of research for more than 40 years, Païdoussis writes with authority and flare, clearly demonstrating his deep physical understanding, mathematical prowess and love for the subject.

Chapter 7 treats ‘‘Thin Shells Containing or Immersed in Flow’’. Having comprehensively covered the dynamics and stability of thick-walled pipes in Chapters 3–6 (Vol. 1), this chapter examines cases in which the wall is sufficiently thin that circumferential as well as axial wall deformations occur and cylindrical shell theory must be employed. While this increases the complexity of the analysis, it also admits more interesting response dynamics. An example is post-divergence coupled mode flutter which is observed experimentally for thin-walled cylindrical tubes (shells) but has been shown theoretically to be impossible for thick-walled pipes. The treatment is extended to cover the effects of various boundary conditions, viscosity, confinement, swirling flows, turbulence, and nonlinearities. Along the way, many physical insights are provided and apparent paradoxes are resolved. The Chapter is completed with a brief coverage of practical applications varying from physiological systems (veins, arteries, airways, etc.) to aeronautical devices such as the conical shells used in jet engine afterburner heat shields and rocket nozzle extensions.

It is probably fair to say that much of the work covered to this point in the book was driven by curiosity and laid the foundation for important practical applications after the fact. This contrasts with the research reviewed in Chapter 8, ‘‘Solitary Cylindrical Structures in Axial Flow’’, which was largely driven by concerns for the structural integrity of such components as nuclear fuel and control rods with axial flow in nuclear power plant. Interestingly, such structures were discovered generally not to be prone to flutter or fluidelastic instabilities which could lead to short term failure. Rather, they are vulnerable to random forced vibration due to turbulence buffeting which can lead to long term failure through fretting wear and possibly fatigue. Païdoussis develops the linear theory, examines the stability behaviour, presents the prediction methods for turbulence-induced small amplitude response and then extends the coverage to tapered cylinders, concurrent internal and external flows, parametric resonances and various support conditions. Also included in this chapter are the static and dynamic instabilities of towed and self-propelled cylinders. Particularly interesting are the applications to towed flexible Dracones and acoustic streamers, as well as the locomotion of slender fish.

Chapter 9 deals with ‘‘Clustered Cylinders in Axial Flow’’. While the dynamic behaviour of such cylinders is similar to that of a solitary cylinder, the coupling between adjacent cylinders in a cluster adds a new dimension. The theory, confirmed by experiment, shows that fluid dynamic coupling with adjacent cylinders is destabilizing, the closer the cylinders, the greater the effect. However, from a practical point of view, the most important effect is shown to be that of hydrodynamic coupling on the spectral response and fluid added mass of the cylinders.

Chapter 10 considers ‘‘Plates in Axial Flow’’. Research on this subject was initially motivated by the failure of 2nd World War German V-2 rocket skins due to supersonic panel flutter. Païdoussis confines his coverage to simplified analyses with emphasis on incompressible flows and representative studies. This is appropriate as it permits linkage of the methods and dynamic behaviour to earlier material in the book while providing a useful lead to the extensive related

[1]Weaver, D.S., 2000. Book Review—Fluid–Structure Interactions: Slender Structures and Axial Flow, Vol. 1. Journal of Fluids and Structures 14, 753–754.

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aeronautical literature for those readers interested in pursuing this subject. Amongst the interesting applications are fluttering flags, travelling paper sheets and high speed computer discs.

Chapter 11 covers "Annular- and Leakage-Flow-Induced Instabilities". The flow rate and associated dynamic pressure of annular flows and flows through restricted passages are very sensitive to small changes in flow area. Thus, flexible structures in annular and leakage flows are very susceptible to a variety of flow excited instabilities. This chapter begins with a simple illustration of a leakage-flow-induced vibration discovered accidentally by Païdoussis when carrying out some laboratory experiments. The example is appropriate because it demonstrates how a "fix" for a minor problem produced vibrations sufficiently violent to render the experiment inoperative and how a relatively minor change in geometry of the leakage flow path eliminated the problem. Païdoussis goes on to discuss the nature of the excitation mechanisms and provides a number of examples of major engineering case histories related to nuclear reactor internals. Existing theoretical models and experiments are presented for vibrations in narrow annuli, 1-D leakage flows, cylinders in annular flows, rotating cylinders and coaxial shells. A spectacular practical example of the latter is shown to be the excessive vibration of the thermal baffle shell overflow weir in the Fast Breeder Reactor Superphenix (SPX 1).

The book finishes with a number of Appendices which provide analysis details and useful information for the various subjects covered. Notably, Appendix P provides a list of what Païdoussis considers some of the most important studies on the flutter of fluid conveying collapsible tubes published from 1969 to 2004. This subject has received a great deal of attention because of its applications in biomechanics and its complexities which have made it so difficult to model and understand. Païdoussis actually runs out of Roman alphabet letters to identify Appendices and quite appropriately uses the Greek Ω for the last appendix which covers recent publications related to Volume 1 and Corrigenda to Volume 1.

In the Epilogue, Païdoussis states that writing this book has been a labour of love and expresses the hope that "by bringing all this material together, this book will be as useful to the research community as its writer has toiled to make it be." In this reviewer's opinion, Païdoussis' hopes have been vastly exceeded. With more than 1400 references, the subject matter has been covered comprehensively. More importantly, it has been critically reviewed and integrated in a way which will make this book an indispensable tool for any researcher in this field for decades to come. The book should be no less valuable to engineering practitioners faced with related problems. While being rather mathematically demanding, the material is presented in a very accessible way with emphasis on physical understanding and numerous practical examples including guidance for avoiding problems at the design stage. Indeed, the book could serve as a model for modern technical literature. The graphics are clear and well chosen to illustrate the arguments being developed. The text is lucid and made more interesting by frequent use of historical notes, amusing anecdotes and personal experiences. Particularly appreciated are the honesty with which deficiencies in existing knowledge or methodologies are treated and the willingness to share experiences in which things did not proceed as expected. We often learn a great deal from unexpected outcomes or mistakes and such lessons are too rarely published.

Finally, this reviewer found amazingly few typographical errors, a remarkable achievement for such a monumental work. Given the scholarship, rigor and thoroughness which Païdoussis brings to his work, this should not be surprising. However, one such slip is worth noting. In an historical footnote related to the earliest awareness of fluid added mass, Païdoussis recounts that the third edition of a book "was written while Count Du Buat was in exile after the French Resolution (sic) (1789)…" Aside from the obvious comment about computers and spell-checkers, one might remark that Païdoussis' rare mistakes are honest and sometimes even amusing.

This book is an essential reference to anyone conducting research in the field, an important asset to practicing engineers faced with related problems, and an interesting and valuable study for anyone working in the broad areas of flow-induced vibrations and the stability of non-conservative elastic systems.

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