

Flow-Induced Vibrations: Classifications and Lessons from Practical Experiences (Second Edition)

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The second edition of the book titled *Flow-Induced Vibration* completes a vision by the authors to present a full treatment of the subject from a broad and decidedly practical standpoint.

The original first edition of this book stems from a Flow-Induced Vibration (FIV) seminar series held by the Japan Society of Mechanical Engineers that spanned the period from 1984 to 1999. The information contained in the many research papers presented during that time period was organized and assembled into the first edition text back in 2003. Three main categories of FIV topics were covered in that first edition: (1) vibrations induced by cross flow, (2) vibration induced by parallel flow and (3) vibration of piping conveying fluids, pressure fluctuations and thermal excitations.

The second edition, published in 2013, seeks to both revise material contained in the first edition (Chapters 1–6 contain revised treatment of the topics 1–3 above) as well as include additional information to finally complete the authors' idea of a thorough treatment of the subject of FIV. In particular, two new categories have been added in the second edition: (4) vibrations in rotary structures in a flow, and (5) vibrations in coupled, fluid–structure interaction (FSI) systems. These additional two topics are contained in Chapters 7 and 8, respectively. According to the text authors, these five broad categories 1–5, now a complete set in the second edition, encompass roughly the entire breadth of relevant FIV problems of interest.

The book's opening chapter contains an excellent introduction to the general topic of FIV. This very informative chapter includes a very well done attempt, via figures and tables, of (a) classification of FIV problems based on the type of flow present, (b) the resulting vibration mechanisms, (c) examples and (d) “pointers” to specific corresponding sections for given categories discussed in the book's later chapters. Chapter 1 also discusses modeling approaches, where the authors' definition of modeling includes numerical simulation, analytical methods and sub-scale experimentation. The remainder of Chapter 1 contains a helpful treatment of the fundamental FIV mechanisms divided primarily

between so-called “self-induced oscillation” (or self-excited vibration) and forced vibration, including the effects of fluid damping and added mass. These last topics are discussed again in more depth in Chapters 7 and 8.

The exploration of vibrations induced by external cross flow is the focus of Chapter 2, easily the text's largest chapter and coming in at nearly twice the size of any other chapter in the book. The book's extensive treatment of cross-flow-induced vibration is not unexpected since this category of FIV is perhaps the most common and important excitation mechanism. Chapter 2 topics include single-, double- and many-cylinder systems subject to cross flow, with each case containing its own discussion of historical evolution of theories, solution approaches and practical illustrative examples. This second chapter also contains sections on cross-flow over non-circular cross-sections (e.g., rectangular) and also acoustic resonances in tube bundles, both following the same discussion outline as the circular cylindrical sections. As with many later chapters, Chapter 2 closes with a short discussion on the design practices for preventing this particular undesirable FIV mechanism (termed “Hints for Countermeasures” in the text).

As with Chapter 1, an attempt at organization of the many cross-flow-induced sub-categories and divisions continues in Chapter 2. This heavy concentration on classification of FIV mechanisms is perhaps the book's greatest advantage and strength. On virtually any topic covered in the text, the reader will come away with an excellent view of the breadth and categorical breakdowns of that given FIV topic area. Sometimes this is accomplished by the authors using tables, in other cases with figures and/or flowcharts. Regardless, it is usually well-done and undoubtedly will be very helpful to steering a practitioner in FIV attempting to classify their particular FIV problem and identify the most applicable solution approaches available.

Chapter 3 shifts the flow direction over a structure 90 degrees and examines FIV caused by axial flow. Primarily, this chapter presents analysis of axial-flow-induced vibration of single- and multiple-cylinder (termed “tube bundles”) systems, elastic plates, and elastic shells. As with Chapter 2, this chapter considers both single- and two-phase flow for excitation. The chapter concludes with a fairly detailed and interesting discussion on the formation of leakage-flow passages in structures due to their large amplitude self-excited vibrations.

Similarly, vibrations induced by internal fluid flow in straight and curved pipes, with both single- and two-phase flows, are considered in Chapter 4. This chapter

also contains a section on highly-flexible pipe sections in piping systems (usually included in a given piping system design in order to account for thermal expansion effects and termed “bellows” in the present text) and the resulting FIVs which frequently arise as a result.

Chapter 5 examines periodic pressure wave loading within piping systems caused by (a) compressors, (b) pumps and hydraulic turbines, (c) transient pressure surges in liquid flow (or “water hammer” events) and (d) valves and their largely self-excited vibration responses. The chapter concludes with a short, high-level, mostly qualitative, treatment of self-excited acoustic noise and resulting pressure loading, due to various separated flow phenomena. While entire texts have been dedicated on this important topic alone, here it contains only a cursory, classification-driven, treatment of this topic. However, it is covered at an appropriate level for the present chapter and text.

Complex acoustic emissions and vibration resulting from thermo-acoustic, or heating-related, loading mechanisms, is the subject of Chapter 6. This induced both periodic narrowband acoustic oscillations from combustion as well as the more broad frequency band and inherently random/stochastic “combustion roar” arising from heat-fluctuation-induced turbulence. Also contained in Chapter 6 are sections on the pressure oscillations due to steam condensation as well as the converse of boiling-process-induced vibrations.

As mentioned, Chapters 7 and 8 contain new material added in the second edition that, in the text authors' overall vision, completes the correct coverage of the overall field of FIV. Chapter 7 is dedicated to rotary machines and the resulting variety of FIV phenomena therein. This includes discussions on the self-excited and forced-flow-related vibrations of blades and blade cascades, partially-filled rotors and confined-flow machinery. Seal-related instabilities under annular flow are also discussed for the remainder of Chapter 7. The only minor criticism of the Chapter 7 material relates to the poor-quality of some of the figures. Figure quality in the rest of the book is very good but many of those in Chapter 7 stand to be improved in any future editions of the text.

Chapter 8 is the final chapter in the text and contains a primarily mathematical treatment of the complex problem of fully-coupled, two-way fluid–structure interaction (FSI) system vibrations. In contrast to most of the earlier chapter in the book, this last chapter is devoted to the mathematical solution approaches for fluid–structure systems in which the induced motion of the fluid due the contacting structural body displacement during

vibration, is important. This full coupling sets up a complex, dynamic feedback loop that needs to be considered in the analysis of certain fluid–structure systems. Chapter 8 discusses the structural vibrations in circular- and arbitrary-shaped cylindrical FSI systems from the standpoint of the fluid's added mass, added damping, free-surface oscillations (or “sloshing”) and contained-fluid vessel vibrations (or “bulging”). Perhaps due to the complexity of the subject matter discussed, Chapter 8 is decidedly more mathematical than the other chapters in this text.

Overall my impression on this book is very positive for what it attempts to accomplish. This second edition of *Flow-Induced Vibrations* is a very well done introductory text covering a broad spectrum of the FIV topic in a helpful, illuminating and organized manner. The reader should also expect a highly practical treatment of the subject, complete with numerous real-world illustrative examples and feasible preventative countermeasures for undesirable vibrations. The text offers an excellent starting point for steering a practitioner toward the correct classification of their individual FIV problem and introductory theory and references for at least sending them down the correct solution approach path.

From an editorial standpoint, references in the book are plentiful and they consist of an appropriate mixture of leading FIV researchers from both native Japan and the international community. There also was a very unified format employed throughout the text with nearly all chapters being organized in the following order: outline/introduction, theoretical treatment, practical examples and preventative practices. Considering the text was authored by six authors (termed “editors” by the authors due to the review-nature of the acquisition of the subject matter), the resulting book contains an admirably consistent format and seamless written tone across its numerous topics and eight chapters. The book reads like any other single/double author technical manuscript or text, not like other edited multi-author technical compilations which read as a disparate collection of related topics by differing-style authors. In addition, the translation of the book was superb and the reader will be unable to tell that a good fraction of the material was translated from Japanese. The only minor drawback was the lack of homework-type problems at the end of each chapter which it is suggested be included in future editions of the book.

In closing, the second 2013 edition of *Flow-Induced Vibrations* is a very well done and interesting book that provides a highly practical and organized treatment of the broad field of FIV. It is recommended by students and practitioners interested in a general introductory,

yet real-world, approach and excellent classification guide to the topic. Reading this book as a first step in FIV will lead them down the correct road for a more detailed study of any of the individual topics in the field.

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