FLUID-STRUCTURE INTERACTIONS

Structures in contact with fluid flow, whether natural or man-made, are inevitably subject to flow-induced forces and flow-induced vibration: from plant leaves to traffic signs and to more substantial structures, such as bridge decks and heat exchanger tubes. Under certain conditions the vibration may be self-excited, and it is usually referred to as an instability. These instabilities and, more specifically, the conditions under which they arise are of great importance to designers and operators of the systems concerned because of the significant potential to cause damage in the short term. Such flow-induced instabilities are the subject of this book. In particular, the flow-induced instabilities treated in this book are associated with cross-flow, that is, flow normal to the long axis of the structure, although the book does not aim to cover every possible type. Instead it treats a specific set of problems that are fundamentally and technologically important: galloping, vortex-shedding oscillations under lock-in conditions, and rain-and-wind-induced vibrations, among others. The emphasis throughout is on providing a physical description of the phenomena that is as clear and up-to-date as possible.

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CROSS-FLOW-INDUCED INSTABILITIES

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Preface

Structures in contact with fluid flow, whether natural (e.g. wind and ocean currents) or man-made, are inevitably subject to flow-induced forces and flow-induced vibration: from plant leaves to traffic signs, to more substantial structures, such as bridge decks and heat-exchanger tubes. These vibrations may be of small or large amplitude, and they may be inconsequential, or of mild or even grave concern.

Consider overhead transmission lines, bridges, tall buildings, and chimneys subjected to wind, offshore risers and umbilicals in ocean currents, cylinders and cylindrical tube arrays in power-generating and chemical plants, for example. Such structures vibrate to some extent at any flow velocity, e.g. due to turbulence or vortex shedding. If the vibrations are of small amplitude, they may lead to fatigue or fretting wear *in the long term*. However, under certain circumstances, the vibration amplitude is large, and damage may occur *in the short term*, in hours or weeks. Moreover, the vibration may be *self-excited*. Typically, but not universally, such vibration is associated with a threshold of flow velocity: on one side of the threshold, oscillations due to some perturbation imparted to the system die out; on the other side, oscillations grow. More generally, we may define self-excited vibration simply as one that grows exponentially with time until it settles down to a limit-cycle motion. Clearly, such phenomena, more specifically the conditions under which they arise, are of great importance to designers and operators of the systems concerned, because of the great potential to cause damage in the short term. Such *flow-induced instabilities* are the subject of this book.

In particular, the flow-induced instabilities treated in this book are associated with cross-flow, i.e. flow normal to the long axis of the structure(s), presuming the geometry is such; i.e. we are mostly concerned with more or less slender structures in cross-flow. These *cross-flow-induced instabilities* are known to be very severe and to occur in the range of natural or engineering flow velocities. Axial-flow-induced instabilities are treated in other books.

Cross-flow about slender structures generally involves flow separation, making its modelling quite difficult compared with axial-flow-related analyses. For that reason, cross-flow-induced instability models inevitably involve some degree of empiricism, and progress in their understanding has only been possible via the intimate interweaving of theory and experiment.

It is not the aim of this monograph to cover every possible type of cross-flow-induced instability. Instead, a specific set of problems is treated which are fundamentally and technologically important: galloping, vortex-shedding oscillations (VIV) under lock-in conditions, rain-and-wind-induced vibrations (RWIV), wake-induced vibrations of small groups of cylinders and flow-induced instabilities of arrays of cylinders, galloping and flutter of bridge decks, and ovalling oscillations of cylindrical shells (e.g. chimney stacks). Flutter in aeronautical structures is not treated in this book.

The emphasis throughout is to provide as clear a physical description of the phenomena as possible, as well as the state of the art in each topic, both in terms of physical understanding and means of prediction. Each topic is first treated in a simplified way, affording an easy grasp of the fundamentals; this is followed by more sophisticated treatment, ending with the most up-to-date state of the art. Care is taken to provide a coherent and fair account of the historical aspects of each topic. An extensive list of references is provided to direct the interested reader to the primary sources, if desired.

This is a monograph for engineers and applied scientists interested in these topics – researchers and practicing professionals alike, working in wind and ocean engineering and in the power-generating industry. It can also serve as a textbook in a graduate-level course.

We are grateful to the Natural Sciences and Engineering Research Council (NSERC) of Canada and Fonds Québécois de la Recherche sur la Nature et les Technologies (FQRNT) of Québec, as well as l'Institut Français du Pétrole, le Centre National de la Recherche Scientifique (CNRS), École Polytechnique, and McGill University.

Writing a book involves hard work and necessitates relentless concentration of effort from time to time, which has meant "disappearances" into our respective offices. We are very grateful to our respective spouses Vrisseis (*Βρισηΐς*), Carol, and Sabine for their forbearance and relentless support.

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