Preface

This monograph is the result of lectures given by the author at the *Université d'Aix-Marseille (France)* to students of the *Diplôme d'Etudes Approfondies de Mécanique* (which is now the *Master de Mécanique*). It is aimed mainly at postgraduate students, PhD students and practicing acoustical scientists and engineers.

Among the most important sources of noise pollution are transport means, that is, cars, trucks, trains, planes, boats, etc. All these vehicles are essentially composed of thin vibrating structures. This is the reason why the present book is devoted to the vibrations and vibro-acoustics of thin structures only.

The simplest thin structure is the thin plate, then comes the circular cylindrical thin shell and the spherical thin shell. These basic structures provide a set of examples which make it possible to understand the basis of the physical phenomena of vibrations and sound radiation. Of course, most of the practical situations involve more complex structures, but their vibratory and acoustic behaviors are very similar to those of the simple structures described here, and the mathematical and numerical tools necessary to predict their response are much the same as those used for the simple examples.

Another aim of this monograph is to propose a homogenous theoretical approach to plates and shells.

Chapter 1 is devoted to equations which describe a good approximation of the vibrations of thin solids, and more precisely: plates, circular cylindrical shells and spherical shells. Analytical or numerical solutions of the mechanics equations are always based on a variational principle, which is, of course, the mathematical transcription of the conservation of energy principle which governs any phenomenon in physics. Thus, to establish the approximate equations governing the vibrations of thin structures we start from the expressions of the potential and kinetic energies of three-dimensional elastic solids, written in a convenient coordinate system: a Cartesian system for the plate, a cylindrical or spherical system for the shells. The hypothesis "thin structure" makes it possible to expand the three components of the displacement and the six independent components of the stresses as Taylor-like series of the transverse variable, leading to an approximate system of equations. We adopt the simplest approximations which are quite sufficient for a good understanding of the physical phenomena. Nevertheless, the method which is used can easily provide more accurate equations as they are proposed in the basic treatises cited in the bibliography.

Chapter 2 deals with the vibrations of *in vacuo* thin structures. The most important part concerns beams and plates. The classical method, based on the separation of variables, used to solve the vibration equation of simple plates of constant thickness (circular and rectangular) is developed in detail. Then, similar methods are applied to plates with a non-constant thickness. Finally, the Boundary Element Method (BEM) is described in some detail and illustrated by a comparison between numerical predictions and experimental results.

The chapter then continues with the problem of shell vibrations. For circular cylindrical shells, some of the existing analytical methods are proposed which enable us to give the expression of the resonance modes and of the response to a harmonic excitation. The Boundary Element Method is also described. For spherical shells, it seems that no analytical method exists. The main reason is that the equations are not separable. Thus, the presentation is limited to the variational equations which govern the resonance modes and the forced harmonic regime and to a general method for solving them is briefly outlined.

The third and last chapter deals with the important problems of acoustical engineering of sound generation by vibrating structures and sound transmission through elastic structures. It starts with a very simple academic one-dimensional example: the transmission of acoustic energy through a spring supported piston in a wave guide and the radiation of sound by such a system. Although this system is not realistic – we do not see how an experiment could be conducted – its simplicity makes it possible to develop an exhaustive study: the equations which describe the system can be solved analytically, both in the frequency and time domains. The interest of such an example is that it points out clearly the main aspects of the phenomena involved in sound transmission and sound radiation by vibrating structures.

After a short section, in which the basic concepts and equations of acoustics are recalled, several vibro-acoustics problems are examined in some detail. These concern plates and circular cylindrical shells. The important notion of "fluid-loaded resonance modes" is introduced: these modes are characteristics of the structure-fluid system and can be used to predict the response to any excitation (harmonic, transient, random). Numerical methods for computing either the resonance modes of a fluid-loaded structure or its response to an external excitation are described. Numerical results are given and, as far as possible, compared with experiments which have been selected from recent PhD theses.

At the end of the three chapters, a few exercises are proposed as complements of the text itself. At the end of this monograph, the bibliography proposes two kinds of references: basic textbooks in which the reader can find much more detail on the different aspects which are developed; specialized papers on the topics, and particularly those from which numerical and experimental results have been used to illustrate the theoretical developments.

The aim of this monograph is to present the basic concepts and methods necessary for the study of vibro-acoustics phenomena. As such, only classical analytical and numerical methods are described: separation of variables, series expansions in terms of special functions, matched asymptotic expansions, Boundary Element Methods (BEM). Nowadays, much more powerful numerical methods have been developed, for example, Statistical Energy Analysis (SEA), Finite Element Methods (FEM) and mixed methods such as various BEM–FEM methods, medium and high frequency approximations, numerical techniques for improving the performances of BEM and FEM computer programs (in particular the Fast Multi-pole Method), etc. Several specialized books have already been published on these topics. Several pieces of software for acoustics and vibro-acoustics engineering are now available.