Mechanical Vibrations

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Modeling and Measurement

Second Edition

Springer

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To our children, Jake, BK, Kellye, and Kyle

Preface

In this second edition textbook, we describe essential concepts in the vibration analysis of mechanical systems. The book incorporates the fundamentals of modal analysis, beam theory, and finite element analysis, as well as the required mathematics and experimental techniques, into a unified framework that is written to be accessible to undergraduate students, researchers, and practicing engineers alike. This book is based on undergraduate courses in mechanical vibrations that we have previously offered and developed the text to be applied in a traditional 15-week course format. It is appropriate for undergraduate engineering students who have completed the basic courses in mathematics (through differential equations) and physics and the introductory mechanical engineering courses including statics, dynamics, and mechanics of materials.

We organized the book into ten chapters. The chapter topics are summarized here.

- Chapter 1—We introduce the types of mechanical vibrations, damping, and periodic motion.
- Chapter 2—We explore topics in single degree of freedom free vibration, including the equation of motion, the damped harmonic oscillator, and unstable behavior.
- Chapter 3—We introduce single degree of freedom forced vibration and discuss the frequency response function, rotating unbalance, base motion, and the impulse response.
- Chapter 4—We extend the analysis in Chap. 2 to consider two degrees of freedom free vibration. This includes the eigensolution for the equations of motion and modal analysis.
- Chapter 5—We extend the analysis in Chap. 3 to consider two degrees of freedom forced vibration. We describe complex matrix inversion, modal analysis, and the dynamic absorber.
- Chapter 6—We analyze model development by modal analysis. This incorporates the peak picking approach for identifying modal parameters from a system frequency response measurement and mode shape measurement.

- Chapter 7—We describe frequency response function measurement techniques. Impact testing is highlighted.
- Chapter 8—The topic of this chapter is continuous beam modeling. We develop closed-form frequency response function expressions for transverse beam vibration, torsion vibration, and axial vibration of beams.
- Chapter 9—We provide an introduction to finite element analysis. Beam models for axial and transverse vibration are derived and implemented; this includes the mass and stiffness matrices. Examples are provided to evaluate model convergence as elements are added. This chapter is new to the second edition.
- Chapter 10—We introduce the concept of receptance coupling, where frequency response functions (receptances) are coupled to predict assembly dynamics.

To demonstrate and unify the various concepts, the beam experimental platform (BEP) is used throughout the text. Engineering drawings for the BEP are included in Appendix A, so that instructors can provide their own demonstrations in the classroom. Additionally, MATLAB® programming solutions are integrated into the text through many numerical examples.

Special features of the book include: (1) MATLAB® MOJO code examples; (2) *By the Numbers* numerical solutions; (3) problems and solutions, including MATLAB® code; (4) non-mathematical *In a Nutshell* explanations that summarize selected concepts in layman's terms; and (5) discussions and numerical examples of model uncertainty.

We conclude by acknowledging the many contributors to this text. They naturally include our instructors, colleagues, collaborators, and students. Among these, we would like to particularly recognize the contributions of J. Tlusty, M. Davies, T. Burns, J. Pratt, and H.S. Kim.

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