Vibration Testing-Theory and Practice
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This second edition of a book that was first published in 1995 is a good foundational text for engineers concerned with component vibration testing as it might relate to failure analysis, qualification testing, reliability testing, and machinery diagnostics. The book is well written and makes the presented concepts easy to understand. I recommend it both as an introduction to laboratory testing techniques for the relative novice and as a reference for experienced practitioners in the field. While the book does provide a basic introduction to modal analysis, it does not address experimental modal analysis in enough detail to satisfy a reader specifically concerned with this topic.

Vibration Testing is divided into eight chapters.

Chapter 1, An Overview of Vibration Testing, begins with a case study that shows the potential pitfalls of laboratory vibration testing. It tells the story of a sensor that was supposed to measure vibration on a naval gun turret, which passed a rigorous set of vertical vibration tests in the laboratory, but failed after the first shot from the gun because the test designers had neglected to consider horizontal vibration and the muzzle blast from the gun. In the remainder of this short chapter the authors introduce the concepts of structural input-output relationships.

In Chapter 2, Dynamic Signal Analysis, the authors present a very thorough development of signal processing concepts, such as classification (periodic, transient, stationary, non-stationary, chaotic) and the time and frequency domains. They discuss the analysis of periodic, transient and random signals and show the distinctions between the Fourier series and Fourier transform. Correlation analyses in the time and in the frequency domains are also covered. A number of simple examples help illustrate key concepts.

Chapter 3, Vibration Concepts, employs the single-degree-of-freedom oscillator to introduce key concepts, such as free and forced vibration, damping models, the frequency response function, impulse response and shock spectra. In one example, the authors use a spring-supported pendulum to show how body orientation (relative to gravity) can affect the natural frequency of a system. A simple two-degree-of-freedom system is used to illustrate the concept of mode shapes, modal orthogonality and generalized coordinates. The properties of continuous systems are introduced using rods and beams. The chapter ends with brief discussions of non-linear systems and chaotic vibration.

Chapter 4, Transducer Measurement Considerations, describes in detail how common sensors (LVDTs, accelerometers, force transducers) are constructed, including the electronic circuits that condition their signals. Mechanical and electrical models of an accelerometer and force transducer are used to demonstrate transducer response to transient inputs. Cross-axis accelerometer sensitivity and a method to correct for this sensitivity are presented. The chapter includes a thorough presentation of transducer calibration methods and ends with a discussion of factors (base strain, cable noise, humidity etc.) that can affect transducer performance.

Chapter 5, The Digital Frequency Analyzer, presents a comprehensive development of the basic principles related to digital sampling and digital frequency analysis. The concepts of aliasing, windowing, leakage, overlap and coherence are discussed, supplemented by a presentation of the associated mathematics. The advantages and disadvantages of four windowing functions (rectangular, Hanning, Kaiser-Bessel, flat top) are presented in terms of their appropriateness in processing periodic, transient and random signals.

Common methods used to excite vibration in structures, including load release, mechanical exciters and impulse devices, are presented in Chapter 6, Vibration Excitation Mechanisms. A considerable part of the chapter is devoted to mechanical exciters including mechanical/electrical models, voltage versus current operating modes, and the possible modification of the test item's dynamics by the shaker.

Chapter 7, The Application of Basic Concepts to Vibration Testing, builds on the background developed in the earlier chapters to present best approaches to vibration testing in practice. Transducer mass effects are illustrated through examples. The appropriate windows for different excitation signals (sinusoidal, chirp, pseudorandom, impulse) are discussed, as are the potential pitfalls of using different windows for the input and output signals. The chapter ends with an example of non linear behavior induced in a linear structure (beam with tip mass) because of the test environment (vertical orientation with horizontal excitation).

In the final chapter, Chapter 8, General Vibration Testing Model: From the Field to the Laboratory, the authors explore the challenges of simulating field conditions in a test laboratory environment, using simple dual input/output models for the test item, field vehicle and test exciter to illustrate the relative importance of replicating attachment motion and forces in the test article. An example to illustrate these concepts ends the chapter.

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