Preface

Materials are generally transported after manufacture or during use. They are subjected to various mechanical and climatic environments that can impair performance and reliability. Therefore, it is essential to design them according to stresses they will experience in an operating environment and to verify their durability through testing before mass production.

The actual mechanical environment in particular is composed of generally random vibrations, sometimes sinusoidal or periodic, and shocks.

This approach therefore requires measuring these stresses under real-world operating conditions. By digitizing them and having analytical tools at hand to estimate and compare their severity, they can be transformed into simplified specifications in a shorter timeframe to allow for qualification testing.

The most common analytical methods use calculations in the frequency domain. They rely on power spectral densities (PSDs) for stationary random vibrations, shock response spectra for shock-type loadings, and extreme response or fatigue damage spectra for other types of vibrations. These tools also make it possible to synthesize the various loadings from a life profile in order to establish representative specifications, while taking into account safety factors related to the statistical nature of vibration environments.

Due to their stochastic nature, random vibrations can only be studied on a probabilistic level. With hypotheses about the distribution of instantaneous signal values, it is possible to calculate a number of parameters to characterize them, for example, the RMS value, the average frequency and the distribution of the largest

peaks. These estimations are made in particular on the stress response of a system with 1 degree of freedom, a model widely used for severity comparisons.

In the field of frequency analysis, PSD calculations are generally performed using the Welch method, which uses Fourier transforms (FFTs), in turn enabling rapid calculations. However, other interesting methods exist that are often overlooked, and their use is facilitated by the speed of today's computing resources. These methods, along with their advantages and disadvantages, are reviewed in this book.

There are books that discuss these subjects, such as those in the *Mechanical Vibration and Shock Analysis* series from the same author.

Shock response spectra, which represent the maximum response of a linear system with a single degree of freedom subjected to a shock, are frequently used in finite element analysis software to estimate the maximum response of multi-degree-of-freedom systems through modal combinations. Several methods are proposed, particularly in earthquake-related standards documents. The most commonly used methods are reviewed, along with some comments on their expected accuracy.

Despite criticisms (its linear, single degree of freedom model), the shock response spectrum remains the preferred tool for analyzing mechanical shocks and earthquakes. Its use extends to finite element analysis software as an input for estimating structural responses in multi-degree-of-freedom models. However, the approximate methods developed for this purpose can sometimes prove quite imprecise.

Vibrations can damage a structure when subjected to excessive instantaneous stress or repeated stress. Extreme response and fatigue damage spectra allow for severity comparisons based on these two criteria, as well as measurements that can be converted into design or testing specifications.

Some topics that are rarely addressed in the literature, such as the performance of bolted assemblies under vibrations, are discussed in detail.

The names of certain authors appear very often in publications on the origin of these methods and during their development, such as, without this list being exhaustive: S.O. Rice for the mathematics relating to random vibrations; J. Bendat, A.G. Piersol, and D.O. Smallwood for analytical methods; and M.A. Biot, A. Der Kiureghian and E. Rosenblueth for shocks and earthquakes, among many others.

All these processes use a specific vocabulary that we felt it useful to compile. In the five volumes of *Practical Notes on Mechanical Vibration and Shock*, we recall the definition of each term and provide some explanation to clarify the possible uses of each concept.

The signal being processed is generally assumed to be an acceleration as a function of time, denoted as $\ddot{x}(t)$.

November 2026