Fundamentals of Vibration for Design Applications

Course No. 117

FOR WHOM INTENDED This course is for design engineers and project managers. It also helps quality and reliability specialists, also personnel in any industry where equipment problems may be encountered during the shipment and use of their product. Project personnel, structural and packaging engineers learn how to take vibration and shock into account in the design process.

BRIEF COURSE DESCRIPTION The course commences with an introduction to vibration and its effects and then proceeds to cover the basic theory needed to understand the material covered during the three days. While mathematics is kept to a minimum, it is necessary to cover a sufficient amount so that the concepts of vibration can be understood. The use and application of decibels (dB) is described, then the theory of dynamics is covered including the relationships between displacement, velocity and acceleration. Videotaped physical demonstrations show how structures behave when mechanically excited. Damping theory and its effect on transmissibility ratio and resonance stacking and on product design is addressed.

Various types of vibration exciters or shakers are discussed next. Random vibration theory, including power spectral density theory, is discussed and video demonstrations show the effects of sinusoidal and random vibration. Some basic theory of spectral analysis, filters and vibration measurement systems provides a background for understanding data acquisition and analysis topics. The course touches on test fixture design for vibration testing.

Different types of sinusoidal and random vibration testing are discussed next. Material fatigue and the correct use of S-N curves for designing product life testing and developing accelerated product development testing procedures are covered. An introduction to modal analysis and testing theory and application is addressed and its use for product design. Environmental stress screening including HALT and HASS applications are addressed.

Mechanical shock applications, including design to withstand shock, are discussed in some detail. Finally, standards and specifications applicable in product design to meet various environmental conditions are discussed, along with methods for tailoring of requirements for the test department.

CERTIFICATE PROGRAMS This course is required for TTi's Mechanical Design Specialist (MDS) Certificate Program and may be used as an elective for any other TTi Certificate Program.

PREREQUISITES There are no definite prerequisites. Supervisors are invited to telephone or e-mail TTi on prospective attendees' backgrounds and needs.

TEXT Each participant will receive a course workbook, which contains most of the viewgraphs used during the presentation.

COURSE HOURS, CERTIFICATE AND CEUs Open courses meet seven hours per day. Upcoming presentation dates can be found on our current open course schedule. Class hours/days for on-site courses can vary from 14–35 hours over 2–5 days as requested by our clients. Upon successful course completion, each participant receives a certificate of completion and one Continuing Education Unit (CEU) for every ten class hours.

For schedules, general information and a registration form, see TTi's web site.

Course Outline

Introduction to Vibration
Understanding Decibels (dB) and Octaves
Electronic Filters & Measurement Systems
- Low-pass, High-pass and Bandpass Networks
- RMS • Complex and Random Signals

Dynamic Force and Motion
- Laws of Motion, Weight vs. Mass • Gravity • Force, Mass and Acceleration • Work, Power, Energy
- Degrees of Freedom • Natural Frequency • Harmonic Waves
- Transmissibility • Isolation • Damping

Vibration Exciters (Shakers):
- Electrohydraulic (EH), Electrodynamic Shakers
- Force Rating and Available Acceleration
- Table Expanders and Oil-Slip Tables

Random Vibration: Power Spectral Density
- Time & Frequency Domain, Spectral Analysis
- Fourier Transforms, FFT, Spectrum Analyzers
- Correlation, Auto- and Cross-Correlation
- Developing RMS G from Spectral Plot

Fixtures: Materials, Fabrication methods
Vibration Measurement: Displacement Sensing
- Strain Gages • Accelerometers

Vibration Testing: Types of Testing:
- Development, Qualification, Acceptance, Screening, Reliability, Life
- Control System Function • Function generators
- Sine Vibration Testing: Sine Sweeps
- Resonant Search • Crossover Frequency
- Random Vibration Testing:
  - Calculating RMS from PSD • Gaussian Random Signal
  - Standard Deviation
  - Statistical Degrees of Freedom, Random Vibration Control

Fatigue: How Materials Behave: The S-N Curve
- Failure Models & Mechanisms • Crack Growth • Miner's Hypothesis
- Accelerated Testing • Durability and Functional Tests

Modal Analysis: Modes • Theoretical Approach
- Structural Dynamic Equations, Modal Testing

Accelerated Testing:
- Linear vs. Non-linear product response • Margins • Assumptions
- Coffin-Manson Inverse Power Law • Cautions
- Synergistic Failure Exaggeration • Cycles

Environmental Stress Screening
- Thermal, Vibration Environments
- Step Stress Tests, HALT and HASS

Mechanical Shock: Shock Testing on various types of machines
- SRS in Shock Testing

Design to Withstand Shock
- Shock Isolation vs. Vibration Isolation • Shock Isolation Example
- Protective Packaging
- Product Fragility • Damage Boundary Theory

Standards vs. Specifications
Summary, Final Review
Award of certificates for successful completion

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