Mechanical Design for Product Reliability

Course No. 310

APPLICATIONS Random vibration and shock are important in most engineering applications where the product is exposed to vibration and shock during transport and service. An understanding of vibration and shock is crucial to improving the reliability of today's products, wherever electronic components appear.

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 the effects of vibration and shock into account in the design process.

BRIEF COURSE DESCRIPTION The course commences with an introduction to vibration and then covers basic dynamics theory including relationships between displacement, velocity and acceleration. Dunkerley's and Rayleigh's methods are introduced, with examples. Damping, transmissibility ratio and resonance stacking are addressed. The course then covers basic structural theory: tension, compression, stress, strain, torsion and moments of inertia. Examples show the torsional shape factors of different structures. The instructor then addresses frequency and stiffness of beams, plates and gussets, providing useful graphs, formulas and examples.

Modal analysis is then discussed, with mention of multi-degree-of-freedom systems, modes and complex systems. Measurement and fixturing for modal analysis and testing are covered before moving on to a brief discussion of random vibration, including power spectral density theory. The concept of RMS acceleration is discussed. Mechanical shock and its design implications are then discussed. Methods of isolating assemblies from shock and vibration are covered.

Fatigue is covered, including discussion of crack-growth rates, fracture mechanics, the S-N curve, and the use and abuse of accelerated testing, including Miner's hypothesis.

Material selection is then covered, with information on overall and design-limiting material properties. Tools are provided for comparing different materials. The course concludes with chassis analysis and general design suggestions, such as methods for increasing natural frequencies.

DIPLOMA PROGRAMS This course is required for TTi's Electronic Design Specialist (EDS) and Mechanical Design Specialist (MDS) Diploma Programs and may be used as an optional course for any other TTi Diploma Program.

RELATED COURSES Course 310 is the mechanical design portion of Course 157-5, Vibration and Shock Test Fixture Design.

PREREQUISITES: Prior participation in TTI's "Fundamentals of Vibration" or the equivalent would be helpful. Participants will need first-year college mathematics (or equivalent experience) and some facility with fundamental engineering computations. Some familiarity with electrical and mechanical measurements will be helpful.

TEXT Each student will receive 180 days access to the on-line electronic course workbook. Renewals and printed textbooks are available for an additional fee..

COURSE HOURS, CERTIFICATE AND CEUs 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

Internet Complete Course 310 features over 17 hours of video as well as more in-depth reading material. All chapters of course 310 are also available as OnDemand Internet Short Topics. See the on-line course outline for details.

Course Outline

Introduction to Vibration
Dynamic Force and Motion
- Laws of Motion, Weight vs. Mass • Gravity • Density
- Force, Mass and Acceleration • Degrees of Freedom
- Displacement • Velocity • Acceleration • Natural Frequency
- Sinusoidal Waveform • Modeling Complex (MDoF) Systems
- Dunkerley's and Rayleigh's Methods
- Transmissibility • Isolation • Damping • Examples

Review of Structural Design Fundamentals
- Material Properties • Tension and Compression
- Stress and Strain • Shear • Torque • Moments of inertia
- Torsional Stiffness • Torsional Shape Factors
- Bending Stiffness • Instability of beams and flanges

Frequency and stiffness: Beams, Plates, Gussets
- Natural frequency and stiffness graphs for various structures
- Beam Formulas • Plate frequency parameters, examples
- Column Resonance • Axial Resonance
- Example: Stresses in a Loaded Beam

Bolted Connections • Preload • Data on Bolts
- Design of Bolted Joints • Stiffness Data
- Required flange material area • Material thickness, stiffness

Modal Analysis and Modal Testing
- Applications • Modes, Natural Frequencies
- Fixturing for Impedance and Modal Testing
- Finite Element Analysis (FEA) • Example

Random Vibration: Demonstrations—Sinusoidal Vibration, Complex Waveform, Random Vibration
- Probability Density • Power Spectral Density (PSD)
- Shaker Power Spectral Density Response • Equalization
- Calculating the RMS Acceleration from Spectral Plot

Mechanical Shock:
- Causes of Shock, Effects and Remedies of Shock
- Transient or Shock Tests
- Shock Pulse shapes, Shock Isolation Example

Fatigue: How Materials Behave: The S-N Curve
- Factors Influencing Fatigue Behavior • Fracture toughness
- Failure Models & Mechanisms • Crack Growth
- Time-Dependent Failures, Time to Failure
- Goodman and Constant Life Diagrams • Miner's Hypothesis
- Accelerated Testing • Durability, Functional Tests

Material Selection in Engineering Design
- Overall & Design-Limiting Material Properties
- Application-Specific Material Properties
- Example: Optimization of Shaker Table

Chassis Analysis Example
- Chassis Dynamics, Section Properties
- Increasing Resonant Frequency, Torsion • Rotational Inertia

Design Suggestions: Overcoming Problems • Design Guidelines
- Structural rules of thumb • Stresses in Printed Circuit Boards

Summary, Final Review
Award of Certificates for Successful Completion

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