Modal Analysis for Structural Validation

Course No. 195

FOR WHOM INTENDED Engineers involved with dynamics and structural test applications.

OBJECTIVES Engineers and designers need to understand and determine the magnitude of vibration and modal characteristics of a structural system in its operating conditions. There are two ways to achieve this:

- modal analysis (the theoretical approach), and
- modal testing (the experimental approach).

BRIEF COURSE DESCRIPTION The single degree of freedom (SDoF) model enables us to understand the fundamental concepts of free and forced vibration, natural frequency, resonance and damping. However in MDoF systems, resonance may occur at a number of different frequencies, each of which corresponds to a different pattern or shape of the system's motion. These are known as the natural or normal modes of vibration or mode shapes. There is a differential equation of motion for each degree of freedom; a set of ***n*** simultaneous equations is needed to mathematically describe a MDoF system. These equations are usually solved using matrix algebra.

In the experimental method, the structure is excited by applying forced vibration and measuring the responses, from which the vibration modes are determined and a structural model developed. This is the reverse process to the theoretical method.

This TTi course begins with a review of structural and dynamic theory before examining methods of measuring frequency response from the structure under test.

Various methods of input excitation are discussed, such as shaker and impact hammer. Structural preparation and suspension methods are also examined.

A review of transducers and signal processing equipment is made before discussing analysis methods, time-domain curve fitting. Modal test philosophy including the sequence of steps and practical considerations in undertaking the test are discussed.

The tabulation of results and derivation of mode shapes and construction of spatial models (mass, stiffness and damping) are covered before discussing the application of the modal test results.

CERTIFICATE PROGRAMS This course is a recommended optional course for TTi's Mechanical Design Specialist (MDS) Diploma Program. It may be used as an optional course for any other TTi diploma program.

RELATED COURSES See course 142-4, which adds material on Mechanical Shock testing to course 195.

PREREQUISITES There are no definite prerequisites for this course. However, this course is aimed toward individuals involved in a related technical field.

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

OnDEMAND INTERNET SHORT TOPICS Many chapters of course 195 are available as OnDemand Internet Short Topics. See the on-line course outline for details.

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.

Course Outline

Background and Theory of Modal Testing
- Experimental Modal Analysis (EMA) • Theoretical Modes
- Experimental Examples — Ship Hull Section, Bridge Deck
- The Time Domain Structural Response • The Frequency Domain
- Experimental Modal Analysis (EMA) Procedure

Single-Degree-of-Freedom (SDoF) and 2DoF Systems
- The Single Degree of Freedom System: Spring, k; Mass, m Damper, c • Motion of an SDoF System
- The Impulse Response Function, h(t)
- The Frequency Response Function (FRF) • Displaying the FRF
- Nyquist Plot • Structural Dynamic Relationships
- Two Degrees of Freedom (2DoF) • 2DoF Frequency Response

Multiple-Degrees of Freedom (MDoF) Systems
- Natural Frequencies and Mode Shapes
- Modal and Frequency Matrices • Orthogonality and Normalization
- Decoupling the Equations • Single Point Excitation and Response
- Mode Shapes for: Cantilever; Plate • Mode Shape Animation

Some Essentials of Signal Processing
- Analog to Digital (A-D) Conversion • Aliasing • FFT • DFT
- Windowing for Continuous, Random and Transient Signals
- System Identification Using the FFT • Signal Averaging
- Coherence • Rules of Signal Processing
- Time and Frequency Domain Terminology

Modal Test Planning and Set-up: Selecting a Test Procedure
- Steady-State • Random • Impact • Burst Random / Chirp
- Shaker Testing • Impact Testing • Response Transducers
- Strain gages • Laser • Accelerometers • Charge accelerometers
- Voltage Accelerometers • Voltage vs. Charge Accelerometers
- Mounting Accelerometers • Transducer Selection

Meshing: Definition, Considerations • The "Pretty Picture" Approach
- Fine Mesh vs. Coarser Mesh • An Interpolation Example
- Practical Aspects of Marking a Mesh

Setting up the Modal Test: Support the Structure
- Free Boundary • Mounting Transducers • Contact Resonance
- Mounting Methods: Stud, Superglue, Beeswax, Magnet, Mounting Base, Double-Mount
- Suggestions for Making Life Easier • Setting up the Analyzer
- Random Excitation • Impact Excitation
- Windowing the Response
- Coherence Function • Coherence Examples

Modal Parameter Extraction
- Natural Frequencies, Modal Damping, and Modal Constant
- Modal Inferposition Using Single Mode Methods
- "Quadrature" method • "Circle Fit" Method • Modal Residues
- Multiple Mode Methods

Documenting Modal Test Results
- Average Coherence Example • Viscous Damping Coefficients
- Presenting Mode Shapes: Deflected Shape, Undeflected & Deflected Shapes, Deflected Extremes, Arrows, Persistence
- Color Rendition • Presenting Mode Shapes – Animations

Summary, Final Review

Award of certificates for successful completion

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