
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 elective for TTI's [Mechanical Design Specialist \(MDS\)](#) Certificate Program. It may be used as an elective for any other [TTI certificate program](#).

RELATED COURSES See [course 142-4](#).

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

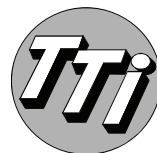
TEXT Each participant will receive a [course workbook](#), which contains most of the viewgraphs used during the presentation.

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

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 Interposition 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, Undeformed & Deflected Shapes, Deflected Extremes, Arrows, Persistence, Color Rendition • Presenting Mode Shapes – Animations
Summary, Final Exam
Award of certificates for successful completion



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