
Fixture Design for Vibration and Shock Testing

Course No. 157-5

FOR WHOM INTENDED This seminar is intended for dynamics test and evaluation personnel desiring an understanding of practical approaches to the design and fabrication of test fixtures used in vibration and shock testing. Tooling Engineers responsible for fixture design need this training.

Quality Assurance and Reliability specialists will find the course useful. So will test and instrumentation specialists. The writers of specifications for environmental tests and for manufacture of fixtures will benefit from knowing of practical limitations that exist. Product designers who are seeking solutions to vibration and shock problems will also find the course helpful.

A fixture designer must be able to design a test fixture that will transmit the intended input forces directly to the Device Under Test. To accomplish this, a designer must have specific skills as well as an understanding of vibration and shock, structures, dynamic theory, materials and fabrication methods.

BRIEF COURSE DESCRIPTION This course incorporates a mechanical design fundamentals segment equivalent to [Course 310, Mechanical Design for Product Reliability](#), which runs concurrently and may be taken by itself. 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. Bolted connections are covered next. Useful data on structures, bolted connections etc., is included in the course workbook which will be an invaluable reference tool back at the workbench.

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 mechanical shock and its design implications. 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 design fundamentals segment covers general design suggestions, such as methods for increasing natural frequencies.

The course then moves on to a brief discussion of random vibration, including power spectral density theory. The concept of RMS acceleration is discussed, followed by a basic introduction to shakers and vibration testing.

General considerations in fixture design are discussed next, along with an introduction to instrumentation and sinusoidal vibration testing, as they apply to the fixture design and evaluation process.

The course outlines a variety of strategies for attaching test items to fixtures, from the simplest adaptor plates to massive custom-designed cast and welded fixtures. Practical simplified designs and fabrication techniques, including bonding, bolting and welding, are discussed and class projects are undertaken to design some typical fixtures.

CERTIFICATE PROGRAMS This course may be used to satisfy the requirement for course 310 in TTI's [Mechanical Design Specialist \(MDS\) Certificate Program](#). It may be used as an elective for any other TTI [Specialist Certificate Program](#).

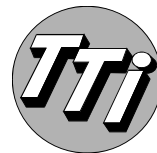
RELATED COURSES The mechanical design portion of Course 157-5 is available separately in [Course 310](#), which runs concurrently. [Course 157-3](#), an abbreviated version of 157-5, is available for on-site presentation to experienced designers.

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 and vibration will be helpful, as will an understanding of and familiarity with tooling and manufacturing.

TEXT Each participant will receive a [course workbook](#), including most of the viewgraphs used during the classroom 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 [registration forms](#), see TTI's web site.



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Course Outline No. 157-5

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
(Course 310 ends here)

Introduction to Vibration Exciters: Electrodynamic Shakers

Force ratings, Displacement and Velocity Limits
Effective Mass of Exciter Table
Electrohydraulic Shakers • Reaction Mass Effect • Slip Plates
Hydrostatic Bearings • Overturning Moment

Introduction to Fixture Design

Purpose of the Fixture • Fixture Performance
Considerations in Fixture Design

Vibration Test Fixtures—General Remarks

The "black art" of designing fixtures • Function of the test fixture
Difficulty in achieving identical motion at all attach points
Required information about the test item and the test program
Required information about shaker • Bolting to the shaker table
Example of successful redesign • Fixture weight vs. DUT weight
Fixture design for combined environments

Interface Items: Introduction • Table expanders

Horizontal accessory tables: oil-film slip tables
Connecting horizontal accessory tables to shakers
Horizontal accessory tables: hydrostatic bearings
Misuse of horizontal accessory tables
Avoid using bolts in shear • A note of warning on wide plates

Measurement of Sinusoidal Vibration-Accelerometer Systems

Accelerometers • Amplifiers • Frequency response
Mounting affects frequency response
Cable routing affects frequency response • Cross-axis sensitivity
Hand-held probe accelerometers
Vibration Intensity and Frequency: Conversion to numbers
Oscilloscopes and oscillographs • X-Y plotters, pen recorders
Decibel scaling • Need for tracking filter in evaluating fixtures
Calibration checks on the entire measuring system
Day-to-day accelerometer calibration in a "working" laboratory

Sinusoidal Vibration Testing

Specifications • Mounting the test article • Eliminating variables
Location of the control accelerometer • Multiple accelerometers
Fixturing to minimize variations in motion intensity
Standardization needed

Basic Fixture Types: Introduction • Adapter plates • Cube fixtures

Hemispheres • Conical fixtures • Enclosed box fixtures
Drum fixtures • L-type fixtures • T-type fixtures
Open box fixtures

Fixture Fabrication Methods: Introduction • Materials for fixtures

Machining fixtures from solid stock • Bolted fixtures
Cast fixtures • Welded fixtures • Bonded fixtures
Laminated fixtures • Epoxy formed fixtures • Potted fixtures
Foamed plastics for damping • Inserts

Analysis of an L-Fixture

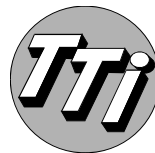
Design of a Cubical test fixture

Appendix: Understanding Decibels (dB) & Octaves

Types of Dynamic Testing • Accelerated Testing

Summary • Final Review

Award of Certificates for successful completion



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