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# 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. Weapon and 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, fabrication and welding.

**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 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 design fundamentals segment concludes with chassis analysis and general design suggestions, such as methods for increasing natural frequencies.

The course then covers the subject of Fixture Design. While a basic knowledge of shakers and vibration testing is a prerequisite for the class, a chapter is included on these topics. General considerations in fixture design are discussed, 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 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](#).

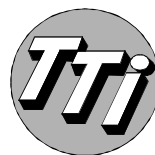
**RELATED COURSES** The mechanical design portion of Course 157-5 is available separately in [Course 310](#), which runs concurrently.

**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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# Fixture Design for Vibration and Shock Testing

## 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  
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

#### Introduction to Vibration Exciters: Electrodynamical 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

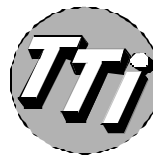
#### Design of a Cubical test fixture

#### Appendix: Understanding Decibels (dB) & Octaves

Types of Dynamic Testing • Accelerated Testing

#### Summary • Final Examination

Award of Certificates for successful completion



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