Transducer Mounting and Test Setup Configurations

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The Modal Shop
Transducer Mounting

• Mechanical connection method
  – Stud mount
  – Adhesive mount
  – Magnetic mount
  – Press-fit friction mount

• Test parameter considerations
  – Frequency range
  – Mass loading
Mechanical Mounting: Impact on Frequency Range

![Chart showing sensitivity deviation vs. log frequency for different mounting methods. The chart includes symbols for Hand Probe, Dual Rail Magnet, Flat Magnet, Mounting Pad, Adhesive Mount, and Stud Mount. The sensitivity deviation is measured in dB relative to 100 Hz.]
Stud Mount Transducers

- Best frequency response characteristics – just like the manufacturer’s cal labs
- Apply silicon grease at mating surface
- Requires surface preparation
- Proper torque recommended
Adhesive Mounting Supplies
Adhesive Mount Transducers

- Cyanoacrylate (superglue)
  - “Instant” adhesive; strong, but still removable
  - Gel vs liquid – depends upon surface flatness
  - Excellent frequency response characteristics
Adhesive Mount Transducers

- Petro wax (bees wax)
  - Ultra convenient and simple
  - Good for short term testing only
  - Frequency response characteristics highly dependent upon surface prep and amount
Adhesive Mount Transducers

- Hot glue
  - Allows attachment to poorly-mated surfaces
  - Good for short term to mid term testing
  - Frequency response characteristics poor, but generally good enough for modal apps
Adhesive Mount Transducers

• Dental cement / fast-cure epoxy
  – Allows attachment to poorly-mated surfaces
  – Pseudo-permanent attachment for reference transducer at shaker input location
  – Use “disposable” mounting pad with stud
Magnetic Mount Transducers

- Extremely convenient
- High attraction forces allow for reasonable high frequency characteristics
- Available in dual-rail style for attachment to curved surfaces
Press-fit Mount Transducers

- Extremely convenient and efficient
- Designed specifically for low frequency (<1000 Hz) laboratory modal applications
- Cable base mounts adhesively, modal sensor mechanically attaches using electrical pins
Mounted Accelerometer
Frequency Response Calibration

![Graph showing frequency response of different mounting materials for accelerometers.](image-url)
Mass Loading Considerations

• Acquire FRF with a single accelerometer
• Mount a second accelerometer next to the first and re-acquire FRF
• Compare for measurable differences
Test Setup Considerations

• Understand goals/reasons for performing experimental modal analysis
  – Troubleshooting or failure analysis
  – Finite element model verification
  – Finite element model correction
  – Component substructure / system modeling
Test Setup Considerations

• Recognize the 4 primary assumptions of experimental modal analysis
  – Observability
  – Time Invariance (Stationarity)
  – Linearity
  – Maxwell’s Reciprocity
Observability Assumption

• Response DOF must have adequate spatial resolution to represent the modes of interest
Observability Assumption

First bending – beam with seven accelerometer measurement points
Observability Assumption

If data acquired only at endpoints… bending is not observable
Observability Assumption
Observability Assumption

• Forcing function(s) applied at input location(s) must adequately excite the modes of interest

AVOID NODES!

Graphic from Agilent Application Note 243-3
Modally-Tuned Impact Hammers as Pre-Test Tool for Evaluating Structures...
... for Optimizing Reference Locations and Ensuring Observability

Good Input Location

Bad Input Location
… for Determining Optimal Frequency Range

• Assure adequate spatial resolution to observe:
  - Important, dominant modes
  - Necessary modal density
… for Testing Boundary Conditions

Rule of Thumb: 5-10x separation between rigid body and flexible modes

Graphic from Agilent Application Note 243-3
**Time Invariance Assumption**

- Test article (and its boundary conditions) must exhibit stationarity
  - Parameter estimation algorithms assume consistent global modal properties throughout data set
  - Environmental changes during data acquisition cause shifts in stiffness/damping properties resulting in measurable shifts in resonant frequencies
  - Roving accelerometers to acquire data set results in variable mass loading on test article
Time Invariance Assumption

• DATA CONSISTENCY
• DATA CONSISTENCY
• DATA CONSISTENCY

• i.e. acquire entire data set simultaneously (single “snapshot”) or at least as fast as possible
**Time Invariance Assumption**

- Test methodology to achieve best data consistency
  - Simultaneous MIMO/SIMO testing
  - Automated bankswitching
  - Manual bankswitching
  - Roving accelerometers
  - Impact testing
### Benefits of Bank-Switching

#### Simultaneous, 288 ch

<table>
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<th>No. of Test Configurations</th>
<th>PreSetup Time</th>
<th>Acquisition Time</th>
<th>Cost Estimate</th>
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#### Roving, 112 ch

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#### Bank-switch, 288 to 112 ch

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**Bank-Switching Example**

- Inputs: 2 vertical, 1 lateral, 1 skewed
Bank-Switching Example

- Response points: 17 patch panels, each bank of 16 accelerometers
Bank-Switching Example

• Bank-switch patches of data (3 x 96 ch) into smaller data acquisition system
Modular Cabling / Patch Panel System for Clean Setup

- Eases setup troubleshooting
- Eliminates messy “rat’s nest” of cables
- Economical multi-conductor cabling
**Time Invariance Assumption**

- Roving accelerometers results in inconsistent global resonant frequencies due to variable mass loading on test structure

Graphic from Agilent Application Note 243-3
Linearity Assumption

• Input and output characteristics remain proportional within measurement range
• Confirm using precisely controlled inputs from shaker(s) across a range force levels
• Impact testing technique poorly suited when dealing with nonlinear test structures
Electrodynamic Modal Shakers as Excitation Source for MIMO

- Allows best control of input forcing function to optimize frequency content and signal-to-noise ratio
- Through-hole armature greatly simplifies setup attachment to test structure
Through-Hole Armature Eases Setup

- Traditional shakers with tapped armature connection leave little tolerance since setup has tapped connection at both ends
Reciprocity Assumption

- Maxwell’s Theory of Reciprocity states that FRF matrix is symmetric
- FRF between input A and output B is the same as output A and input B
- Confirm using multiple shaker locations and impedance heads for driving point measurement
Impedance Heads for Verifying Reciprocity Assumption

Accelerometer built into preload stud of force transducer
Other Pre-Test Considerations

- Free Boundary Conditions
  - Shock Cord
  - Foam Rubber
  - Air Suspension
Other Pre-Test Considerations

- Fixed Boundary Conditions
- Realistic Boundary Conditions
- Match Impedance(s) at Boundaries
- Mass Loaded Boundary Conditions
Other Pre-Test Considerations

• Transducer selection
  – Single axis vs triaxial package
  – Sensitivity, measurement range & resolution
  – Frequency range & mass
Transducer Electronic Data Sheet (TEDS, IEEE 1451.4)

- Identifies transducer (type, serial number, location)
- Stores calibration data
- Automates book keeping, reducing errors

Uses reverse bias scheme to access digital memory
Other Transducer Setup Considerations

- Use PDA scanner with bar-coded TEDS transducers to ease bookkeeping
**Final Channel Setup Definition**

- Combine Data From Geometry, PDA, and TEDS
- Complete Test Set-up Information Defined in Universal Files
  - Virtual Channel Table (1807)
  - Channel Table (1808)
  - Geometry (15)

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<tr>
<td>Geometry</td>
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Thank you for your time.