Test Cases for Modeling and Validation of Structures with Piezoelectric Actuators

LaRC

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Outline

- Objectives and background
- Approach
- Modeling methods
- Aluminum beam testbed description/results
- Composite beam testbed description/results
- Concluding remarks

Objective

Investigate and validate techniques for modeling structures with surface bonded piezoelectric actuators using commercially available FEM codes.

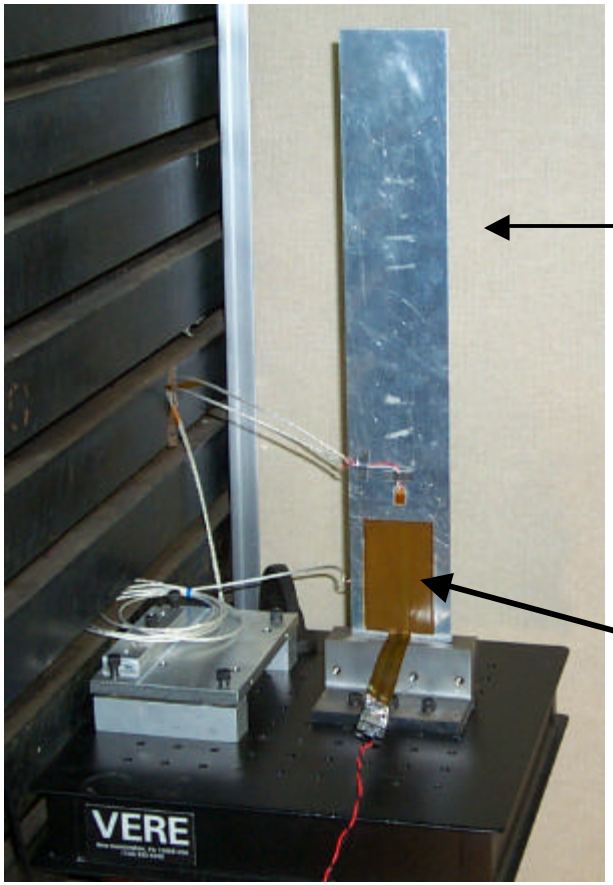
Approach

- Develop and validate FEM models of the following structures:
  - Aluminum beam testbed
  - Composite beam testbed
- Study the following piezoelectric modeling approaches:
  - Piezoelectric effect via thermal analogy and Ritz vectors
  - Piezoelectric element using NASTRAN dummy element capability
  - ANSYS piezoelectric element

Modeling Approaches

- Thermal Strain Analogy
  - Induced strain using thermal load
  - 4-node composite quadrilateral element
  - Ritz vectors computed to capture local effect
- MRJ piezoelectric elements implemented in User-Modifiable MSC/NASTRAN
  - Piezoelectric induced strains
  - Coupled field 4-node composite quadrilateral element
- ANSYS
  - 3-D Coupled Field Solid element
  - Full harmonic analysis

Aluminum Beam Testbed



Aluminum Beam

LaRC Piezoelectric Actuator

Aluminum Beam Testbed

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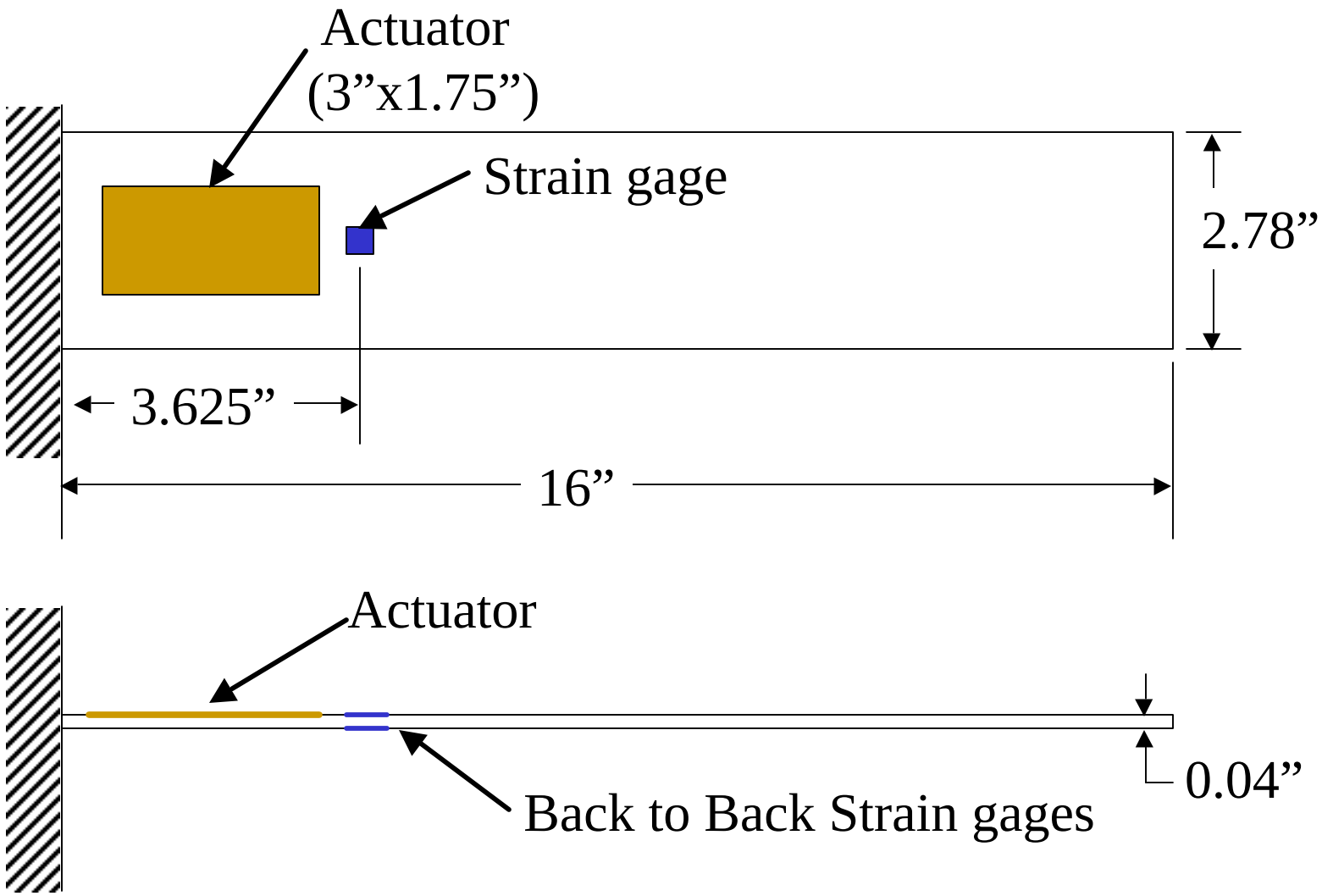

Instrumented Aluminum Beam

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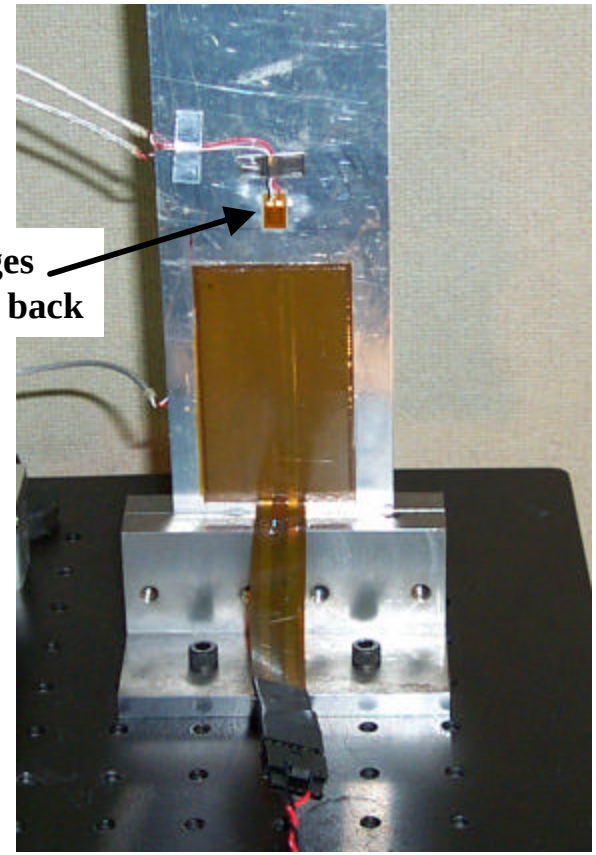
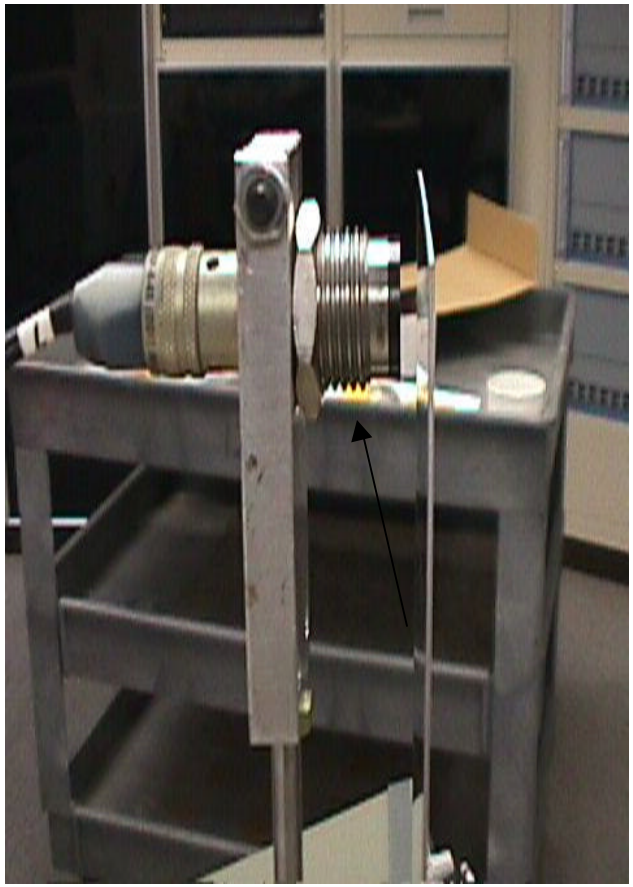


Strain gages and Actuator



Proximity Probe

Aluminum Beam Analysis Results

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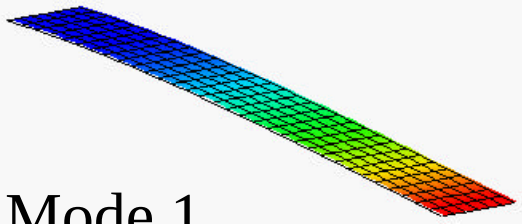
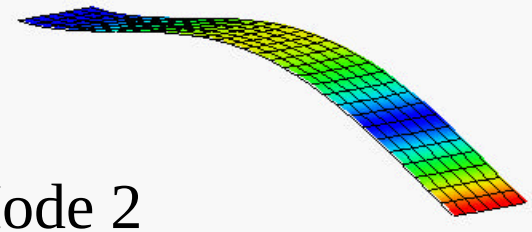
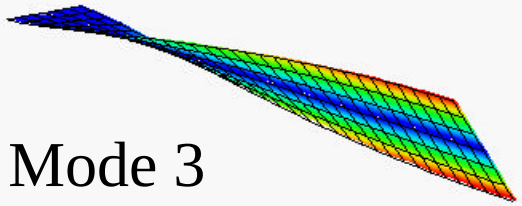


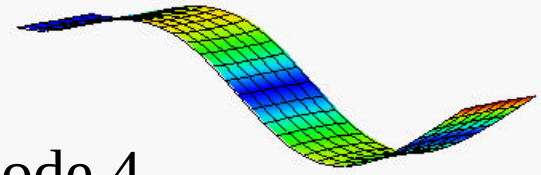
Mode 1
@ 5.06 Hz



Mode 2
@ 31.8 Hz



Mode 3
@ 57.6 Hz



Mode 4
@ 89.4 Hz

Composite Box Beam Testbed

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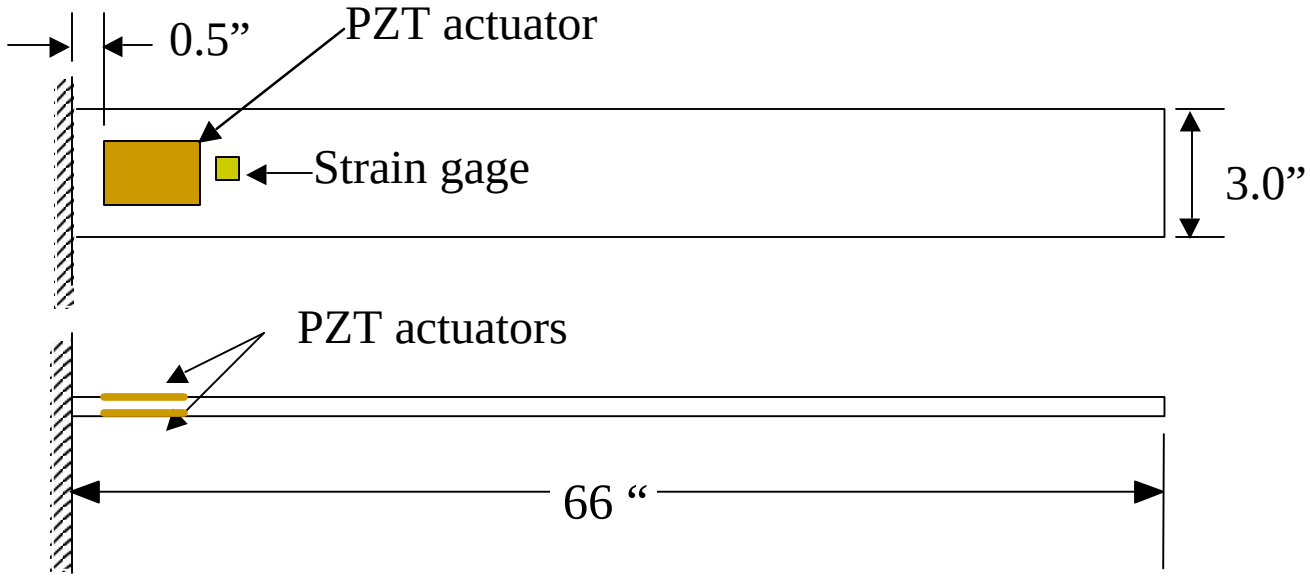
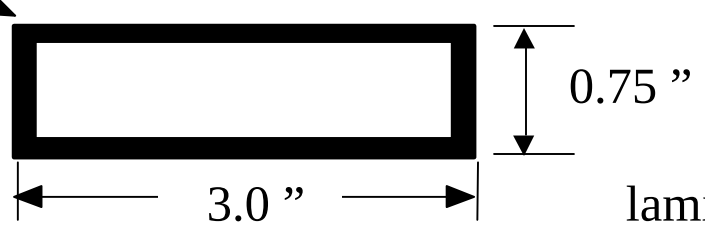


Beam cross section
(Outside dimensions)



Material T300/976

laminate thickness = 0.03”
laminate layout $[45,-45,0]_s$

AL Beam Correlation from Various Analysis Codes

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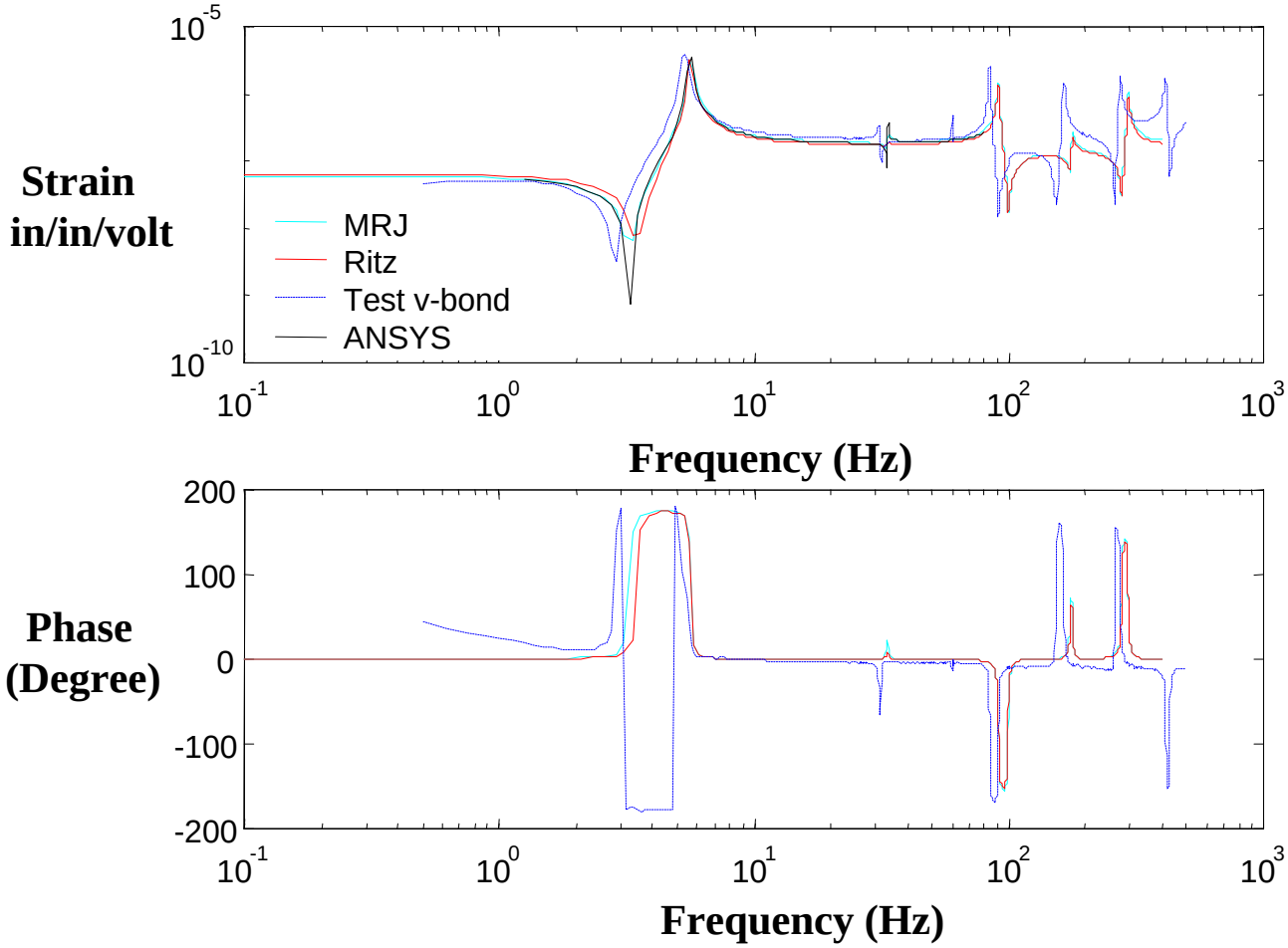
Strain measurements versus Analysis Correlation



AL Beam Correlation from Various Analysis Codes

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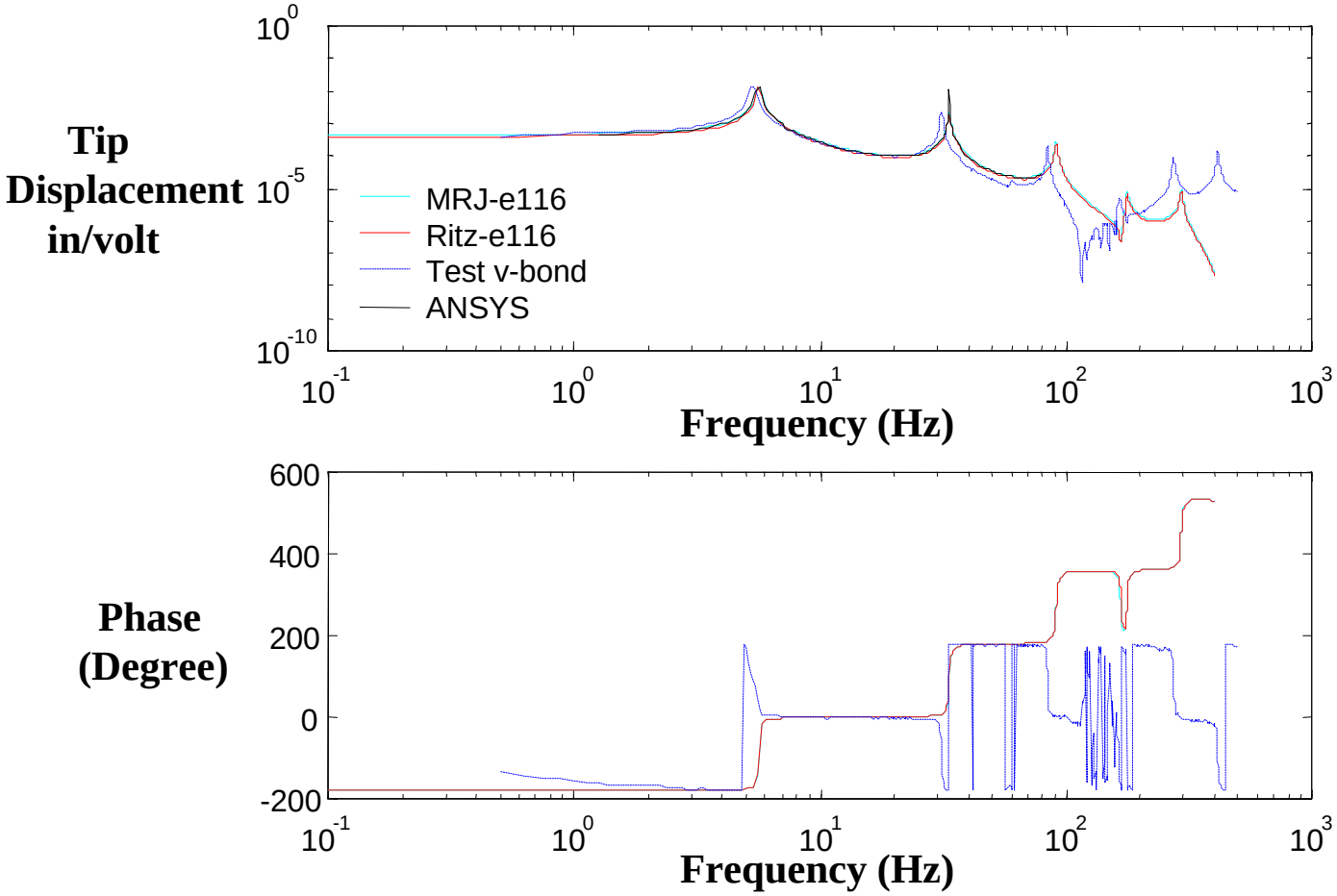
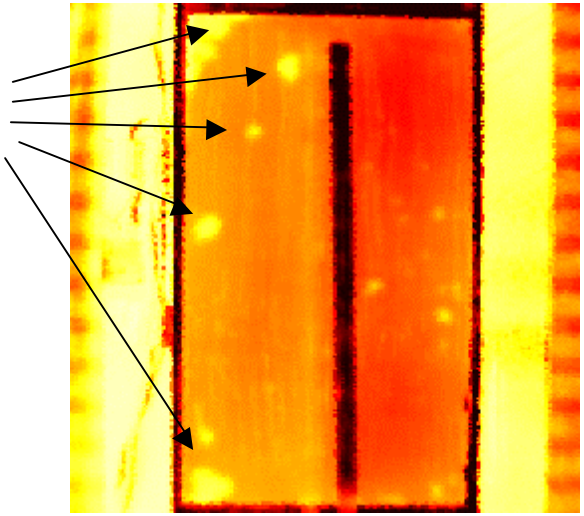
Out of Plane Displacement Measurement versus Analysis Correlation



Results from Thermal Mapping Test on AL Beam

Possible disbonds



Thermal mapping image of actuator bonded to the aluminum beam

Comparison of Actuator Effectiveness on AL Beam

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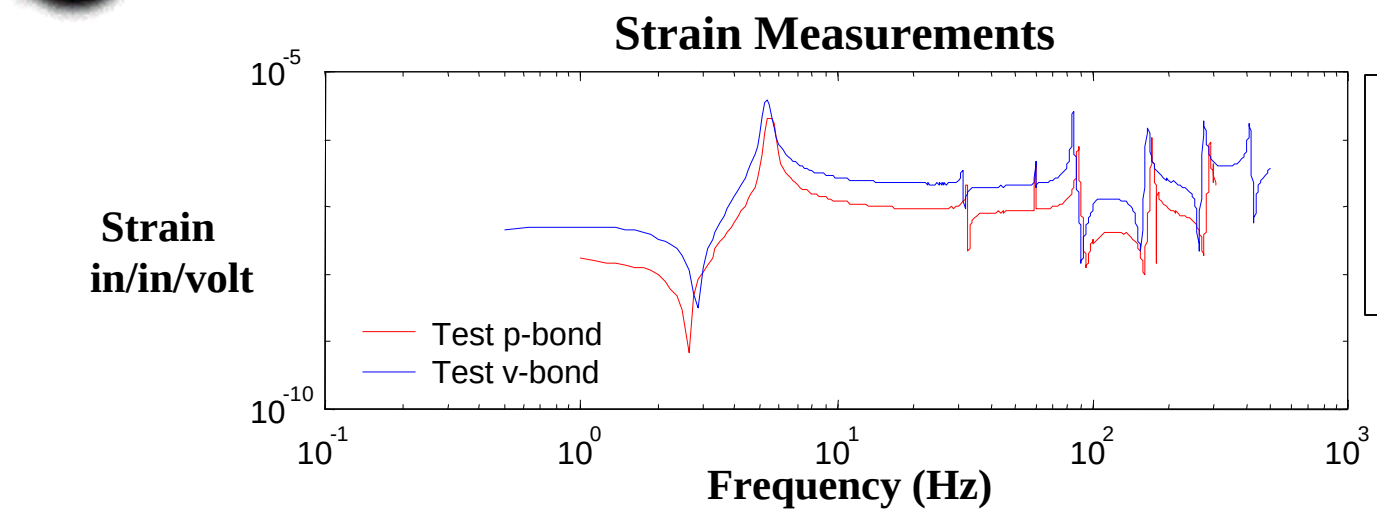
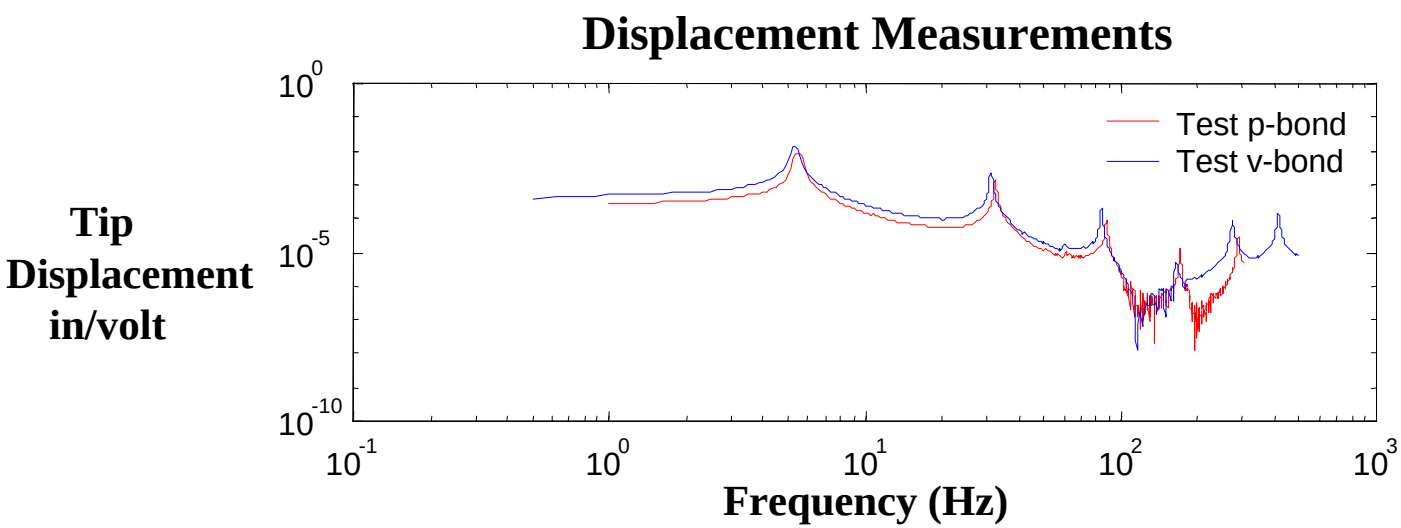


Bonding Technique

v-bond- 14.5 psi, 24 hrs cure, vacuum bag

p-bond- 1 psi, 24 hrs cure, ambient



Instrumented Composite Box Beam Testbed

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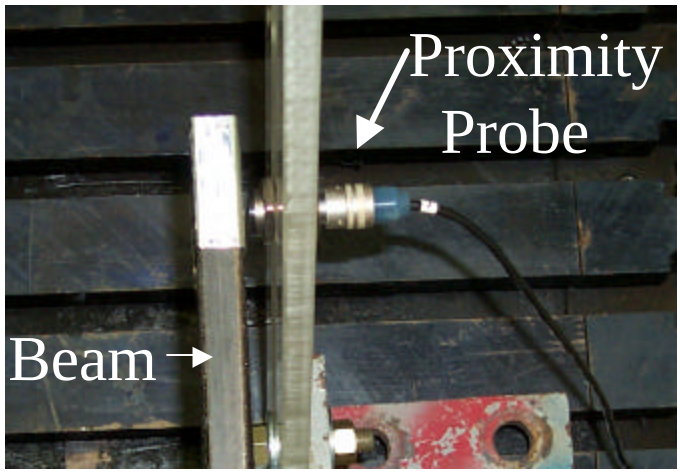

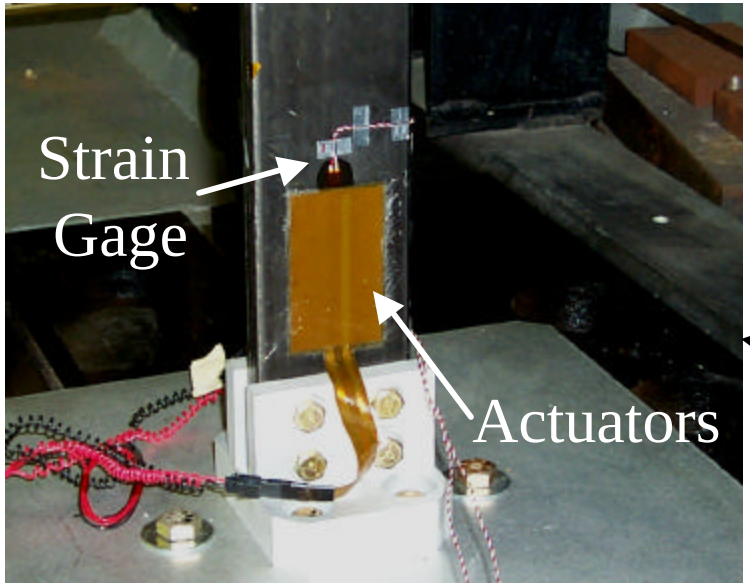

Composite Box Beam Analysis Results

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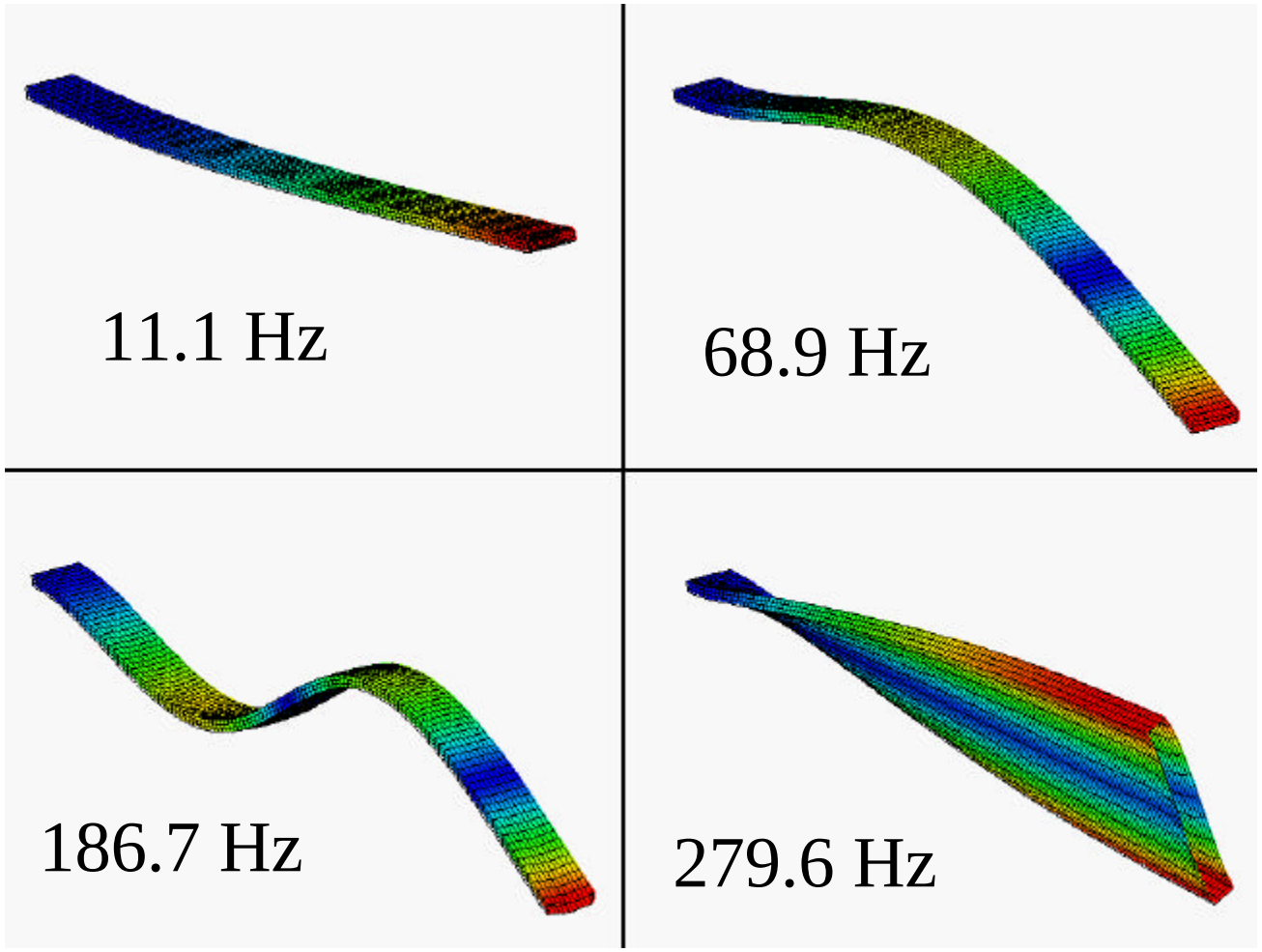

Box Beam Test versus Analysis Correlation

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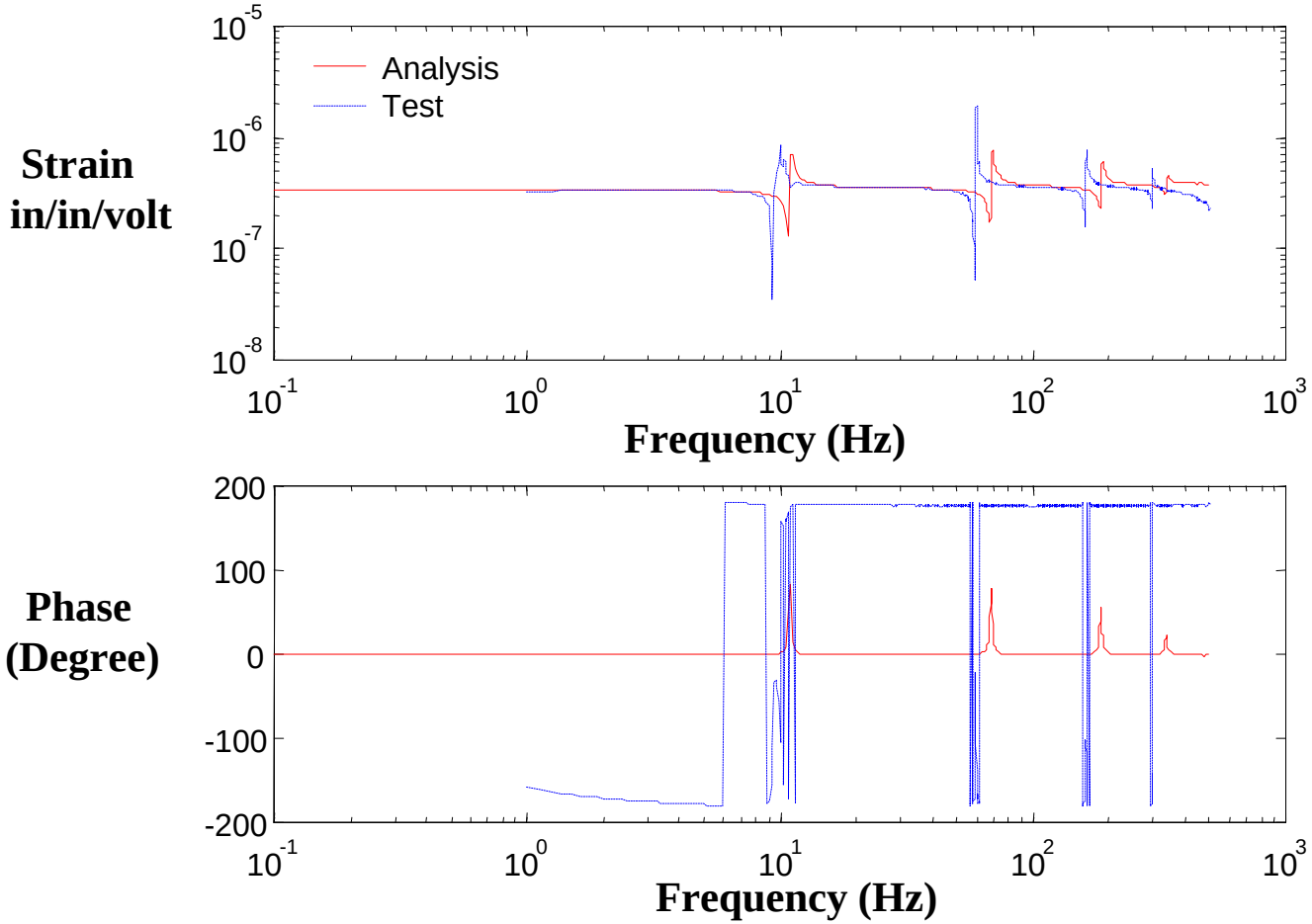
Strain measurements versus Analysis Correlation



Box Beam Test versus Analysis Correlation

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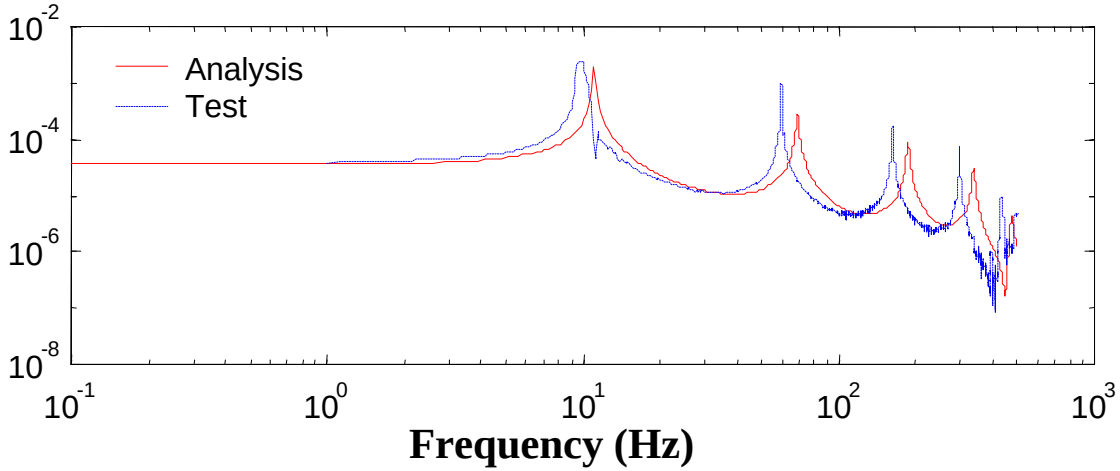
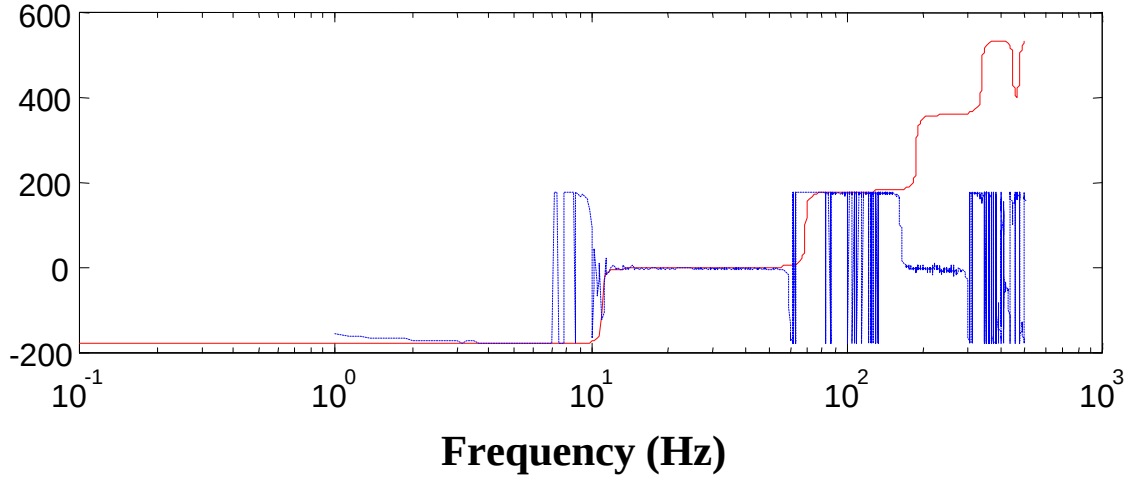
Out of Plane Displacement Measurement versus Analysis Correlation

Tip Displacement in/volt



Phase (Degree)



Concluding Remarks

- Two testbeds developed and tested for validation of commercial analysis tools
- Frequency response functions results using three different analysis approaches provided comparable test/analysis correlation
- Low frequency resonance predicted within 5 and 13% but antiresonance showed errors of 16%
- Improper bonding of actuators showed reductions in electrical to mechanical effectiveness of 64 %