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Using Piezoelectric Film Actuators as Excitation Sources in Modal Tests

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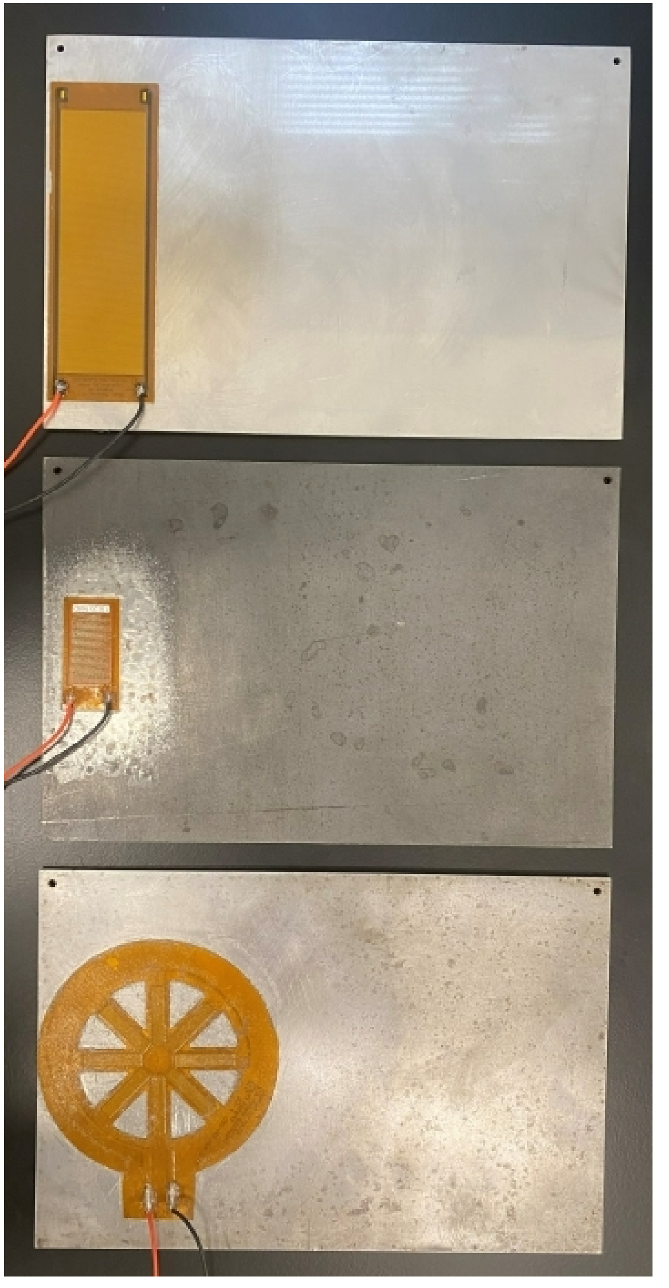
Introduction

- Often wish to perform modal or qualification tests on internal components
- These parts are inaccessible to modal hammers or shakers
- Idea: use actuated piezoelectric film as excitation sources in modal tests
- Piezo embedded with the component and can be used for health monitoring

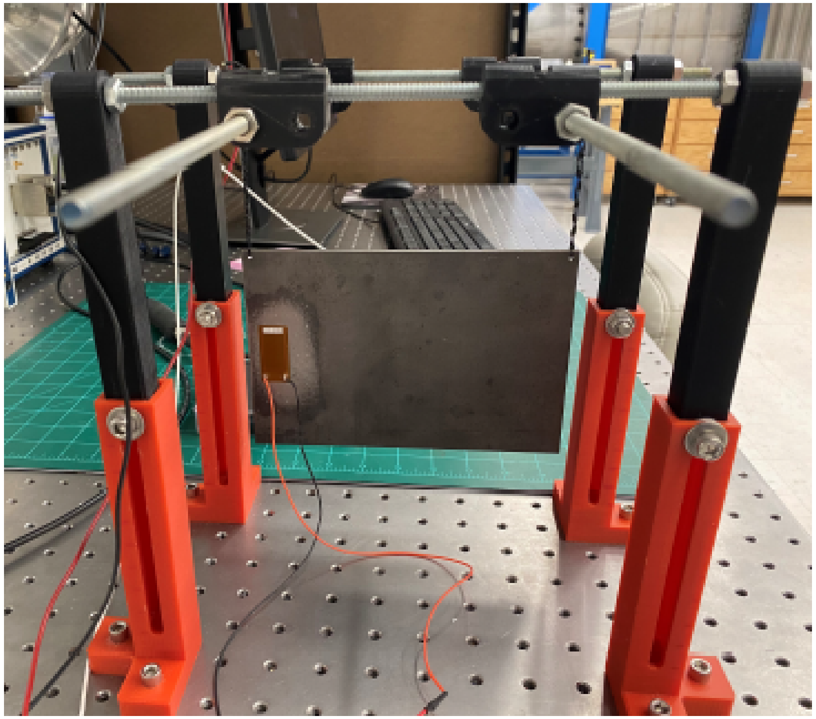
Potential Challenges

- Piezoelectric patch changes the structural system
  - Added mass and stiffness
- Dynamic response affected by electromechanical coupling
- Piezoelectric actuation is relatively weak and directional
  - May not sufficiently excite system
  - May not excite all modes
- Piezo introduces modeling challenges:
  - Material is anisotropic
  - Bonding layer between film and substrate
  - Electromechanical coupling



Test Article Design

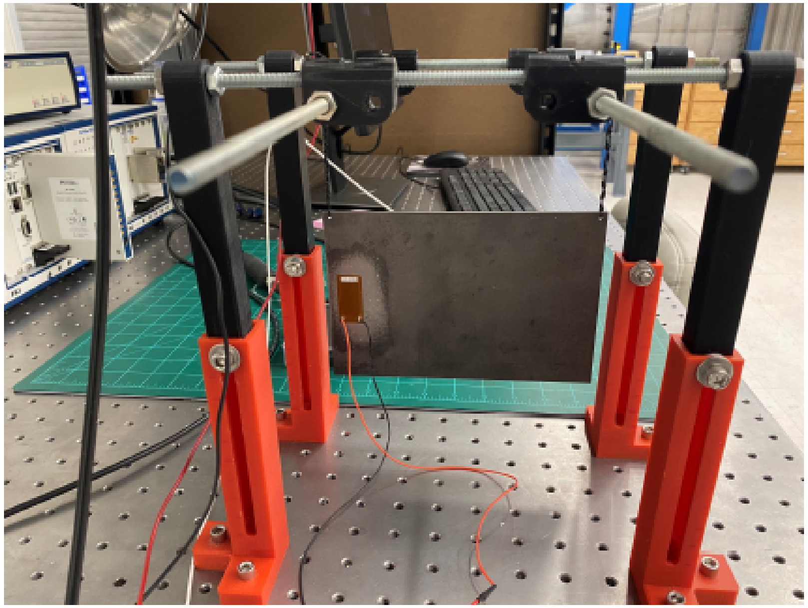
- To reduce coupling effects and changes to the structural system, considering a film bonded to relatively thick steel plate
  - Plate dimensions: 19 cm x 12.7 cm x 2.9 mm
    - Aspect ratio: 1.5
  - Piezo film dimensions: 28 mm x 14 mm x 0.3 mm
  - Plate to film thickness ratio: 9.7
- Use of a relatively thick plate may reduce ability to effectively excite the structure
- Single elongating macro fiber composite (MFC) attached to one side of test plate
- Following previous study [1], patch is centered along short edge of the plate

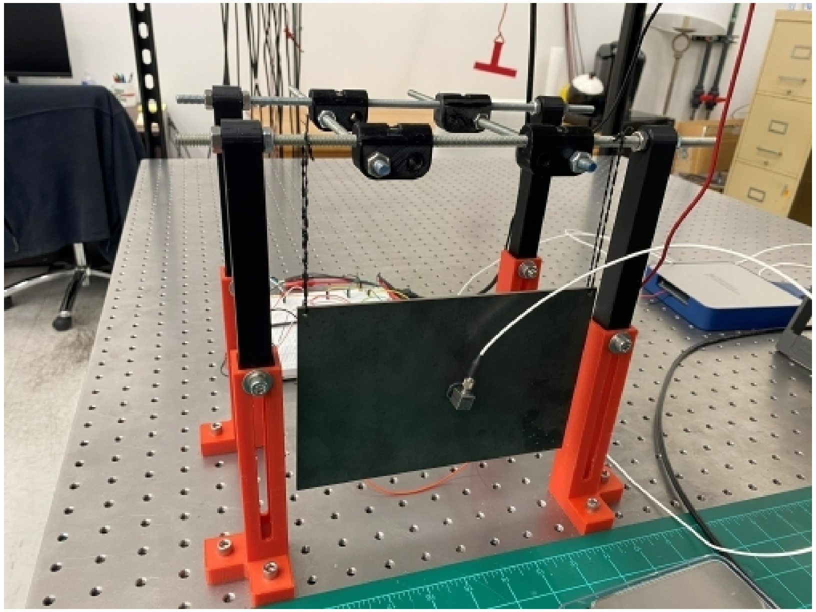


[1] **Davis, R. B., Agramonte, D. E., Lopp, G. K.** and **Schultz, R.**, *Optimizing the Size and Placement of Piezoelectric Actuators for Modal Testing, IMAC XXXIX*, Society of Experimental Mechanics, 2020.

Test Procedure

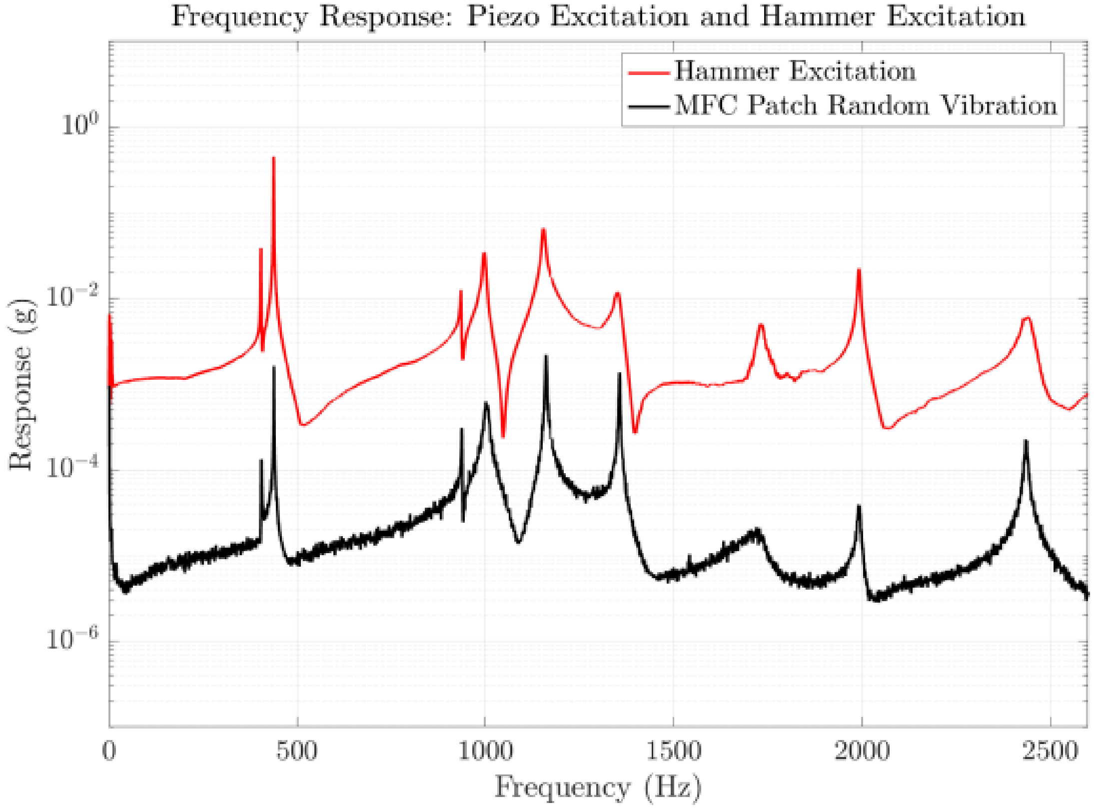
- Suspend test plate with elastic cords
- MFC actuated with band limited (1 Hz – 2500 Hz) stationary random signal passed through a high voltage amplifier
- Response of plate measured with single uniaxial accelerometer
- Corresponding impact hammer test conducted by leaving accel in place and striking hammer in center of MFC





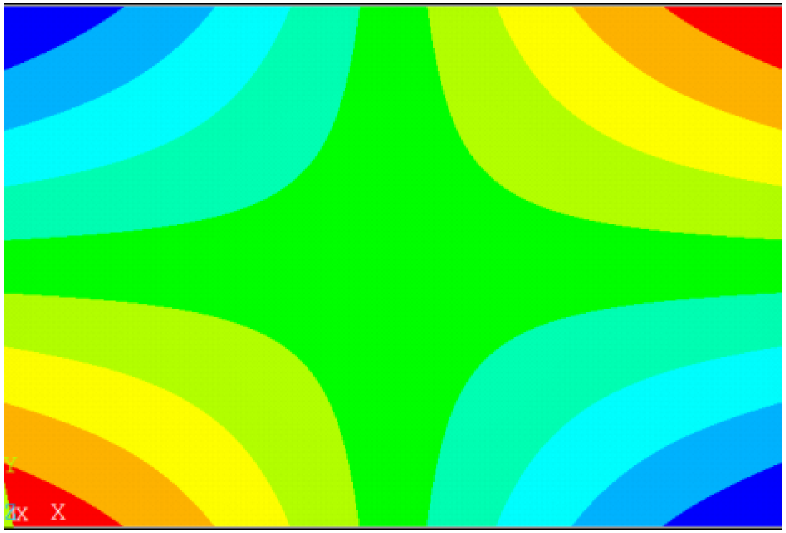
System ID

- Natural frequencies and damping ratios extracted from drive point frequency response
  - Accelerometer placed at patch location on other side of plate at patch center
- Damping ratios determined using half-power point method
- Natural frequencies found by dividing the experimentally determined resonance frequencies by $\sqrt{1-2\zeta^2}$

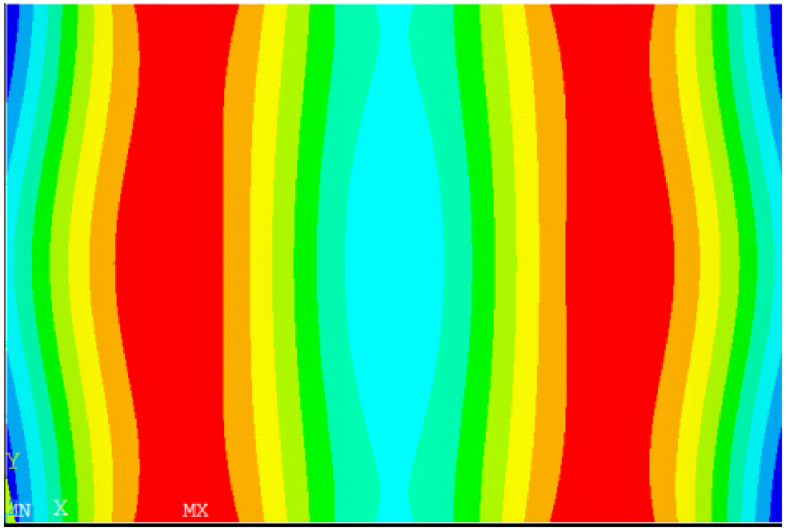


Model

- Test structure modeled with ANSYS to produce theoretical natural frequencies for comparison
- For now, model does not consider mass and stiffness properties of piezo
- Separate analysis showed for the present test article, the presence of unactuated MFC caused negligible changes to natural frequency even with a very large MFC patch



Mode 1 – 391 Hz



Mode 9 – 2551 Hz

Results

- Nine modes predicted below 2,600 Hz
- All nine modes identified by both test methods
- Both tests show less than 5.8% error with model
- Less than 1.2% difference between test methods

Mode #	Predicted f_n (Hz)	MFC Excited f_n (Hz)	Hammer Excited f_n (Hz)	MFC Excited ζ	Hammer Excited ζ
1	391	406	406	0.0016	0.00049
2	449	438	434	0.0013	0.00054
3	887	938	936	0.0013	0.0015
4	1012	1005	1007	0.0030	0.0035
5	1171	1162	1159	0.0021	0.0036
6	1318	1357	1352	0.0066	0.0068
7	1650	1720	1741	0.0031	0.0054
8	1917	1992	1970	0.0015	0.0014
9	2562	2437	2421	0.0028	0.0063

Conclusions & Future Work

- Demonstrated extraction of natural frequencies and damping ratios using piezoelectric actuators excited with a random signal
- Excellent agreement between piezo actuated and hammer actuated results
- Future work will involve:
  - Consideration of other types of piezo actuators
  - Consideration thinner test articles
  - Modeling of piezoelectric material and coupling effects
  - Design and fabrication of demonstration unit showing modal testing of embedded test structure