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Using Piezoelectric Film Actuators as Excitation Sources in Modal Tests

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Extended Abstract

1 INTRODUCTION

Establishing piezoelectric actuators as excitation sources in modal testing would enable *in situ* testing of components that are inaccessible to modal hammers or shakers. However, effective experimental methods associated with this approach have not been established. To this end, we use a single patch of piezoelectric film to drive a rectangular plate across a broad frequency range. Natural frequencies and mode shapes are extracted from the resulting frequency response functions (FRFs) and are compared to those obtained using a traditional modal hammer.

2 TEST SETUP

Fig. 1 shows a suspended test plate with a bending-type macro fiber composite (MFC) patch (length=28 mm, width=14 mm, thickness=0.3 mm) bonded to one side. The steel plate is 2.9 mm thick and is 12.7 cm by 19 cm (aspect ratio=2/3). Following a previous study by the authors, the MFC patch is centered along one of the plate's shorter edges. This placement was shown to maximally excite the first five non-rigid-body modes of a plate with a similar aspect ratio [1]. The MFC is actuated with a band-limited (1 Hz to 2500 Hz) stationary random signal that is passed through a high-voltage amplifier (model HV-AMD2021-CE3). The response is measured with a uniaxial accelerometer (PCB 333B30). Natural frequencies and damping are identified from a the drive-point FRF (i.e., the accelerometer is placed at the center of the MFC patch, but on the opposite side of the plate). In the corresponding hammer test, the accelerometer is placed in the same location, and hammer strike point is the center of the MFC. Damping is estimated from the FRF using the half-power point method. Once a given damping ratio is calculated, the natural frequency is determined by dividing the resonance frequency by $\sqrt{1-2\zeta^2}$.

3 MODEL

The test article is modeled in ANSYS to obtain analysis natural frequencies and mode shapes to which the test results can be compared. The plate is assumed to have a Young's modulus of $E = 200$ GPa, a density of $\rho = 7300$ kg/m^3, and a Possion's ratio of $\mu = 0.28$. The accelerometer is modeled as a 7.3 gram point mass. At this time, the mass and stiffness properties of the MFC patch are not included in the ANSYS model.

4 RESULTS

Table 1 shows a comparison of the model-based natural frequencies along with those identified in the hammer and piezo tests. Both the hammer and piezo tests identify all nine of the non-zero natural frequencies below 2600 Hz. For both tests, there is excellent agreement between test and analysis, with all identified test natural frequencies exhibiting less the 5.4% error. Further, the modal damping estimates were obtained from the two tests using the half power point method. The damping results are largely consistent between the two tests.

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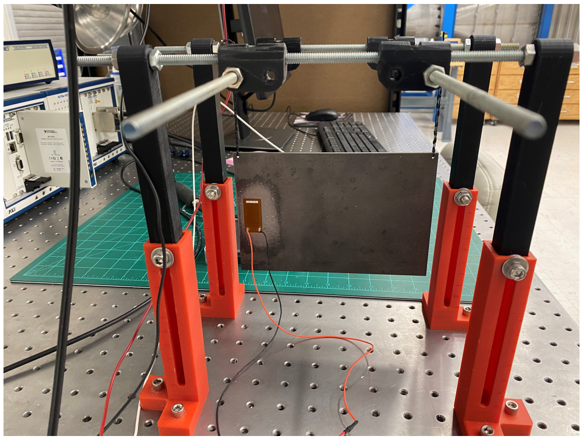
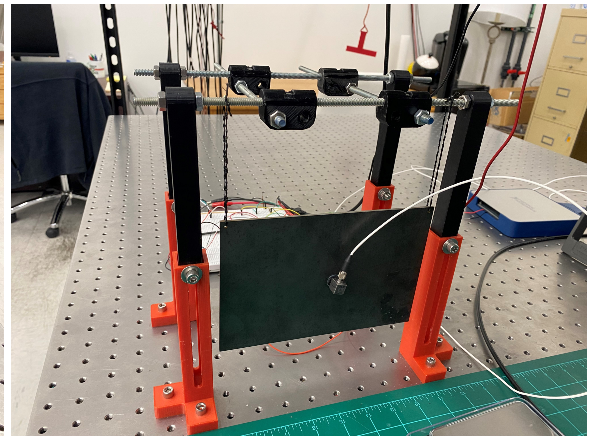


(a)



(b)

Figure 1: The (a) front and (b) back of the test article. The fixed location of the MFC patch is visible on the front side, while the accelerometer is seen on the back side in a representative location.

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

TABLE 1: A comparison of the model-based natural frequencies along with those identified in the hammer and piezo tests.

5 CONCLUSIONS AND FUTURE WORK

The results of this initial test suggest that commercial off-the-shelf piezoelectric actuators can be effectively used as excitation sources in modal testing. The natural frequencies and damping identified while using the piezoelectric patch as an excitation source show excellent agreement with those identified using a traditional modal hammer. The present test article was designed to be relatively thick such that elctromechanical coupling effects did not confound the results. Future work will address how to accurately extract structural natural frequencies, damping, and modes when significant electromechanical coupling effects are present. Future work may also include the construction of a demonstration unit where one or more piezoelctric patches are used to modal test an embedded test structure that cannot be accessed by traditional excitation sources.

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REFERENCES

[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.