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A Demonstration Unit for Piezo-Excited Modal Testing

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Extended Abstract

INTRODUCTION

Piezoelectric actuators can be used to excite components that are embedded in a larger structure and inaccessible to traditional exciters such as modal hammers and electrodynamic shakers. Here, we consider the use of Macro Fiber Composites (MFC) to excite a beam attached to the top of a multi-tiered structure. The beam represents a component embedded inside a complicated surrounding structure. Using this demonstration unit, we seek to show the advantages of using direct component-level piezoelectric actuation relative to traditional methods that indirectly excite embedded components via seismic excitation of the entire surrounding structure.

TEST SETUP

A four-tiered demonstration unit is fabricated from 6061-T6 aluminum to test the capabilities and limitations of piezo-excited testing. Fig. 1 shows the assembled demonstration unit mounted on an electrodynamic shaker (TMS 2075E). On the top tier is the test beam with a 7x14 mm bending-type MFC patch affixed to its underside. This relatively small bending-type patch was chosen based on a preliminary study that investigated the excitation of plates using a wide variety of MFC patches. Fig. 2 compares the response of a test article when (a) excited by bending and elongating MFC patches as well as (b) different size bending MFC patches. While the elongating patch generally elicits higher response, the bending patch was chosen for further study since it actuates the structure bi-directionally. Bi-directional actuation will likely be preferred when testing embedded structures that resemble plates or shells. In general, larger patches cause higher response levels; yet, the smallest of the three patch sizes was chosen for this study because it was shown to still adequately excite the plate while having the smallest footprint and added mass.

A series of tests are conducted to understand the differences in the dynamic response of the test beam under indirect seismic excitation and direct excitation methods. First, the entire structure is excited seismically using the shaker and a band-limited (100 Hz to 3000 Hz) stationary random signal. Direct excitation of the test beam is achieved through both piezo-based actuation and a modal hammer while the structure remains mounted on the shaker. In the case of piezo actuation, the MFC is driven with a band-limited (100 Hz to 3000 Hz) stationary random signal that is passed through a high-voltage amplifier. The response of the test component is measured using a uniaxial accelerometer in the same location for all three tests.

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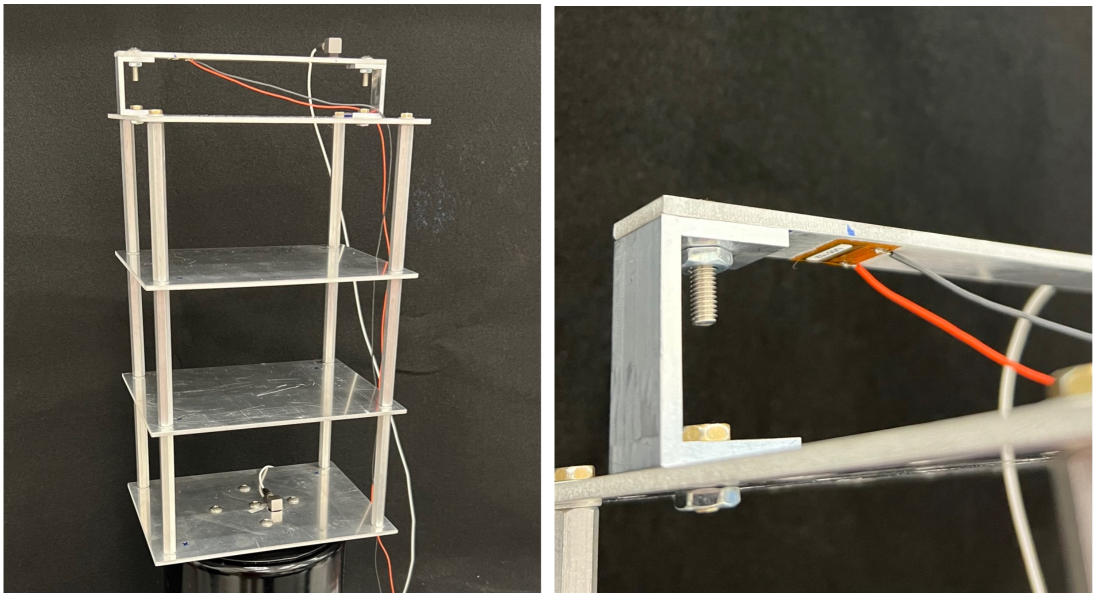

Figure 1: Demonstration unit with MFC bonded to test component. Bonded to the component is a (7x14 mm) bending-type patch.

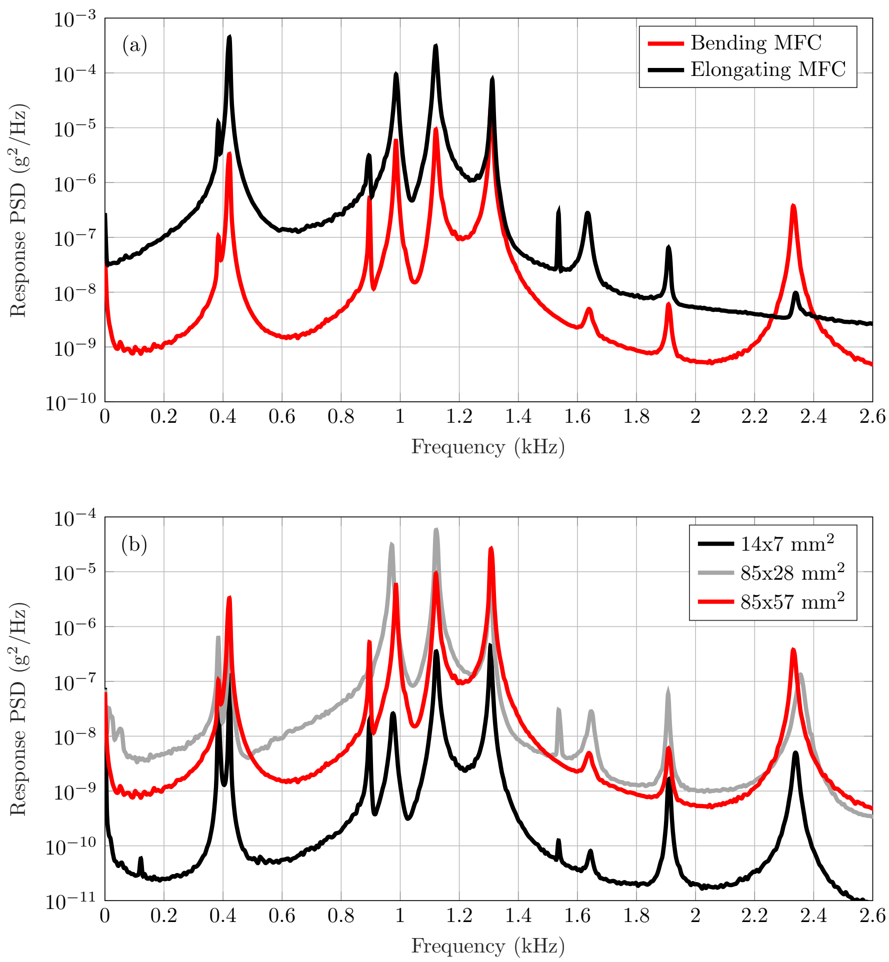

Figure 2: Response PSD comparing (a) the same size bending and elongating and (b) different size bending MFC actuators.

MODEL
Experimentally determined natural frequencies and modes of the built-up structure are compared to those from an ANSYS model. Currently, the model does not account for the boundary condition with the shaker. Further refinement of the model is necessary to obtain better agreement with the experimental results. The ANSYS model will assist in determining which modes are dominated by motion in the test beam and the built-up structure, respectively.

RESULTS
Fig. 3 shows the acceleration PSD response of the test beam when subject to direct hammer, direct piezo, and seismic shaker excitation. There is good agreement between the direct piezo-forcing and the direct hammer-forcing response. The MFC was able to excite every mode that the hammer was able to excite. However, the response to seismic excitation was not able to capture every mode (e.g., the mode near 175 Hz was not excited in the seismic case). Additionally, seismic excitation resulted in at least one resonance (near 580 Hz) that was not readily observed in the direct excitation.

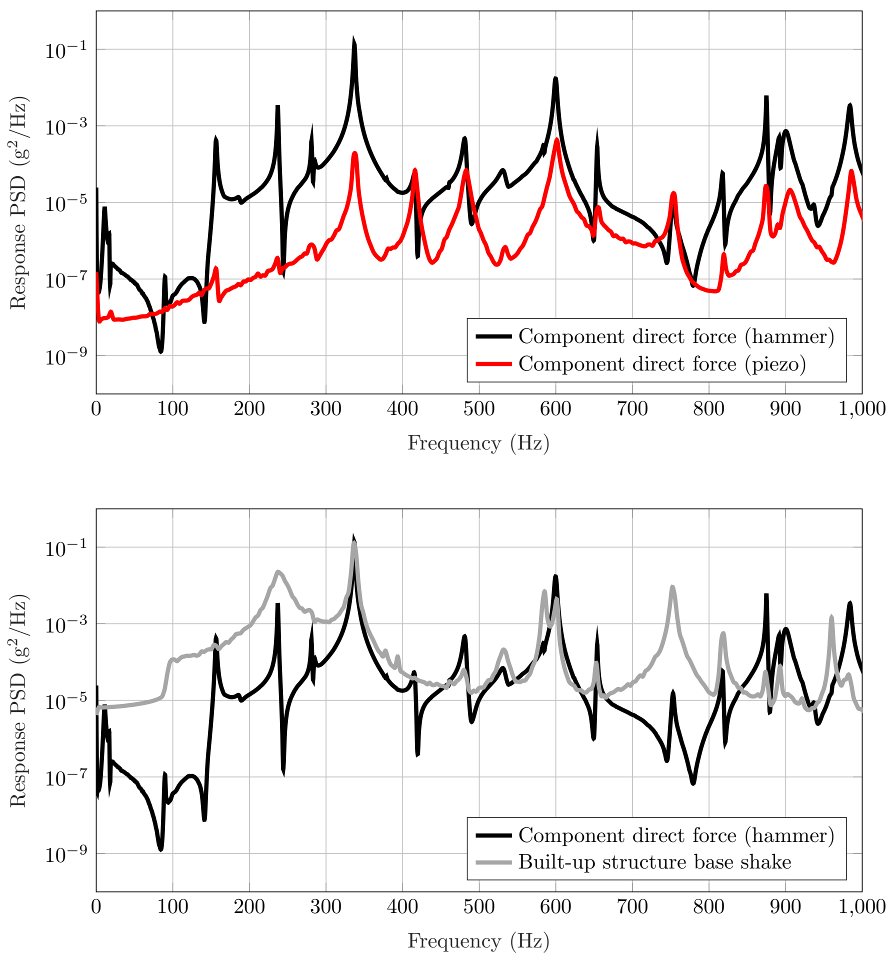

Figure 3: Response PSD of the component when subject to direct hammer excitation, direct MFC excitation, and seismic shaker excitation.

CONCLUSIONS AND FUTURE WORK
Based on preliminary results, direct, component-level, piezoelectric excitation is a promising alternative to system-level seismic excitation. The results indicate a one-to-one correspondence between the resonances in the direct piezo-exited and the direct hammer-excited responses. This one-to-one agreement was not observed when comparing the indirect seismic excitation and direct hammer-excited responses.

In addition to refining the finite element model, future work includes modifying the boundary conditions of the test beam to determine the effectiveness of using direct piezo-excitation to detect structural changes. Finally, we would like to demonstrate that—from a fatigue-life standpoint—direct piezo-excitation is far less damaging to a structure than traditional seismic testing methods.

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