A Comprehensive Experimental Evaluation of Actively Controlled Piezoceramics with Positive Position Feedback for Structural Damping

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(Abstract)

This study evaluates the effectiveness of actively controlled piezoceramics with positive position feedback (PPF) for reducing structural vibrations. A comparison is made between active control with PPF and a parallel resistor-inductor (RLC) shunt technique. The primary objectives of this study are to:

1. Explore the feasibility of using smart materials and fiber optics for simultaneous health monitoring and active damping of a representative aircraft panel.
2. Determine how optical fiber sensors may be used to detect vibration modes of an aircraft panel by investigating their use on a representative test article.
3. Determine how piezoelectric patches may be used to detect and counteract fundamental resonances of a representative test article.
4. Determine a control algorithm and hardware system to increase substantially the damping in the fundamental mode of the representative test article over a wide temperature range.
5. Develop a health-monitoring algorithm based on fiber optic sensors to detect impedance changes in a representative test article.
6. Make a comparison between active control with PPF and an RLC shunt technique.

To achieve the objectives of this study, a special test rig was used to evaluate the performance of piezoelectric materials (PZTs) for vibration suppression. The test rig was used to rigidly clamp a flat 20-gauge steel plate, and then excite the plate in various frequency ranges with an electromagnetic shaker. For each test, a data acquisition system was used to acquire the data to evaluate the performance of each PPF controller. Once the data was obtained, a comparison was made between active damping with PPF and passive damping with the RLC shunt technique.

The active damping technique used for this study combined piezoelectric actuators with fiber optic sensors to achieve simultaneous active control and health monitoring of a test plate. The results of the active damping tests show that piezoelectric materials can provide substantial narrowband and broadband frequency reductions, while at the same time detecting damage on the test plate. More specifically, the test results indicate that smart damping materials can decrease the fundamental mode of vibration of the test plate by 23 dB and detect damage such as a loose bolt in the clamping frame, with the addition of only 0.04 lb of PZT on the test plate. The active damping technique reduced the plate vibrations at each mode within the frequency range of interest, with only one-third the amount of piezoelectric material needed for an RLC shunt circuit technique.