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Active Vibration Reduction for a Flexible Structure Bonded with Sensor/Actuator Pairs on Efficient Locations Using a Developed Methodology

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Abstract : With the extensive use of high specific strength structures to optimise the loading capacity and material cost in aerospace and most engineering applications, much effort has been expended to develop intelligent structures for active vibration reduction and structural health monitoring. These structures are highly flexible, inherently low internal damping and associated with large vibration and long decay time. The modification of such structures by adding lightweight piezoelectric sensors and actuators at efficient locations integrated with an optimal control scheme is considered an effective solution for structural vibration monitoring and controlling. The size and location of sensor and actuator are important research topics to investigate their effects on the level of vibration detection and reduction and the amount of energy provided by a controller. Several methodologies have been presented to determine the optimal location of a limited number of sensors and actuators for small-scale structures. However, these studies have tackled this problem directly, measuring the fitness function based on eigenvalues and eigenvectors achieved with numerous combinations of sensor/actuator pair locations and converging on an optimal set using heuristic optimisation techniques such as the genetic algorithms. This is computationally expensive for small- and large-scale structures subject to optimise a number of s/a pairs to suppress multiple vibration modes. This paper proposes an efficient method to determine optimal locations for a limited number of sensor/actuator pairs for active vibration reduction of a flexible structure based on finite element method and Hamilton's principle. The current work takes the simplified approach of modelling a structure with sensors at all locations, subjecting it to an external force to excite the various modes of interest and noting the locations of sensors giving the largest average percentage sensors effectiveness measured by dividing all sensor output voltage over the maximum for each mode. The methodology was implemented for a cantilever plate under external force excitation to find the optimal distribution of six sensor/actuator pairs to suppress the first six modes of vibration. It is shown that the results of the optimal sensor locations give good agreement with published optimal locations, but with very much reduced computational effort and higher effectiveness. Furthermore, it is shown that collocated sensor/actuator pairs placed in these locations give very effective active vibration reduction using optimal linear quadratic control scheme.

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