ACTIVE VIBRATION CONTROL OF SMART STRUCTURES USING FUZZY LOGIC CONTROLLER AND ITS EXPERIMENTAL IMPLEMENTATION

A Thesis

submitted

by

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Thesis Certificate

This is to certify that the thesis entitled "**Active Vibration Control of Smart Structures Using Fuzzy Logic Controller And Its Experimental Implementation**" submitted by Mr. Anshul Sharma to the Indian Institute of Technology Mandi for the award of the degree of Doctor of Philosophy is a bonafide record of research work carried out by him under our supervision in the School of Engineering, Indian Institute of Technology Mandi. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

In keeping with the general practice of reporting scientific observation, due acknowledgements have been made wherever the work described is based on the findings of other investigators.

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ABSTRACT

Active vibration control of flexible shell structures using piezoelectric sensors and actuators is addressed in this thesis. The objective of the thesis is to design a simple and effective active fuzzy logic controller for vibration suppression of flexible structures.

The flexible shell structures used in automobile, marine, aerospace and communication industries are exposed to harsh environmental conditions in most of the practical applications. Space antenna reflector is the most common aerospace structure operates in harsh thermal environment. The sensing sensitivity and actuation capability of surface bonded piezoelectric materials are influenced by varying temperature field. Hence, there is a need to investigate the active vibration control performance of piezolaminated structures over a wide range of temperature both numerically and experimentally.

A finite element formulation is implemented to determine the static and dynamic response of layered shell structure under coupled hygro-thermo-piezo-elastic model. The FEM formulation is based on first order shear deformation theory and linear piezoelectric theory. The degenerated shell element with mechanical, electric, thermal and hygral degrees of freedom is used to model the thin piezolaminated shell structures. The finite element formulation and developed computer code is validated with existing theoretical and experimental results available in the literature.

The shell structures are highly nonlinear systems with time varying structural parameters. Hence, the active vibration control of shell structures is not very effective using conventional controllers. Fuzzy logic controller has been established and successfully demonstrated as a valuable tool for vibration control of smart beam and plate structures in the existing literature. The vibration control of cylindrical, spherical and paraboloidal shell structure is investigated using fuzzy logic controller in this

thesis. An experimental setup is fabricated to validate the developed finite element modelling.

As the sensor sensitivity and actuation capability of piezoelectric material is influenced by temperature variation, the experiments are performed for active vibration control of smart beam structure over wide temperature range of -70ºC to 70 ºC. The fuzzy logic controller is implemented experimentally for vibration control of first four vibration modes at different temperatures subjected to initial tip deflection. Thereafter, numerical simulations are carried out for active vibration control of space antenna reflector over temperature ranging from -70ºC to 120 ºC using fuzzy logic controller exposed to thermal shock. It is observed both numerically and experimentally that the performance of piezoelectric materials is influenced by variation in temperature. The performance of the piezoelectric sensor degrades with rise in temperature while the performance of piezoelectric actuator becomes better with increase in temperature.

The lead-based piezoelectric material of PZT family has been widely used for active vibration control applications as smart structures. However, the toxicity associated with lead based piezoelectric materials motivated to investigate the performance of lead-free piezoelectric materials for active vibration control application. In weight critical applications, it is not feasible to completely cover the host structure with piezoelectric layers. A number of piezoelectric patches need to be place strategically on the surface of the structure. The optimum placement of sensor/actuator pair for vibration control of shell structures is investigated using genetic algorithm. The optimal patch locations are obtained to maximize the strain energy. The optimum vibration control of shell structures using fuzzy logic controller is examined.

The versatility and effectiveness of finite element formulation, fuzzy logic controller and corresponding developed computer code have been demonstrated through investigations on active vibration control of different laminated shell structures having different boundary conditions subjected to hygro-thermo-mechanical loading.

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