

**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 -70°C to 70°C . 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 -70°C to 120°C 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 placed 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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Title	Page
DECLARATION	i
ABSTRACT	v
ACKNOWLEDGEMENT	vii
CONTENTS	ix
LIST OF FIGURES	xiii
LIST OF TABLES	xxiii
NOMENCLATURE	xxv
CHAPTER 1: INTRODUCTION	
1.1 Overview	1
1.2 Vibration control of flexible structures	1
1.2.1 Passive vibration control	2
1.2.2 Active vibration control	2
1.3 Control strategies	4
1.4 Smart systems and structures	5
1.5 Smart materials	7
1.6 Piezoelectricity and piezoelectric materials	9
1.7 Research background and literature review	11
1.7.1 Piezoelectricity and piezoelectric materials for active vibration control	12
1.7.2 Static and dynamic response of piezolaminated smart structures	14
1.8 Classification of finite element models	26
1.9 Control algorithms	28
1.9.1 Conventional controllers	30
1.9.2 Adaptive and robust controllers	31
1.9.3 Nonconventional (intelligent) controllers	32
1.10 Scope and objectives of thesis	37
1.11 Structure and organization of thesis	39
CHAPTER 2: FINITE ELEMENT MODELLING OF PIEZOLAMINATED STRUCTURE AND ITS VALIDATION	
2.1 Introduction	43
2.2 Finite element formulation	44
2.2.1 Geometry and displacement field	47
2.2.2 Strain displacement relationship	51
2.2.3 Hygrothermal field	54

2.2.4 Electric field	55
2.2.5 Strain energy	57
2.2.6 Electrical energy	58
2.2.7 Kinetic energy equation	59
2.2.8 Work done by the external forces and electrical charge	60
2.2.9 Equations of motion	61
2.3 Application to smart shell	63
2.3.1 Sensor Output	65
2.4 Modal domain conversion and state space representation	67
2.5 Validation of finite element formulation	69
2.5.1 Static analysis of bare structures	70
2.5.2 Dynamic analysis of bare structures	73
2.5.3 Static analysis of piezolaminated structures	76
2.5.4 Dynamic analysis of piezolaminated structures	80
2.6 Closure	84

CHAPTER 3: FUZZY LOGIC CONTROLLER DESIGN

3.1 Introduction	87
3.2 Architecture of fuzzy logic controller	88
3.2.1 Fuzzification	90
3.2.2 Fuzzy rule base	91
3.2.3 Fuzzy interface mechanism	96
3.2.4 Defuzzification	96
3.3 Working of fuzzy logic controller for active vibration control of smart structure	97
3.4 Conventional control algorithms	101
3.5 Comparison of designed fuzzy logic controller with conventional controllers: Numerical Simulations	103
3.5.1 Performance evaluation of fuzzy logic controller compared to optimal proportional derivative (PD) controller	105
3.5.2 Performance evaluation of fuzzy logic controller compared to negative velocity feedback controller	109
3.6 Comparison of designed fuzzy logic controller with conventional controllers: Experimental observations	114
3.7 Closure	116

CHAPTER 4: VIBRATION CONTROL OF SHELL STRUCTURES

4.1 Introduction	119
4.2 Cylindrical Shell	119
4.3 Spherical Shell	133

4.4 Paraboloidal Shell	142
4.5 Closure	146

CHAPTER 5: EFFECT OF OPERATING TEMPERATURE ON ACTIVE VIBRATION CONTROL

5.1 Introduction	147
5.2 Experimental setup	148
5.2.1 Smart structure	148
5.2.2 Piezo sensing system	149
5.2.3 Active band pass filter	149
5.2.4 Real time controller	150
5.2.4.1 Analog-to-digital converter	150
5.2.4.2 Real time processor	151
5.2.4.3 Digital-to-analog convertor	151
5.2.5 Piezo actuation system	152
5.3 Working of complete experimental setup	152
5.4 Validation of finite element formulation with experimental results	155
5.5 Experimental evaluation of active vibration control of beam structure over wide temperature range	158
5.6 Active vibration control of space antenna reflector over wide temperature range: Numerical investigation	168
5.7 Closure	178

CHAPTER 6: PERFORMANCE EVALUATION OF DIFFERENT PIEZOELECTRIC MATERIALS AND OPTIMUM PATCH LOCATION

6.1 Introduction	179
6.2 Materials	181
6.3 Priority vector for materials properties	183
6.3.1 Analytic hierarchy process (AHP)	183
6.3.2 Technique for order preference by similarity to ideal solution (TOPSIS)	184
6.4 Material selection for plate structure	185
6.5 Active vibration control of cylindrical shell using lead-free piezoelectric materials	196
6.6 Optimum vibration control	201
6.6.1 Optimum patch location for cantilever cylindrical shell structure	202
6.6.2 Optimum patch location for space antenna reflector using genetic algorithm	211
6.7 Closure	217

CHAPTER 7: CONCLUSIONS AND FUTURE SCOPE	
7.1 Conclusions	219
7.2 Future scope	222
REFERENCES	225
APPENDIX-A	239
APPENDIX-B	241
LIST OF PUBLICATIONS	245