

Contents

Approval	i
Certificate	iii
Acknowledgement	v
Declaration	vii
Author's Resume	ix
Abstract	xi
List of Symbols	xiii
List of Figures	xv
List of Tables	xix
Chapter 1 Introduction	1
1.1 General	1
1.2 Review of Literature	2
1.2.1 Multilayered Composite Shells	3
1.2.2 Coupled Piezo-Elastic Smart Composite Shells	11
1.3 Appraisal of the Past Work	14
1.4 Objectives and Scope of the Present Work	15
1.5 Organisation of the Thesis	18

Chapter 2 Theoretical Formulation	21
2.1 Introduction	21
2.2 Geometric Description of Shell	22
2.3 Geometric Quantities Associated to Middle Surface	22
2.4 Development of Shell Kinematics	25
2.5 Strain Displacement Equations	31
2.6 Electric Field- Electric Potential Relationship	34
2.7 Constitutive Relations for Lamina	35
2.8 Construction of the Mixed Functional	38
2.9 Finite Element Equations	44
2.10 Recovery of the Transverse Shear Stresses	46
2.10.1 Recovery using Weighted Residual Method	47
Chapter 3 Bending of Composite Shells	49
3.1 Introduction	49
3.1.1 Abbreviations Used	50
3.1.2 Shell Geometry Considered	50
3.1.3 Geometric and Electrical Boundary Conditions	52
3.1.4 Material Properties	53
3.1.5 Non-dimensional Parameters	53
3.2 Numerical Results	53
3.2.1 Test for Rank Sufficiency	54
3.2.2 Element Distortion Sensitivity and Convergence	55
3.2.3 Sandwich Plates with Cross-ply Face Sheets	59
3.2.4 Ren's Cylinder	59
3.2.5 Cylindrical and Spherical Shell Panels	61
3.2.6 Hyperbolic Paraboloidal Panels	93
Chapter 4 Bending of Smart Composite Shells	113
4.1 Introduction	113
4.1.1 Material Properties	114
4.1.2 Non-dimensional Parameters	114
4.2 Validation Problem-1: Analysis of a Sensor Plate	114
4.3 Validation Problem-2: Analysis of a Actuator Plate	115
4.4 Bending of a Four Layer Sensor Shell	116
4.5 Static Analysis of a Four Layer Actuator Shell	133

4.6	Seven Layer Smart Sandwich Shell under complex Loading	155
Chapter 5	Free Vibration of Smart Shells	165
5.1	Introduction	165
5.2	Validation of the Present Formulation	165
5.3	Vibration of Laminated Composite Shells	166
5.4	Vibration of Laminated Sandwich Shells	171
5.5	Vibration of Four Layer Smart Shells	171
5.6	Vibration of Seven Layer Smart Shells	181
Chapter 6	Critical Discussion and Concluding Remarks	183
6.1	Introduction	183
6.2	Critical Discussion of Results	183
6.2.1	Bending of Composite and Sandwich Shells	184
6.2.2	Bending of Smart Shells	186
6.2.3	Vibrations of Smart Shells	188
6.3	Concluding Remarks	190
6.4	Contributions of the Present Thesis	191
6.5	The Scope for Future Research	192
References		195
Appendix A		207
A.1	Inertia Coefficients	207
A.2	Element Mass Matrix	207
A.3	Modified Subspace Iteration	208