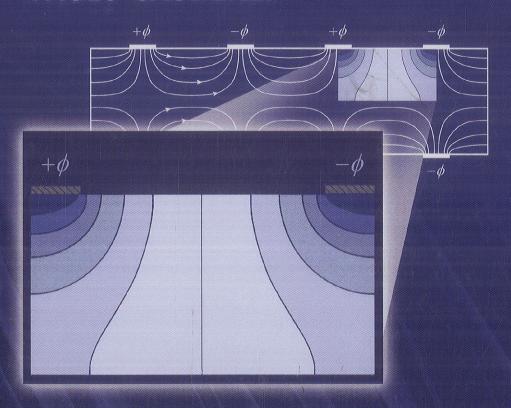
## **PAOLO GAUDENZI**



## SMART STRUCTURES

Physical behaviour, mathematical modelling and applications



八值

## Contents

List of Figures  Preface				
1.1	Smart S	Structures and Traditional Structures: Definition and Main		
	Constit	uents	1	
1.2	Smart Structures and Active Materials			
1.3	The Physical Behaviour of Active Materials for Actuation			
	and Sensing			
	1.3.1	Piezoelectric Materials	5	
	1.3.2	Electrostrictive Materials	18	
	1.3.3	Magnetostrictive Materials	18	
	1.3.4	Shape Memory Alloys	23	
1.4	Motiva	tions for the Use of Smart Structure Technologies	26	
1.5	Monitoring Structural Integrity		27	
1.6	Shape I	Morphing	29	
1.7	Vibratio	on Control	30	
1.8	Energy Harvesting		32	
	References		33	
2	Mathematical Modelling of Piezoelectric Bodies			
2.1	Analysis of Piezoelectric Continua			
	2.1.1	Constitutive Relations of Piezoelectric Materials	37	
	2.1.2	Energy Coupling Coefficients	41	
	2.1.3	The Equations of Linear Piezoelectricity		
		for a Three-dimensional Continuum	43	
	2.1.4	Energy Considerations	45	
	2.1.5	Governing Equations in Terms of Displacements		
		and Electric Potential	47	
	2.1.6	Analysis of a Two-dimensional Piezoelectric Continuum		
	5.	under Electrical and Mechanical Loading	49	
2.2	Finite I	Element Equations for Piezoelectric Problems	51	
		v		

	2.2.1	Variational Principles	52		
	2.2.2	The Case of Linear Constitutive Relations	53		
	2.2.3	Finite Element Discretization of the Linear Piezoelectric			
		Equations	53		
	2.2.4	Finite Element Solution	55		
	2.2.5	An Iterative Approach to the Solution	55		
	2.2.6	The Case of Nonlinear Constitutive Relations	57		
2.3	Finite F	Element Simulation of Piezoelectric Analyses of Practical Interest	t 58		
2.4		Plate and Shell Models	63		
	Referer	nces	64		
3	Actuat	ion and Sensing Mechanisms	67		
3.1	The Inc	duced Strain Actuation Mechanism	67		
3.2	Axial A	Actuation	72		
	3.2.1	Static Actuation	72		
	3.2.2	Dynamic Actuation	75		
3.3	Bendin	g Actuation	79		
	3.3.1	The Thermocouple Analogy	79		
	3.3.2	Pure Bending Induced by Patched Actuators	83		
	3.3.3	Pure Axial Extension Induced by Patched Actuators	86		
	3.3.4	The Pin-force Model	87		
3.4	The Ge	eneralization of Pin-force and Euler-Bernoulli Beam Actuation	89		
	3.4.1	Pin-force Model	89		
	3.4.2	Euler-Bernoulli Model	93		
3.5	Static F	Response of a Beam Subjected to Bending Actuation	96		
3.6		ic Response of a Beam Actuated in Bending	101		
3.7	Higher Order Models for Beam Bending Actuation				
	3.7.1	Single Layer Higher Order Model	109 111		
	3.7.2	Multilayer Higher Order Model	119		
	3.7.3	Equilibrium Equations	121		
3.8	Sensing	g Mechanism	123		
3.9	Control Issues				
	3.9.1	The Use of Piezoelectric Materials for the Control			
		of Structural Vibrations	128		
	3.9.2	Experimental Case Study	129		
	Referen	·	134		
4	Active	Composites	137		
4.1		encept of Active Composites	137		
4.2	Piezoelectric Fibre Composites 13				
4.3	Interdigitated Electrodes for Piezoelectric Components 139				
4.4		nechanics of a Piezoelectric Fibre Composite	142		
	4.4.1	Elastic Properties of a Fibre Composite	143		
	4.4.2	Dielectric Properties of a Fibre Composite	146		

4.5	Finite Element Evaluation of the Piezoelectric Properties of the Active				
4.5	Compo		148		
4.6	Macromechanics of Active Composites				
4.0	4.6.1	Constitutive Relations of a Piezocomposite Lamina	149		
	4.6.2	Macromechanics	152		
	4.6.3	Finite Element Models for Active Laminated Shells	155		
	Referen	nces	159		
5	Applica	ation of Smart Structures in Engineering Practice	161		
5.1		Morphing	162		
5.2	Vibration Control				
0.2	5.2.1	The Finite Element Model	164		
	5.2.2	Model Reduction	166		
	5,2.3	The Control System	167		
	5.2.4	Controlled Response	168		
5.3	Ultrasonic Motors				
	5.3.1	The Working Principle of a Travelling Wave			
		Ultrasonic Motor	170		
	5.3.2	The Piezoelectric Forcing	170		
	References		174		
Index			175		