

Contents

1	Introduction	1
1.1	Definition of Poisson's Ratio	1
1.2	History of Poisson's Ratio	2
1.3	Definition of Auxetic Materials	3
1.4	History of Negative Poisson's Ratio	5
1.5	Naturally Occurring Auxetic Materials	6
1.6	Auxetic Foams	7
1.7	Auxetic Yarns and Textiles	32
1.8	Auxetic Liquid Crystalline Polymers	37
1.9	Other Topics	38
	References	40
2	Micromechanical Models for Auxetic Materials	45
2.1	Introduction	45
2.2	Re-entrant Open-Cell Microstructure	45
2.3	Nodule Fibril Microstructure—Hinging, Flexure and Stretching Modes of Fibrils	48
2.4	Generalized 3D Tethered-Nodule Model	58
2.5	Rotating Squares and Rectangles Models	62
2.6	Rotating Triangles Models	72
2.7	Tetrahedral Framework Structure	76
2.8	Hard Cyclic Hexamers Model	79
2.9	Missing Rib Models	81
2.10	Chiral and Anti-chiral Lattice Models	88
2.11	Interlocking Hexagons Model	97
2.12	Egg Rack Structure	103
	References	103
3	Elasticity of Auxetic Solids	107
3.1	Constitutive Relationships	107
3.2	Bounds in Poisson's Ratio for Isotropic Solids	113

3.3	Constitutive Relationships for Isotropic Solids	117
3.4	Moduli Relations	120
3.5	Density-Modulus Relation in Auxetic Foams	122
3.6	Large Elastic Deformation of Auxetic Solids	125
3.7	Anisotropic Auxetic Solids.	128
3.8	Elastoplasticity of Auxetic Solids	142
3.9	Viscoelasticity of Auxetic Solids.	144
	References.	144
4	Stress Concentration, Fracture and Damage	
	in Auxetic Materials	147
4.1	Introduction	147
4.2	Stress Concentration in Auxetic Solids with Cavities.	148
4.3	Stress Concentration in Auxetic Solids with Rigid Inclusions	149
4.4	Stress Concentration in Auxetic Plates.	151
4.5	Stress Concentration in Auxetic Rods	152
4.6	Fracture Characteristics of Auxetic Solids	156
4.7	Stress and Displacement Fields Around Notches in Auxetic Solids	158
4.8	Mode I Dimensionless Displacement Fields	161
4.9	Mode II Dimensionless Displacement Fields.	162
4.10	Mode III Dimensionless Displacement Field.	165
4.11	Damage in Auxetic Solids	166
4.12	Fatigue in Auxetic Materials	167
	References.	168
5	Contact and Indentation Mechanics of Auxetic Materials	171
5.1	Introduction	171
5.2	Line Contact on Auxetic Materials	171
5.3	Point Contact on Auxetic Materials.	180
5.4	Effect of Indenter Shape on Auxetic Materials	185
5.5	Contact Between Auxetic Spheres.	191
5.6	Contact Deformation in Auxetic Composites	195
5.7	Indentation of Auxetic Foams.	197
	References.	199
6	Auxetic Beams	201
6.1	Stretching of Auxetic Bars.	201
6.2	Cantilever Bending of Auxetic Beams with Circular Cross Sections	203
6.3	Cantilever Bending of Auxetic Beams with Rectangular Cross Sections	205

6.4	Cantilever Bending of Auxetic Beams with Narrow Rectangular Cross Sections	206
6.5	Cantilever Bending of Auxetic Beams with Wide Rectangular Cross Sections	206
6.6	Cantilever Bending of Auxetic Beams with Regular Rectangular Cross Sections	207
6.7	Uniformly Loaded Auxetic Beams with Narrow Rectangular Cross Sections	210
6.8	Torsion of Auxetic Rods	211
6.9	Remarks on Auxetic Rods with Circular Cross Sections.	213
	References.	215
7	Auxetic Solids in Polar and Spherical Coordinates	217
7.1	Introduction	217
7.2	Thick-Walled Auxetic Cylinders	218
7.3	Rotating Thin Auxetic Disks	221
7.4	Rotating Thick Auxetic Disks.	224
7.5	Thick-Walled Auxetic Spheres	226
	References.	230
8	Thin Auxetic Plates and Shells	231
8.1	Introduction	232
8.2	Flexural Rigidity of Auxetic Plates	232
8.3	Circular Auxetic Plates	241
8.4	Rectangular Auxetic Plates.	259
8.5	Auxetic Plates on Auxetic Foundation.	275
8.6	In-Plane Compression of Constrained Auxetic Plate	283
8.7	Spherical Auxetic Shells	285
	References.	291
9	Thermal Stresses in Auxetic Solids	293
9.1	Introduction	293
9.2	General Thermoelasticity of Auxetic Solids	294
9.3	Thermoelasticity of 3D Auxetics with Complete Geometrical Constraints.	298
9.4	Thermoelasticity of Plates with Temperature Variation Along Thickness.	298
9.5	Thermoelasticity of Beams with Temperature Variation Along the Beam Thickness	300
9.6	Dimensionless Thermal Stresses for Auxetic Plates and Shells	302
9.7	Thermal Stresses for Auxetic Plates and Shells.	308

9.8	Summary on Thermal Stresses in Auxetic Plates and Shells . . .	316
9.9	Thermal Conductivity in Multi-re-entrant Honeycomb Structures.	318
	References.	320
10	Elastic Stability of Auxetic Solids	321
10.1	Introduction	321
10.2	Buckling of Auxetic Columns	322
10.3	Buckling of Rectangular Auxetic Plates	324
10.4	Buckling of Circular Auxetic Plates	328
10.5	Buckling of Cylindrical Auxetic Shells	332
10.6	Buckling of Spherical Auxetic Shells	336
10.7	Recent Advances on Instability in Relation to Auxetic Materials and Structures.	338
	References.	344
11	Vibration of Auxetic Solids	345
11.1	Introduction	345
11.2	Vibration of Circular Auxetic Plates	346
11.3	Vibration of Rectangular Auxetic Plates.	350
11.4	Vibration of Cylindrical Auxetic Shells	358
11.5	Vibration of Spherical Auxetic Shells	361
11.6	Advanced Topics on Vibration and Acoustics of Auxetic Solids and Structures.	362
	References.	364
12	Wave Propagation in Auxetic Solids	367
12.1	Introduction	367
12.2	Longitudinal Waves in Prismatic Auxetic Bars	369
12.3	Plane Waves of Dilatation in Auxetic Solids	370
12.4	Plane Waves of Distortion in Auxetic Solids	371
12.5	Rayleigh Waves in Auxetic Solids	373
12.6	Non-dimensionalization of Wave Velocities	374
12.7	Advanced Topics on Wave Motion in Auxetic Solids	380
	References.	382
13	Wave Transmission and Reflection Involving Auxetic Solids	385
13.1	Introduction	385
13.2	Analysis	387
13.3	Longitudinal Wave (1D Stress State or 3D Strain State).	389
13.4	Longitudinal Wave (Width-Constrained Plates).	390
13.5	Plane Waves of Dilatation (1D Strain State or 3D Stress State).	390

13.6	Torsional Waves	391
13.7	Rayleigh Waves	392
13.8	Non-dimensionalization of Transmitted and Reflected Stresses	392
13.9	Dimensionless Transmitted Stress in Longitudinal Waves (1D Stress State).	394
13.10	Dimensionless Transmitted Stress in Longitudinal Waves (Constrained-Width Plates).	395
13.11	Dimensionless Transmitted Stress in Plane Waves of Dilatation.	397
13.12	Dimensionless Transmitted Stress in Torsional Waves	399
13.13	Dimensionless Transmitted Stress in Rayleigh Waves	401
13.14	Summary on Stress Wave Transmission Involving Auxetic Solids	403
	References.	404
14	Longitudinal Waves in Auxetic Solids	405
14.1	Introduction	405
14.2	Review of Elementary Analysis	407
14.3	Density Correction	408
14.4	Lateral Inertia.	409
14.5	Density Correction and Lateral Inertia	411
14.6	Analogy with Plane Waves of Dilatation	416
14.7	Lateral Inertia in Auxetic Love Rods.	419
14.8	Lateral Inertia and Density Correction in Auxetic Love Rods	422
	References.	425
15	Shear Deformation in Auxetic Solids	427
15.1	Introduction	427
15.2	Laterally-Loaded Thick Auxetic Beams	428
15.3	Shear Correction Factors for Isotropic Plates Within $-1 \leq \nu \leq 0.5$	436
15.4	Laterally-Loaded Thick Circular Auxetic Plates	440
15.5	Laterally-Loaded Thick Polygonal Auxetic Plates	444
15.6	Laterally-Loaded Thick Rectangular Auxetic Plates	447
15.7	Buckling of Thick Auxetic Columns	453
15.8	Buckling of Thick Auxetic Plates	459
15.9	Vibration of Thick Auxetic Plates	467
	References.	472
16	Simple Semi-auxetic Solids	475
16.1	Introduction	475
16.2	Elastic Properties of a Directional Semi-auxetic Solid	476

16.3	Kinematical Studies on Rotation-Based Semi-auxetics	482
16.4	Analysis of Semi-auxetic Yarns	489
16.5	Processing of Semi-auxetic Yarns	498
16.6	Functionally-Graded Semi-auxetic Beams.	503
16.7	Semi-auxetic Rods	508
16.8	Semi-auxetic Sandwich Plates.	515
16.9	Mixed Auxeticity of Semi-auxetic Sandwich Structures	521
	References.	531
17	Semi-auxetic Laminates and Auxetic Composites	533
17.1	Introduction	533
17.2	Semi-auxetic Unidirectional Fiber Composites	534
17.3	Out-of-Plane Modulus of Semi-auxetic Laminates.	536
17.4	In-plane Modulus of Semi-auxetic Laminates	544
17.5	Further Counter-Intuitive Modulus from Semi-auxetic Laminates	550
17.6	Comparison Between In-Plane and Out-of-Plane Modulus of Semi-auxetic Laminates	557
17.7	Semi-auxetic and Alternating Positive and Negative Thermal Expansion Laminates	558
17.8	Auxetic Composites	569
	References.	579
	Index	581

Auxetic Materials and Structures

Lim, T.-C.

2015, XV, 587 p. 375 illus., 60 illus. in color., Hardcover

ISBN: 978-981-287-274-6