

Contents

Preface xi

Chapter 1 Introduction 1

References 12

Chapter 2 Elastic behavior 13

- 2.1 Elastic deformation of atomic bonds 14
- 2.2 Failure of Hooke's Law 17
- 2.3 Engineering elastic constants 18
- 2.4 Strain at a point 24
- 2.5 Transformation of strains 30
- 2.6 Dilatational and deviatoric strains 34
- 2.7 Strain compatibility 35
- 2.8 Tensors 36
- 2.9 Coefficients of thermal expansion 36
- 2.10 Definition of stress 40
- 2.11 General version of Hooke's Law 44
- 2.12 Elastic behavior of anisotropic materials 47
- 2.13 Elastic behavior of isotropic materials 55
- 2.14 Miscellaneous effects on the elastic constants 57
- 2.15 Propagation of mechanical disturbances 58
- 2.16 Resonant vibrations 60

2.17	Measurement of elastic constants	62
	Problems	65
	References	69
Chapter 3	Effect of structure on elastic behavior	70
3.1	Relationship of elastic constants to interatomic potential	70
3.2	Elastic anisotropy and atomic structure	75
3.3	Elastic behavior of particulate composites	78
3.4††	Advanced constitutive relationships for composites	83
3.5	Constitutive relations for random polycrystals	87
3.6	Effects of porosity and microcracking on elastic constants	88
3.7	Thermal expansion behavior of polycrystalline ceramics	94
3.8	Elastic behavior of sandwich panels	98
	Problems	99
	References	103
Chapter 4	Elastic stress distributions	105
4.1	Statically determinate and indeterminate problems	106
4.2	Thin-walled pressure vessels	107
4.3	Bending of beams	108
4.4	Elastic stability and buckling	113
4.5	Plane stress and plane strain	114
4.6	Cylindrical polar coordinates	117
4.7	Pressurized thick-walled cylinders	118
4.8	Residual stresses in composites	120
4.9	Stress concentrations due to pores and inclusions	124
4.10	Contact forces	127
	Problems	129
	References	133
Chapter 5	Viscosity and viscoelasticity	134
5.1	Newton's Law of viscosity	134
5.2	Temperature dependence of viscosity	137
5.3	Simple problems of viscous flow	139
5.4††	General equations for slow viscous flow	142
5.5	Non-linear viscous flow	145
5.6	Dispersion of solid particles in a fluid	146
5.7	Viscoelastic models	148

Contents

ix

5.8	Anelasticity in ceramics and glasses	156
	Problems	158
	References	161
Chapter 6	Plastic deformation	162
6.1	Theoretical shear strength	162
6.2	Dislocations	164
6.3	Stress fields of dislocations	166
6.4	Attributes of dislocations	169
6.5	The geometry of slip	172
6.6	Partial dislocations	176
6.7	Plasticity in single crystals and polycrystalline materials	179
6.8	Obstacles to dislocation motion	183
6.9	Plasticity mechanics	186
6.10	Hardness	188
	Problems	189
	References	191
Chapter 7	Creep deformation	193
7.1	Creep in single crystals	195
7.2	Creep in polycrystals	196
7.3	Deformation mechanism maps	201
7.4	Measurement of creep mechanisms	202
	Problems	204
	References	208
Chapter 8	Brittle fracture	210
8.1	Theoretical cleavage strength	210
8.2	Stress concentrations at cracks	212
8.3	The Griffith concept	213
8.4	Nucleation and formation of cracks	216
8.5	Linear elastic fracture mechanics	218
8.6	Stress intensity factor solutions	224
8.7††	Methods of determining stress intensity factors	231
8.8	Indentation fracture	243
8.9	<i>R</i> curves	245
8.10	Mixed mode fracture	247
8.11	Microstructural aspects of crack propagation	248

x	Contents
8.12	Sub-critical crack growth 264
8.13	Fractography 266
8.14	Contact-damage processes 269
8.15††	<i>J</i> -integral 278
	Problems 280
	References 283
Chapter 9	Strength and engineering design 285
9.1	Strength testing 285
9.2	Failure statistics 286
9.3	Time dependence of strength 291
9.4	Determination of sub-critical crack growth parameters 293
9.5	SPT diagrams 295
9.6	Improving strength and reliability 296
9.7	Temperature dependence of strength 298
9.8	Thermal stresses and thermal shock 298
9.9	Thermal shock resistance parameters 301
9.10	Residual stresses 305
	Problems 306
	References 314
	Comprehension exercises 316
	Appendices
1	Explicit relations between the stiffness and compliance constants for selected crystal classes 325
2	Young's modulus as a function of direction for various single crystals 326
3	Relationship between engineering elastic constants for isotropic materials 327
4	Madelung constants for various crystal types 328
5	Stress and deflection for common testing geometries 329
	<i>Index</i> 331