

Contents

1	Introduction	1
1.1	Conventional Failure Criteria	1
1.2	Characteristic Brittle Failures	4
1.3	Griffith's Work	6
1.4	Fracture Mechanics	10
	References	14
2	Linear Elastic Stress Field in Cracked Bodies	15
2.1	Introduction	15
2.2	Crack Deformation Modes and Basic Concepts	15
2.3	Westergaard Method	17
2.4	Singular Stress and Displacement Fields	20
2.5	Stress Intensity Factor Solutions	27
2.6	Three-Dimensional Cracks	28
	Examples	30
	Problems	45
	Appendix 2.1	59
	References	62
3	Elastic-Plastic Stress Field in Cracked Bodies	65
3.1	Introduction	65
3.2	Approximate Determination of the Crack-Tip Plastic Zone	66
3.3	Irwin's Model	71
3.4	Dugdale's Model	73
	Examples	76
	Problems	80
	References	84
4	Crack Growth Based on Energy Balance	85
4.1	Introduction	85
4.2	Energy Balance During Crack Growth	86

4.3	Griffith Theory	87
4.4	Graphical Representation of the Energy Balance Equation	89
4.5	Equivalence Between Strain Energy Release Rate and Stress Intensity Factor	93
4.6	Compliance	96
4.7	Crack Stability	98
	Examples	101
	Problems	119
	Reference	130
5	Critical Stress Intensity Factor Fracture Criterion	131
5.1	Introduction	131
5.2	Fracture Criterion	132
5.3	Variation of K_c with Thickness	132
5.4	Experimental Determination of K_{Ic}	136
5.5	Crack Growth Resistance Curve (<i>R</i> -Curve) Method	141
5.6	Fracture Mechanics Design Methodology	146
	Examples	147
	Problems	159
	Appendix 5.1	164
	References	165
6	<i>J</i>-Integral and Crack Opening Displacement Fracture Criteria	167
6.1	Introduction	167
6.2	Path-Independent Integrals	167
6.3	<i>J</i> -Integral	170
6.4	Relationship Between the <i>J</i> -Integral and Potential Energy	173
6.5	<i>J</i> -Integral Fracture Criterion	175
6.6	Experimental Determination of the <i>J</i> -Integral	176
6.7	Stable Crack Growth Studied by the <i>J</i> -Integral	183
6.8	Crack Opening Displacement (COD) Fracture Criterion	185
	Examples	190
	Problems	205
	References	212
7	Strain Energy Density Failure Criterion: Mixed-Mode Crack Growth	215
7.1	Introduction	215
7.2	Volume Strain Energy Density	216
7.3	Basic Hypotheses	220
7.4	Two-Dimensional Linear Elastic Crack Problems	221
7.5	Uniaxial Extension of an Inclined Crack	222
7.6	Ductile Fracture	229

7.7	The Stress Criterion	233
	Examples	235
	Problems	247
	References	256
8	Dynamic Fracture	259
8.1	Introduction	259
8.2	Mott's Model	260
8.3	Stress Field Around a Rapidly Propagating Crack	263
8.4	Strain Energy Release Rate	266
8.5	Crack Branching	269
8.6	Crack Arrest	271
8.7	Experimental Determination of Crack Velocity and Dynamic Stress Intensity Factor	272
	Examples	274
	Problems	281
	References	284
9	Fatigue and Environment-Assisted Fracture	287
9.1	Introduction	287
9.2	Fatigue Crack Propagation Laws	289
9.3	Fatigue Life Calculations	293
9.4	Variable Amplitude Loading	294
9.5	Environment-Assisted Fracture	298
	Examples	299
	Problems	315
	References	319
10	Micromechanics of Fracture	321
10.1	Introduction	321
10.2	Cohesive Strength of Solids	322
10.3	Cleavage Fracture	325
10.4	Intergranular Fracture	326
10.5	Ductile Fracture	326
10.6	Crack Detection Methods	329
	References	331
11	Composite Materials	333
11.1	Introduction	333
11.2	Through-Thickness Cracks	334
11.3	Interlaminar Fracture	339
	References	351

12 Thin Films	353
12.1 Introduction	353
12.2 Interfacial Failure of a Bimaterial System	354
12.3 Steady-State Solutions for Cracks in Bilayers	359
12.4 Thin Films Under Tension	362
12.5 Measurement of Interfacial Fracture Toughness	365
References	370
13 Nanoindentation	371
13.1 Introduction	371
13.2 Nanoindentation for Measuring Young's Modulus and Hardness	372
13.3 Nanoindentation for Measuring Fracture Toughness	376
13.4 Nanoindentation for Measuring Interfacial Fracture Toughness – Conical Indenters	378
13.5 Nanoindentation for Measuring Interfacial Fracture Toughness – Wedge Indenter	382
References	385
14 Cementitious Materials	387
14.1 Introduction	387
14.2 Why Fracture Mechanics of Concrete?	388
14.3 Tensile Behavior of Concrete	389
14.4 The Fracture Process Zone	392
14.5 Fracture Mechanics	393
14.6 Modelling the Fracture Process Zone	394
14.7 Experimental Determination of G_{Ic}	396
14.8 Size Effect	398
14.9 Fiber Reinforced Cementitious Materials (FRCMs)	399
References	400
15 Experimental Methods	403
15.1 Introduction	403
15.2 Electrical Resistance Strain Gages	404
15.3 Photoelasticity	409
15.4 The Method of Caustics	416
15.5 Interferometric Methods	431
15.6 Thermoelastic Methods	434
Examples	435
References	443
16 Numerical Methods	445
16.1 Introduction	445
16.2 Bueckner's Principle	445
16.3 Green's Function	446

16.4	Weight Functions	449
16.5	Boundary Collocation	450
16.6	Alternating Method	451
16.7	Integral Transforms	452
16.8	Continuous Dislocations	454
16.9	Finite Elements	454
	16.9.1 Basic Principles	455
	16.9.2 Application to Crack Problems	457
	16.9.3 Determination of Stress Intensity Factors	458
	Examples	469
	References	471
Index		475