

Contents

Part I Elasticity

1	Elastic Boundary-Value Problems	3
1.1	Displacement, Strain, and Compatibility Condition	3
1.2	Stress and Equilibrium Conditions	5
1.3	Stress–Strain Relationship	6
1.4	Stress Function	8
1.5	Elastic Boundary-Value Problem	9
1.6	Solution Based on a Polar Coordinate System	11
	References	16
2	Stress Concentration Problems	17
2.1	Mechanisms and Solution Methods of Stress Concentration	17
2.2	A Concentrated Force Acting at the Tip of a Wedge	18
2.3	Axisymmetric Solution	20
2.4	Stress Concentration Caused by a Circular Hole	22
2.5	Stress Concentration Factor	24
2.6	Elliptic Hole in Tension	25
	References	30
3	Analysis of Two-Dimensional Cracks	31
3.1	Stress Field Around a Crack	31
3.2	Williams’ Expansion at a Crack Tip	36
3.3	Method of Muskhelishvili for a Straight Crack	40
3.3.1	Solution of a Straight Crack of Length $2a$	40
3.3.2	Solution of a Semi-Infinite Straight Crack Subjected to a Force Couple	43
	References	44

Part II Fracture

4	Brittle Fracture	47
4.1	Theory of Brittle Fracture.....	47
4.2	Brittle Fracture of Welded Steel Structures	54
4.3	Strip-Yielding Model.....	55
4.4	J-Integral for Work Hardening Materials.....	60
4.5	Stability of Crack Propagation.....	62
	References.....	68
5	Fatigue Crack Propagation	69
5.1	Fatigue Crack Growth.....	69
5.2	Effective Stress Intensity Range	73
5.3	Simulation of Crack Opening and Closure.....	79
5.3.1	Stress Field Near a Crack Tip	79
5.3.2	Crack Tip Opening and Closure Simulation.....	80
5.3.3	Crack Growth Model Based on Stress Intensity Range with Repeated Tensile Plasticity	84
5.4	Effects of Stress Ratio and Load Sequence	86
	References.....	90

Part III Morphology

6	Pattern-Formation of Interacting Brittle Cracks	93
6.1	Stability of a System of Straight Brittle Cracks.....	93
6.1.1	Variational Principle and Normal Behavior	94
6.1.2	Critical States	99
6.1.3	Non-Interacting Crack and Two-Interacting Cracks	100
6.1.4	Perfect System	104
6.2	Thermally Induced Brittle Cracks	108
6.2.1	System of Parallel Edge Cracks.....	108
6.2.2	Numerical Simulation and Experiments	110
	References.....	112
7	Crack Paths in Brittle Solids	115
7.1	Slightly Kinked and Curved Crack	115
7.1.1	Statement of Problem.....	116
7.1.2	Method of Analysis.....	117
7.1.3	A Straight Crack with a Slightly Branched and Curved Extension in a Finite Domain.....	122
7.2	Crack Path Criteria and Crack Path Stability	128
7.2.1	Crack Path Criteria	128
7.2.2	Crack Curving and Crack Path Stability.....	131
7.3	Wavy Crack Propagation in Brittle Solids	140
7.3.1	Cracking in Glass Plates.....	140

7.3.2	Statement of Problem and Numerical Simulation.....	141
7.3.3	Wavy Versus Straight Formation of Crack Propagation and Its Controlling Parameter	145
	References	150
8	Brittle Fracture Along Butt-Weld	153
8.1	Second Order Perturbation Solution of a Kinked and Curved Crack	153
8.1.1	Second Order Perturbation Analysis.....	154
8.1.2	Approximate Description of a Slightly Kinked and Curved Extension of a Straight Crack	157
8.1.3	A Matched Asymptotic Expansion Method for a Finite Body.....	160
8.2	Crack Path Based on the Minimum Potential Energy	162
8.2.1	Energy Release Rate	162
8.2.2	Inhomogeneous Fracture Toughness.....	163
8.3	Brittle Fracture Along Butt-Weld.....	164
8.3.1	Morphological Aspects of Brittle Fracture Along Butt-Weld.....	164
8.3.2	Analytical Model for Crack Path Prediction	166
8.3.3	Effect of Residual Stress and Toughness Along Weld	170
	References.....	172
9	Fatigue Crack Paths	173
9.1	Crack Path Criteria in Fatigue	173
9.2	Fatigue Crack Paths Under Biaxial Stress.....	177
9.2.1	Fatigue Crack Paths	177
9.2.2	Experiments Under Biaxial Loading Conditions.....	178
9.3	Fatigue Crack Paths in a Welded Structure	183
9.3.1	Measurement of Welding Residual Stress	183
9.3.2	Effects of Welding Residual Stress to Fatigue	185
9.3.3	Simulation Under the Effects of Structural Redundancy and Welding Residual Stress	187
	References.....	190

Part IV Design

10	Simulation of Crack Propagation	195
10.1	Simulation Methods for Engineering Structures	196
10.2	Formulation for a 3-D Plate Structure	200
10.2.1	Boundary-Value Problem for Multiple Growing Cracks	200
10.2.2	An Alternating Procedure Combined with a First Order Perturbation Analysis.....	203
10.2.3	Crack Path Prediction Based on the Local Symmetry Criterion	206

10.3	Interactive Propagation of Brittle Cracks	207
10.3.1	Avoiding Cracks	207
10.3.2	Interactive Crack Growth in a Heterogeneous Material ..	208
10.4	Interactive Growth of Fatigue Cracks: A Case Study	212
10.4.1	Crack Propagation in a Stiffener of a Welded Plate Structure	212
10.4.2	Effects of the Applied Boundary Conditions	216
	References	219
11	Fracture Control of Engineering Structures	223
11.1	Design Concepts for Fracture Control	223
11.1.1	Safe-Life Design and Damage-Tolerant Design	223
11.1.2	Fracture Control Design	226
11.2	Retardation Due to Load Sequence	230
11.2.1	Retardation Due to Overloads	230
11.2.2	Random Sequence of Clustered Loads	231
11.3	Fracture Control of Marine Structures	238
11.3.1	Liquefied Gas Containment Systems	238
11.3.2	Deck Structures of Container Ships	241
	References	246
	Appendix A Complex Potentials	249
A.1	Complex Number and Complex Functions	249
A.2	Airy's Stress Function	250
A.3	Conformal Mapping	254
	Reference	256
	Appendix B The Hilbert Problems	257
B.1	Some Definitions and Integrals of the Cauchy Type	257
B.2	The Plemelj Formulae	259
B.3	Sectionally Holomorphic Function	262
B.4	Homogeneous Hilbert Problem	263
B.5	Nonhomogeneous Hilbert Problem	266
B.6	Solution for an Example Problem $\Phi^+ + \Phi^- = g$	267
	References	269
	Appendix C Method of Superposition	271
C.1	Basic Boundary-Value Problem	271
C.2	Analysis of Stress Intensity Factors	273
C.3	Derivatives of Stress Intensity Factors	275
	References	277
	Index	279

Mathematical and Computational Analyses of Cracking
Formation

Fracture Morphology and Its Evolution in Engineering
Materials and Structures

Sumi, Y.

2014, XII, 282 p. 168 illus., 12 illus. in color., Hardcover

ISBN: 978-4-431-54934-5