
CONTENTS

| | |
|---|------------|
| Preface | xi |
| List of symbols | xiv |
| 1 Background and overview | 1 |
| 1.1 Introduction | 1 |
| 1.1.1 Inertial effects in fracture mechanics | 2 |
| 1.1.2 Historical origins | 3 |
| 1.2 Continuum mechanics | 13 |
| 1.2.1 Notation | 13 |
| 1.2.2 Balance equations | 16 |
| 1.2.3 Linear elastodynamics | 22 |
| 1.2.4 Inelastic materials | 29 |
| 1.3 Analytic functions and Laplace transforms | 30 |
| 1.3.1 Analytic functions of a complex variable | 30 |
| 1.3.2 Laplace transforms | 33 |
| 1.4 Overview of dynamic fracture mechanics | 37 |
| 1.4.1 Basic elastodynamic solutions for a stationary crack | 38 |
| 1.4.2 Further results for a stationary crack | 40 |
| 1.4.3 Asymptotic fields near a moving crack tip | 42 |
| 1.4.4 Energy concepts in dynamic fracture | 44 |
| 1.4.5 Elastic crack growth at constant speed | 47 |
| 1.4.6 Elastic crack growth at nonuniform speed | 49 |
| 1.4.7 Plasticity and rate effects during crack growth | 52 |
| 2 Basic elastodynamic solutions for a stationary crack | 55 |
| 2.1 Introduction | 55 |
| 2.2 Suddenly applied antiplane shear loading | 60 |
| 2.3 Green's method of solution | 65 |

| | | |
|----------|--|------------|
| 2.4 | Suddenly applied crack face pressure | 72 |
| 2.5 | The Wiener-Hopf technique | 77 |
| 2.5.1 | Application of integral transforms | 78 |
| 2.5.2 | The Wiener-Hopf factorization | 84 |
| 2.5.3 | Inversion of the transforms | 91 |
| 2.5.4 | Higher order terms | 96 |
| 2.6 | Suddenly applied in-plane shear traction | 97 |
| 2.7 | Loading with arbitrary time dependence | 100 |
| 3 | Further results for a stationary crack | 104 |
| 3.1 | Introduction | 104 |
| 3.2 | Nonuniform crack face traction | 106 |
| 3.2.1 | Suddenly applied concentrated loads | 107 |
| 3.2.2 | Fundamental solution for a moving dislocation | 110 |
| 3.2.3 | The stress intensity factor history | 112 |
| 3.3 | Sudden loading of a crack of finite length | 117 |
| 3.4 | Three-dimensional scattering of a pulse by a crack | 123 |
| 3.5 | Three-dimensional stress intensity factors | 131 |
| 3.6 | Fracture initiation due to dynamic loading | 140 |
| 3.6.1 | The Irwin criterion | 140 |
| 3.6.2 | Qualitative observations | 141 |
| 3.6.3 | Experimental results | 144 |
| 4 | Asymptotic fields near a moving crack tip | 152 |
| 4.1 | Introduction | 152 |
| 4.2 | Elastic material; antiplane shear | 155 |
| 4.3 | Elastic material; in-plane modes of deformation | 160 |
| 4.3.1 | Singular field for mode I | 161 |
| 4.3.2 | Higher order terms for mode I | 169 |
| 4.3.3 | Singular field for mode II | 170 |
| 4.3.4 | Supersonic crack tip speed | 171 |
| 4.4 | Elastic-ideally plastic material; antiplane shear | 175 |
| 4.4.1 | Asymptotic fields for steady dynamic growth | 178 |
| 4.4.2 | Comparison with equilibrium results | 182 |
| 4.5 | Elastic-ideally plastic material; plane strain | 184 |
| 4.5.1 | Asymptotic field in plastically deforming regions | 187 |
| 4.5.2 | A complete solution | 190 |
| 4.5.3 | Other possible solutions | 194 |
| 4.5.4 | Discontinuities | 197 |
| 4.5.5 | Elastic sectors | 202 |
| 4.6 | Elastic-viscous material | 206 |

| | | |
|----------|--|------------|
| 4.6.1 | Antiplane shear crack tip field | 207 |
| 4.6.2 | Plane strain crack tip field | 214 |
| 4.7 | Elastic-viscoplastic material; antiplane shear | 215 |
| 5 | Energy concepts in dynamic fracture | 221 |
| 5.1 | Introduction | 221 |
| 5.2 | The crack tip energy flux integral | 224 |
| 5.2.1 | The energy flux integral for plane deformation | 224 |
| 5.2.2 | Some properties of $F(\Gamma)$ | 227 |
| 5.3 | Elastodynamic crack growth | 231 |
| 5.3.1 | Dynamic energy release rate | 231 |
| 5.3.2 | Cohesive zone models of crack tip behavior | 235 |
| 5.3.3 | Special forms for numerical computation | 240 |
| 5.4 | Steady crack growth in a strip | 243 |
| 5.4.1 | Strip with uniform normal edge displacement | 243 |
| 5.4.2 | Shear crack with a cohesive zone in a strip | 247 |
| 5.5 | Elementary applications in structural mechanics | 250 |
| 5.5.1 | A one-dimensional string model | 250 |
| 5.5.2 | Double cantilever beam configuration | 254 |
| 5.5.3 | Splitting of a beam with a wedge | 257 |
| 5.5.4 | Steady crack growth in a plate under bending | 261 |
| 5.5.5 | Crack growth in a pressurized cylindrical shell | 262 |
| 5.6 | A path-independent integral for transient loading | 264 |
| 5.6.1 | The path-independent integral | 264 |
| 5.6.2 | Relationship to stress intensity factor | 269 |
| 5.6.3 | An application | 271 |
| 5.7 | The transient weight function method | 274 |
| 5.7.1 | The weight function based on a particular solution | 274 |
| 5.7.2 | A boundary value problem for the weight function | 280 |
| 5.8 | Energy radiation from an expanding crack | 289 |
| 6 | Elastic crack growth at constant speed | 296 |
| 6.1 | Introduction | 296 |
| 6.2 | Steady dynamic crack growth | 298 |
| 6.2.1 | General solution procedure | 299 |
| 6.2.2 | The Yoffe problem | 300 |
| 6.2.3 | Concentrated shear traction on the crack faces | 305 |
| 6.2.4 | Superposition and cohesive zone models | 306 |
| 6.2.5 | Approach to the steady state | 310 |

| | | |
|----------|--|------------|
| 6.3 | Self-similar dynamic crack growth | 313 |
| 6.3.1 | General solution procedure | 314 |
| 6.3.2 | The Broberg problem | 318 |
| 6.3.3 | Symmetric expansion of a shear crack | 330 |
| 6.3.4 | Nonsymmetric crack expansion | 334 |
| 6.3.5 | Expansion of circular and elliptical cracks | 336 |
| 6.4 | Crack growth due to general time-independent loading | 340 |
| 6.4.1 | The fundamental solution | 342 |
| 6.4.2 | Arbitrary initial equilibrium field | 350 |
| 6.4.3 | Some illustrative cases | 353 |
| 6.4.4 | The in-plane shear mode of crack growth | 355 |
| 6.4.5 | The antiplane shear mode of crack growth | 356 |
| 6.5 | Crack growth due to time-dependent loading | 356 |
| 6.5.1 | The fundamental solution | 358 |
| 6.5.2 | Arbitrary delay time with crack face pressure | 362 |
| 6.5.3 | Incident plane stress pulse | 365 |
| 7 | Elastic crack growth at nonuniform speed | 367 |
| 7.1 | Introduction | 367 |
| 7.2 | Antiplane shear crack growth | 369 |
| 7.3 | Plane strain crack growth | 378 |
| 7.3.1 | Suddenly stopping crack | 379 |
| 7.3.2 | Arbitrary crack tip motion | 387 |
| 7.3.3 | In-plane shear crack growth | 392 |
| 7.4 | Crack tip equation of motion | 393 |
| 7.4.1 | Tensile crack growth | 395 |
| 7.4.2 | Fine-scale periodic fracture resistance | 401 |
| 7.4.3 | Propagation and arrest of a mode II crack | 407 |
| 7.4.4 | A one-dimensional string model | 410 |
| 7.4.5 | Double cantilever beam: approximate equation of motion | 421 |
| 7.5 | Tensile crack growth under transient loading | 426 |
| 7.5.1 | Incident plane stress pulse | 426 |
| 7.5.2 | An influence function for general loading | 431 |
| 7.6 | Rapid expansion of a strip yield zone | 432 |
| 7.7 | Uniqueness of elastodynamic crack growth solutions | 437 |
| 8 | Plasticity and rate effects during crack growth | 442 |
| 8.1 | Introduction | 442 |
| 8.2 | Viscoelastic crack growth | 442 |
| 8.3 | Steady crack growth in an elastic-plastic material | 448 |

| | |
|--|------------|
| 8.3.1 Plastic strain on the crack line | 451 |
| 8.3.2 A growth criterion | 459 |
| 8.3.3 A formulation for the complete field | 461 |
| 8.3.4 The toughness-speed relationship | 465 |
| 8.3.5 The steady state assumption | 467 |
| 8.4 High strain rate crack growth in a plastic solid | 469 |
| 8.4.1 High strain rate plasticity | 470 |
| 8.4.2 Steady crack growth with small-scale yielding | 474 |
| 8.4.3 An approximate analysis | 477 |
| 8.4.4 Rate effects and crack arrest | 481 |
| 8.5 Fracture mode transition due to rate effects | 485 |
| 8.5.1 Formulation | 486 |
| 8.5.2 A rate-dependent cohesive zone | 488 |
| 8.5.3 The crack growth criteria | 494 |
| 8.6 Ductile void growth | 498 |
| 8.6.1 Spherical expansion of a void | 500 |
| 8.6.2 A more general model | 506 |
| 8.7 Microcracking and fragmentation | 508 |
| 8.7.1 Overall energy considerations | 509 |
| 8.7.2 Time-dependent strength under pulse loading | 512 |
| Bibliography | 521 |
| Index | 559 |