Fracture Mechanics Topics & References

Color Code: Covered, Brief Discussion, Not Covered

1. Preliminaries: Tensors; Kinematics (displacement, strain); Stress; Balance laws; Constitutive equations
   Saouma 5.1-5.4; Anderson A2.1
2. History
   Anderson 1.2.1-1.2.5
3. Fracture modes
   3.1. Classification
      Murakami 1.1.1, 1.1.2, **1.1.3**; Saouma **4.1-4.4** (buckling, fracture, yielding, etc.); Schreurs 2.1.
   3.2. Ductile fracture
      3.2.1. Dislocation dynamics
         Hertzberg 2 (theory), 3 (slip and twinning)
      3.2.2. Void nucleation, growth, and coalescence
         Anderson **5.1**
   3.3. Brittle fracture
      Anderson 5.2; Lawn
   3.4. Ductile-brittle transition
      3.4.1. Temperature
         Anderson 5.3
      3.4.2. Radiation embrittlement
         Anderson 7.8; Hertzberg 10.6.3
      3.4.3. Hydrogen embrittlement
         Anderson 11.4; Hertzbeg 11.1
      3.4.4. Strain rate
         Anderson 4.1.1; Hertzberg 5.2
      3.4.5. Size effect
         Samoua 16.2.3 (Bazant), 16.2.4 (Carpintieri)
4. Linear Elastic Fracture Mechanics (LEFM)
   4.1. Griffith energy approach
      4.1.1. Atomic view of fracture; mismatch with experiments
         Anderson 2.1; Saouma 8.1.1
      4.1.2. Effect of flaws, Griffith experiment
         Anderson 2.1; Saouma 8.2
      4.1.3. Energy equation, Fracture Resistance (R)
         Anderson 2.3; Saouma 9.1
      4.1.4. Energy Release Rate (G)
         Anderson 2.4
      4.1.5. Crack Stability, R and Π curve
         Anderson 2.5; Saouma 9.1.2, **9.3**
   4.2. Stress solutions, Stress Intensity Factor K (SIF)
      4.2.1. Airy stress functions
         Anderson A2.1; Saouma 5.6; Schreurs 5.8 (general indicial expressions)
      4.2.2. Complex variables and cylindrical coordinate
         Sauoma 5.7, 5.8; Zender 2.4

4.2.3. Stress solutions, stress concentration
Saouma 6.1, 6.3, **6.5**; Anderson A2.3; Schreurs 6.2
4.2.4. Crack tip stress fields, SIF
Saouma 6.4; Schreurs 6.3-6.6; Anderson A2.3
4.2.5. Relation between K & R (SIF & Resistance)
Saouma **9.2**; Anderson 2.7;
4.2.6. SIF Handbooks, design
Saouma **7.2**; Schreurs **6.7**; Anderson 2.6.3; Laham

4.3. Mixed mode fracture
4.3.1. Crack propagation criteria
Saouma **10.1**; Schreurs **7.3**; Lawn **2.8**
4.3.2. Nucleation criteria

4.4. Crack interactions
Anderson 2.12

5. Elastoplastic fracture mechanics
5.1. Introduction to plasticity
Saouma **2**; Schreurs 9.1-9.4
5.2. Plastic zone models
5.2.1. 1D models: Irwin, Dugdale, and Barenbolt models
Saouma **11.1**; Anderson 2.8
5.2.2. 2D models: plane stress versus plane strain plastic zones
Anderson 2.8.4; 2.10.1-2.10.3; Saouma 11.2-11.3; Schreurs 9.1, 9.3-6
5.3. J Integral
5.3.1. Path independence
Schreurs 10.2.1-10.2.2; Saouma 13.2; Anderson 3.2.2 (Saouma 13.11-13.12 generalizations for dynamic, crack surface loading, body force, etc loading)
5.3.2. Relation between J and G
Saouma **13.3**, 13.4; Anderson 3.2.1
5.3.3. Relation between J and K
Schreurs 10.2.3; Saouma **13.10**; Anderson 3.2.3
5.3.4. Energy Release Rate, crack growth and R curves
Anderson 3.2.1, 3.2.5, 3.4, **3.5**; Saouma 13.6, 13.7
5.3.5. Plastic crack tip fields; Hutchinson, Rice and Rosengren (HRR) solution
Saouma **13.8**; Schreurs 10.3.1-10.3.2
5.3.6. Small scale yielding (SSY) versus large scale yielding (LSY)
Schreurs 9.9 (SSY); Anderson 3.6.1 (LSY T-stress effect), 3.6.2 (J-Q theory)
5.3.7. Fracture mechanics versus material (plastic) strength
5.4. Crack tip opening displacement (CTOD), relations with J and G
Anderson 3.1, **3.3**; Saouma 12

6. Computational fracture mechanics
6.1. Fracture mechanics in Finite Element Methods (FEM)
6.1.1. Introduction to Finite Element method
6.1.2. Singular stress finite elements
Saouma **19.2-19.6**; Schreurs 11.1-11.4

        6.1.3. Extraction of K (SIF), G
            K: Anderson **12.2.1;** Saouma **19.7.1**
            G: Anderson 12.2.2-12.2.4; Saouma **20.2** (Mixed mode)
        6.1.4. J integral
            Anderson 12.3; Saouma 21.1, 21.3.1.1; Schreurs 11.7
        6.1.5. Finite Element mesh design for fracture mechanics
            Anderson 12.4, 12.5
        6.1.6. Computational crack growth
        6.1.7. Extended Finite Element Method (XFEM)
    6.2. Traction Separation Relations (TSRs)
7. Bulk damage models
    7.1. Representative Volume Element (RVE) and damage representation
        Murakami 1.2, 2.1
    7.2. Continuum models based on thermodynamics
        7.2.1. Thermodynamic laws, Thermodynamic and dissipation potentials
            Murakami 3.1-3.2.2
        7.2.2. Damage evolution with plasticity
            Murakami 4.1 (1D), **4.2.1-4.2.5** (3D)
    7.3. Micromechanics based damage models
        7.3.1. Ductile void evolution models
            Murakami 6.5.1 (Gurson) & 6.5.2 GTN (Tvergaard & Needleman)
8. Fatigue
    Suresh
    8.1. Fatigue regimes
    8.2. S-N, P-S-N curves
        Schreurs 12.3
    8.3. Fatigue crack growth models (Paris law)
        Anderson 10.2, 10.4 (fatigue threshold); Schreurs 12.5
    8.4. Variable and random load
        Anderson 10.5; Schreurs 12.6
9. Dynamic fracture mechanics and rate effects
    9.1. LEFM solution fields
        Freund; Anderson A4.1
    9.2. Dynamics of moving crack tip, process zone size, crack speed
        Freund; Anderson 4.1.2.2-4.1.2.3
    9.3. Crack path instabilities
    9.4. Rate effects, viscoelastic and viscoplastic
        Anderson 4.3; Kanniwen 2.5, 2.7
    9.5. Creep
        Kanniwen 7
10. Statistical fracture
    10.1. Flaws
        Lawn 9 Introduction, 9.1 microcontacts, 9.2 dislocation pile up, 9.3 Chemical, thermal, and radiation source
    10.2. Weakest link, Weibull distribution
        Anderson **A5.1**; Lawn 10.1.1

10.3. Probabilistic fracture analysis
Anderson A5.2, Lawn 10.2

11. Experimental fracture
    11.1. SIF (K)
    Zender 5.5.1-5.5.3
    11.2. Fracture toughness
    Zender 6
    11.3. J
    Anderson 3.2.5

12. Material specific fracture analysis
    12.1. Metals
    Anderson 7
    12.2. Ceramics
    Anderson 6.2, 8.3 (experimental); Lawn 7.6, 9.4
    12.3. Polymers
    Anderson 6.1; 8.1 (experimental)