FALL 2025
CEE 575–AE 521 Fracture and Fatigue

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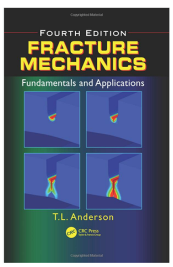
Class times: Monday and Wednesday, 2:00pm-3:20pm in 2310 Newmark

Office hours: Tuesday, 4:00-5:30pm online via Zoom

Textbook: There is no required textbook. The recommended textbook is "Fracture Mechanics: Fundamentals and Applications" by T. L. Anderson, 4th edition, CRC Press.



Copies of the slides presented during the lectures can be found on the course Canvas web site (https:// https://canvas.illinois.edu/courses/61174). You are encouraged to download and/or print them prior to the lectures. The slides contain primarily the theoretical part of the course. Many of the illustrative examples will be solved in class on the board.

Prerequisites: TAM 451 or CEE 471 or TAM 551 (or equivalent). A knowledge of 3D linear elasticity is required, preferably with use of indicial notation and tensor analysis. Helpful, though not required: Some knowledge of plasticity is helpful. We will also deal briefly with complex number calculus so having taken a course on the subject is advantageous. Finally, knowledge of wave propagation in solid media is helpful in the section on Dynamic Fracture Mechanics. A small overview of each of these three subjects (complex calculus, plasticity, wave propagation) will be given at the appropriate sections in the course.

Homework, exam, and final project: A series of homework problems will be handed out approximately every second week. You are expected to do the homework and submit it online through Canvas in in a timely fashion. You may work in groups toward the solution of the homework exercises, but each student must hand in their own homework that they themselves have put together on their own (i.e., you cannot copy someone else's homework!). An in-class exam will be held sometime between the midpoint and end of the semester. There will also be a project which will consist of a fracture-related paper review and report assignment. More details on the final project will be provided in class a few weeks into the semester. There is no final exam.

Grading:

Homework	30%
"Midterm" Exam:	50%
Final Project (paper review):	20%

COURSE OUTLINE

0. Introduction – Historical Perspectives of Fracture

1. Linear Elastic Fracture Mechanics (LEFM)

1.1. Review of elasticity theory and complex calculus

1.2. Stress-based approach to fracture problem

1.2.1. Stress concentration and stress singularity
1.2.2. Near-tip asymptotic *K*-fields and Stress Intensity Factor (SIF)
1.2.3. Computation of stress intensity factors)
- Analytical methods
- Experimental methods
- Numerical aspects

1.3. Energy-based approach to fracture problem

1.3.1. Griffith's energy balance
1.3.2. Energy release rate, G
1.3.3. Conservation integral, J
1.3.4. Relation to SIF

1.4. Crack growth and stability

- Applied load
- Applied displacement

1.5. Mixed-Mode fracture

1.5.1. Maximum hoop stress
1.5.2. Minimum strain energy density
1.5.3. Maximum energy release rate

1.6. Cohesive failure

2. Linear Elastic Interfacial Fracture Mechanics (LEIFM)

2.1. Dundurs' parameters

2.2. LEIFM

- Asymptotic formulation
- Complex SIF
- Pathologies: Oscillatory index, Small scale contact

2.3. CSIF measurement and 3D effects

2.4. Interfacial crack growth

- Phase angle
- Crack kinking

3. Elasto-Plastic, or non-linear, Fracture Mechanics (EPFM)

3.1. Fundamentals of plasticity theory

3.2. Estimation of plastic zone

3.2.1. Small-Scale Yielding (SSY) and Irwin approach
3.2.2. Shape of plastic zone
3.2.3. 3D effects

3.3. HRR field

3.3.1. Mode I
3.3.2. J-Q theory
3.3.4. Mixed mode

3.4. Experimental determination of J

3.5. Elastic-plastic crack growth

4. Material Aspects of Fracture

4.1. Metals

4.2. Polymers

4.3. Ceramics

4.4. Toughening

5. Fatigue Failure

5.1. Introduction

5.2. Physical aspects of fatigue

5.2.1. Crack nucleation
5.2.2. Stages of fatigue crack growth

5.3. Fracture Mechanics approach

5.3.1. Design
5.3.2. Paris "Law"

5.4. Crack closure

- Effective SIF
- Near fields vs. far field

5.5. Overload effects

6. Dynamic Fracture Mechanics

6.1. Introduction: Review of elastodynamics

6.2. Stationary cracks

- Dynamic loading
- Initiation criterion
- Loading rate effects

6.3. Growing cracks–Mode I

- Asymptotic fields
- Crack tip equation of motion
- Limiting speed
- Transient effects
- Crack arrest

6.4. Thermoplasticity