MECH 5328-001: Fracture Mechanics

Class Reference Number: 28971


Required Software: PTC MathCAD and Excel

References:

1. R. J. Sanford, Principles of Fracture Mechanics, Prentice Hall

Class/Lab Meeting: Hybrid MW 1:30pm-2:50pm

Class Room: Physical Science Building 314
or
Microsoft Teams

Instructor: Dr. Calvin M. Stewart, Ph.D.
Associate Professor, Department of Mechanical Engineering
Office: Engineering A117
Email: cmstewart@utep.edu
Phone: 915-747-6179
Office Hours: MW 3:00pm-4:00pm, or by appointment

Course Objectives

A review of classical and modern methods of fracture mechanics and the physical process therein. Primary emphasis relates to metallic, polymeric, and ceramic materials. Students will be challenged to develop both analytical and practical skills fracture mechanics.

Goals
1. Review and extend the basics of design against fracture;
2. Learn the microstructural aspects that lead to fracture;
3. Apply advanced mathematical theories to characterize and predict fracture;

Topics Covered

Grades

Your final grade for this course will be based on the following activities

<table>
<thead>
<tr>
<th>Assignments</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>Homework</td>
<td>75%</td>
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<tr>
<td>Project(s)</td>
<td>25%</td>
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<tr>
<td>Total</td>
<td>100%</td>
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Grade Scale

<table>
<thead>
<tr>
<th>Percentage</th>
<th>Grade</th>
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<tbody>
<tr>
<td>100-90%</td>
<td>A</td>
</tr>
<tr>
<td>89-80%</td>
<td>B</td>
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<tr>
<td>79-70%</td>
<td>C</td>
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<tr>
<td>69-60%</td>
<td>D</td>
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<tr>
<td>&lt;60%</td>
<td>F</td>
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The instructor reserves the right to revise this grading plan.

Online Course

Fracture mechanics is a hybrid course. Students will learn by reading the book, attending in-person or live-streamed lectures, and completing assignments for each topic in the course. The week can be divided as follows

Weekly Schedule

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tbody>
<tr>
<td>Lecture</td>
<td>Reading</td>
<td>Lecture</td>
<td>Reading</td>
<td>Assignments/Projects</td>
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<tr>
<td>Office Hours</td>
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<td>Office Hours</td>
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The lectures and reading for each week are listed in the course schedule.

Assignments are listed at the end of the lecture notes.

Lectures

Lectures are hybrid to be held in-class and live-streamed on Microsoft Teams. Students are encouraged to attend the lectures in-person or virtually during the assigned course time. The lectures will be recorded and can be viewed later.

MW from 1:30pm to 2:50pm

Microsoft Teams

Office Hours

Office hours are held in-person at Engineering A117 or on Microsoft Teams. If you cannot attend office
hours, make an appointment by email for an alternative meeting time. Use the same link to join the meeting room.

MW from 3:00pm to 4:009m
Microsoft Teams

Course Content

The syllabus, schedule, lecture videos and notes, and other materials will be posted to Microsoft Teams.

Cheating

All-scholastic activities must be completed individually (unless noted in writing). Students are expected to be above reproach in all-scholastic activities. Students who engage in scholastic dishonesty are subject to disciplinary penalties, including the possibility of failure in the course and dismissal from the university. Scholastic dishonesty includes but is not limited to cheating, plagiarism, collusion, the submission for credit of any work or materials that are attributable in whole or in part to another person, taking an examination for another person, any act designed to give unfair advantage to a student, or the attempt to commit such acts (Regents= Rules and Regulations, Part One, Chapter VI, Section 3, Subsection 3.2, Subdivision 3.22). Scholastic dishonesty harms the individual, all students, and the integrity of the university; policies on scholastic dishonesty will be strictly enforced. If there is evidence that you have cheated, the evidence will be submitted to the Office of Student Conduct and Conflict Resolution with the recommendation of Expulsion from the University.

COVID-19 PRECAUTIONS

Please stay home if you have been diagnosed with COVID-19 or are experiencing COVID-19 symptoms. If you are feeling unwell, please let me know as soon as possible, so that we can work on appropriate accommodations. If you have tested positive for COVID-19, you are encouraged to report your results to covidaction@utep.edu, so that the Dean of Students Office can provide you with support and help with communication with your professors. The Student Health Center is equipped to provide COVID 19 testing.

The Center for Disease Control and Prevention recommends that people in areas of substantial or high COVID-19 transmission wear face masks when indoors in groups of people. The best way that Miners can take care of Miners is to get the vaccine. If you still need the vaccine, it is widely available in the El Paso area, and will be available at no charge on campus during the first week of classes. For more information about the current rates, testing, and vaccinations, please visit epstrong.org

Attendance

If a student misses ANY assignment due to university related duty, serious illness, or family emergency a makeup assignment may be arranged. Written proof must be provided along with contact information for verification. The instructor MUST be notified of an absence PRIOR to the absence.
Disability and Accommodations
If you have a disability and need classroom accommodations, please contact The Center for Accommodations and Support Services (CASS) at 747-5148, or by email to cass@utep.edu, or visit their office located in UTEP Union East, Room 106. For additional information, please visit the CASS website at www.sa.utep.edu/cass.

Course Schedule and Assigned Reading

1. **Introduction to Fracture** (Anderson Chp 1, Janssen Chp 1, Sanford Chp 1)
   a. Failure of Structures
   b. Definition
   c. Significance
   e. Materials
   f. Methods

2. **Historical Prospective** (Anderson Chp 1, Janssen Chp 1, Sanford Chp 1)

3. **Solid Mechanics** (Anderson A2, Janssen Chp 2, Sanford Chp 2)
   a. Interatomic View of Fracture (Anderson p 31-33)
   b. Linear Elasticity, (Janssen p25-30, Anderson A2)
      i. Equilibrium of Stress
      ii. Compatibility Equation of Strain
   c. Airy Stress Functions (Janssen p25-30, Anderson A2)
   d. Stress Concentration Factors (Anderson p33-36) – extract from SM II Intro
      i. Circular hole (Sanford Chp 2, tablet notes)
      ii. Elliptical hole (Sanford Chp 2, tablet notes)
   e. Limitations of SCF approach and the need for LEFM

4. **Linear Elastic Fracture Mechanics** (Anderson Chp 2, Janssen Chp 2, Sanford Chp 3)
   a. Crack Tip Singularity (Sanford p51-52, Anderson 2.6 p 44)
   b. Williams Solution: Sharp Crack, Complex Functions, Westergaard Stress Function,
      Westergaard Example: Central Crack Problem (Sanford p51-116, Janssen p 30-37)
   c. Stress Intensity Factors (Janssen p41-59, Anderson p51-67)

5. **Linear Elastic Fracture Mechanics II** (Anderson Chp 2, Janssen Chp 2, Sanford Chp 3)
   a. Stress Intensity Factors (Janssen p41-59, Anderson p51-67)
   b. Definitions
   c. Fracture Modes
   d. K Expression for Common Geometry
   e. Determination of SIF

6. **Fracture Toughness and Problem Solving** (Fatemi Chp 6, Suresh Chp 9-10, Banna Chp 3, Schijve Chp 8, Fracture Mechanics Lecture Notes)
a. Crack Tip Plasticity
b. Influence of Fracture Behavior (Anderson p82-84)
c. Influence of Fracture Toughness (Sanford p221-230, Anderson 84-91)
d. Fracture Testing
e. Properties
f. Problem Solving

7. Energy Methods (Anderson Chp 2, Janssen, Chp 4, Sanford Chp 7)
a. Definitions
b. Griffith Energy Balance (Sanford p237-240)
c. Relationship between G and K (Sanford p240-243, Janssen90-93)
d. Compliance (Sanford p243-248, janssen p.93-95)
e. Resistance $R$ Curve (Sanford p230-233, Janssen p96-105)

8. LEFM Testing (Anderson Chp 7-8, Janssen, Chp 5, Sanford Chp 8)
a. Plane Strain Fracture Toughness (Janssen p107-114, p251-265)
   i. Test Standards
   ii. Test Procedure
b. Plane Stress Fracture Toughness (Janssen p115-120)
c. $K$-$R$ Curve Testing (Janssen p120-129)
d. Measuring Crack Length

a. Introduction
b. The $J$ integral concept and examples (anderson p 122-129, Sanford p338-343, Janssen p 135-149)
   i. Concept
   ii. Examples
   iii. $J$ as a path-independent line Integral
   iv. $J$ as a Stress Intensity Parameter
c. Crack Opening Displacement (Anderson p.138-142, Janssen p.149-154)
d. Time-Dependent Fracture Mechanics (TDFM) -> C*, C(t) integral

10. Fracture Microstructural & Mechanisms (Hertzberg, Anderson Chp 5-6, Janssen, Chp 12-13, Sanford Chp 11)
a. Introduction
b. Material Properties
c. Mechanisms in Metallic Materials
   i. Ductile Transgranular Fracture by Microvoid Coalescence
   ii. Brittle Transgranular Fracture (Cleavage)
   iii. Transgranular Fracture by Fatigue
   iv. Intergranular Fracture (with/without microvoid coalescence)
Books