MCEN 5228-025
Special Topic: Fracture Mechanics
Fall 2022

Lectures: Tuesdays and Thursdays 3:30-4:45pm DUAN G2B21

Instructor: Dr. Rong Long
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Office hours: 1:30-2:30pm on Tuesdays & Thursdays in ECME 273 or by appointment
Zoom link for office hours: https://cuboulder.zoom.us/j/92571946758

Course Description:
This course will introduce fundamental concepts, analytical approaches, and experimental methods to characterize the fracture of solid materials. Topics to be discussed include: linear elastic analysis of 2D cracks, energy flows and criteria for elastic fracture, experimental methods for elastic fracture, application of fracture mechanics in adhesion, introduction to elastic plastic fracture, and nonlinear fracture mechanics of soft materials.

Textbook: A.T. Zehnder, *Fracture Mechanics*, Springer, 2012 (electronic version available through CU library).
Suggested reference (*optional*): T.L. Anderson, *Fracture Mechanics: Fundamentals and Applications*, third edition, CRC Press, 2005.
Lecture notes and assignments will be distributed online through Canvas.

Grading:
The final grade will be evaluated based on three components: homework assignments (30%), in-class quizzes (35%), and a final take-home exam (35%).

- *Assignments* (30%): There will be 7 bi-weekly assignments throughout the semester. Each assignment will consist of 2~3 questions. Assignments must be turned in *Canvas* before the due time specified in each assignment set. No late assignment will be accepted. The percentage grades of the best 6 out of 7 assignments will be used for evaluating the final grade. The tentative due dates of the assignments are: 9/15, 9/29, 10/13, 10/27, 11/10, 12/1, 12/8.
- *In-class quizzes* (35%): The purpose of the in-class quizzes is to get feedback as we progress through the course. The quizzes will only include conceptual questions that do not require substantial calculation and analysis. There will be 5 quizzes and the tentative dates are: 9/22, 10/6, 10/20, 11/3, 11/17.
- *Final exam* (35%): There will be a final take-home exam at the end of the semester. The exam will be distributed on December 8 (last day of classes). You will have 1 week to complete the exam. Completed exams will be submitted in *Canvas*.
- *Make-up policy for quizzes*: If you miss any of the quizzes for a valid excuse, the weight of the missing quiz will be transferred to other quizzes. The maximum number of missing quizzes that can be transferred is 2. Acceptable excuses are serious medical conditions and urgent family matters. No make-up quizzes will be provided.

Online resources: Lecture notes, assignments, and solutions to assignments and quizzes will be posted on Canvas.

Course Outline

1: Introduction and preliminaries

- Basic fracture mechanics concepts
- Introduction to linear elasticity
- Anti-plane shear, plane stress and plane strain problems

2: Linear elastic analysis of 2D cracks

- Asymptotic solution of crack tip stress/strain fields (Mode I, II, and III)
- Stress intensity factors
- Examples of full-field solution for 2D cracks

3: Energy flows in elastic fracture

- Energy release rate.
- J-integral: a contour integral for the energy release rate.

4: Criteria for elastic fracture

- Initiation of crack under Mode-I loading
- Crack growth resistance curve
- Initiation and growth of crack under mix-mode loading
- Fatigue crack growth

5: Methods to determine energy release rate and toughness

- Analytic methods
- Computational methods
- Experimental methods

6: Interface fracture and adhesion

- Contact mechanics of spherical indenters
- John-Kendall-Roberts theory
- Cohesive zone model
- Experimental methods to test adhesion

7: *Elastic plastic fracture (if time allows)*

- Yielding at crack tip
- Energy flow and fracture criteria.

8: Fracture of soft materials (if time allows)

- Large deformation and crack blunting
- Viscoelastic dissipation and toughening.

Note: this outline is tentative and is subjected to change during the semester.

University Policies:

Classroom Behavior: Both students and faculty are responsible for maintaining an appropriate learning environment in all instructional settings, whether in person, remote or online. Those who fail to adhere to such behavioral standards may be subject to discipline. Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with race, color, national origin, sex, pregnancy, age, disability, creed, religion, sexual orientation, gender identity, gender expression, veteran status, political affiliation or political philosophy. For more information, see the classroom behavior policy, the Student Code of Conduct, and the Office of Institutional Equity and Compliance.

Requirements for COVID-19: As a matter of public health and safety, all members of the CU Boulder community and all visitors to campus must follow university, department and building requirements and all public health orders in place to reduce the risk of spreading infectious disease. CU Boulder currently requires COVID-19 vaccination and boosters for all faculty, staff and students. Students, faculty and staff must upload proof of vaccination and boosters or file for an exemption based on medical, ethical or moral grounds through the MyCUHealth portal.

The CU Boulder campus is currently mask-optional. However, if public health conditions change and masks are again required in classrooms, students who fail to adhere to masking requirements will be asked to leave class, and students who do not leave class when asked or who refuse to comply with these requirements will be referred to Student Conduct and Conflict Resolution. For more information, see the policy on classroom behavior and the Student Code of Conduct. If you require accommodation because a disability prevents you from fulfilling these safety measures, please follow the steps in the "Accommodation for Disabilities" statement on this syllabus.

If you feel ill and think you might have COVID-19, if you have tested positive for COVID-19, or if you are unvaccinated or partially vaccinated and have been in close contact with someone who has COVID-19, you should stay home and follow the further guidance of the Public Health Office (contacttracing@colorado.edu). If you are fully vaccinated and have been in close contact with someone who has COVID-19, you do not need to stay home; rather, you should self-monitor for symptoms and follow the further guidance of the Public Health Office (contacttracing@colorado.edu).

Accommodation for Disabilities: If you qualify for accommodations because of a disability, please submit your accommodation letter from Disability Services to your faculty member in a timely manner so that your needs can be addressed. Disability Services determines accommodations based on documented disabilities in the academic environment. Information on requesting accommodations is located on the Disability Services website. Contact Disability Services at 303-492-8671 or dsinfo@colorado.edu for further assistance. If you have a temporary medical condition, see Temporary Medical Conditions on the Disability Services website.

Preferred Student Names and Pronouns: CU Boulder recognizes that students' legal information doesn't always align with how they identify. Students may update their preferred names and pronouns via the student portal; those preferred names and pronouns are listed on instructors' class rosters. In the absence of such updates, the name that appears on the class roster is the student's legal name.

Honor Code: All students enrolled in a University of Colorado Boulder course are responsible for knowing and adhering to the Honor Code. Violations of the Honor Code may include, but are not limited to: plagiarism, cheating, fabrication, lying, bribery, threat, unauthorized access to academic materials, clicker fraud, submitting the same or similar work in more than one course without permission from all course instructors involved, and aiding academic dishonesty. All incidents of academic misconduct will be reported to Student Conduct & Conflict Resolution (honor@colorado.edu); 303-492-5550). Students found responsible for violating the Honor Code will be assigned resolution outcomes from the Student Conduct & Conflict Resolution as well as be subject to academic sanctions from the faculty member. Additional information regarding the Honor Code academic integrity policy can be found on the Honor Code website.

Sexual Misconduct, Discrimination, Harassment and/or Related Retaliation: CU Boulder is committed to fostering an inclusive and welcoming learning, working, and living environment. University policy prohibits sexual misconduct (harassment, exploitation, and assault), intimate partner violence (dating or domestic violence), stalking, protected-class discrimination and harassment, and related retaliation by or against members of our community on- and off-campus. These behaviors harm individuals and our community. The Office of Institutional Equity and Compliance (OIEC) addresses these policies, and individuals who believe they have been subjected to misconduct can contact OIEC at 303-492-2127 or email cureport@colorado.edu. Information about university policies, reporting options, and support resources can be found on the OIEC website.

Please know that faculty and graduate instructors have a responsibility to inform OIEC when they are made aware of any issues related to these policies regardless of when or where they occurred to ensure that individuals impacted receive information about their rights, support resources, and resolution options. To learn more about reporting and support options for a variety of concerns, visit Don't Ignore It.

Religious Holidays: Campus policy regarding religious observances requires that faculty make every effort to deal reasonably and fairly with all students who, because of religious obligations, have conflicts with scheduled exams, assignments or required attendance.

See the campus policy regarding religious observances for full details.

Mechanical Engineering Department Policies:
Racist Language, Behavior, and Discrimination:
The ME department holds students, faculty, and staff accountable for racist comments and behavior, whether intentional or unintentional. We expect members of our community to take responsibility for understanding why some comments and actions may be racist and actively eliminating language and behaviors that perpetuate racial inequities. More information is available at An Antiracist CU.

Discrimination and Harassment:
Discriminatory and harassing behavior will not be tolerated in the Department of Mechanical Engineering. A safe and inclusive environment will be created and maintained by the students and instructing faculty member. Students with concerns about discrimination or harassment actions should immediately contact the instructor, the Department Chair or their academic advisor, or the Office of Institutional Equity and Compliance.