CEE 770: Engineering Fracture Mechanics
Fall, 2002

COURSE SYLLABUS

Overall Course Objectives

Prerequisite to this course are T&AM 753 (or equivalent), a first course in fracture mechanics theory, and CEE 772 (or equivalent), a first course in the finite element method for analysis of continua. The objectives for CEE 770 are, therefore, to:

- *Review* LEFM and non-LEFM concepts previously learned, and *show how to compute or measure parameters required by these concepts.*

- *Show how the concepts can be integrated and applied to practical engineering and current research problems using modern computational mechanics techniques.*

Specific Learning Objectives

In this course you will learn how to use modern numerical methods:

- To compute stress intensity factors and energy release rates and their derivatives in 2D and 3D.

- To simulate crack propagation under LEFM conditions in 2D and 3D. This means using crack front field information to determine local stability and evolving crack trajectory/shape.

- To predict fracture instability and fatigue life of structural components under LEFM conditions.

- To predict crack front growth and instability under elasto-plastic conditions using the J-integral, CTOD, and cohesive crack criteria.

You will also learn:

- About current standards and databases for measuring and obtaining, respectively, material fracture and crack growth parameters.

- How to perform physical measurement of fracture toughness and fatigue crack growth parameters on a variety of materials.

Finally, you will discover the boundaries of current knowledge about the physics and mechanics of cracking, including techniques for physical measurement and observation of such processes and cutting-edge models for nano- and meso-scale modeling of them.

Requirements

The following are required for successful completion of this course:

- Attendance at and participation in all class meetings (25 % of final grade)
- Completion of all professional assignments (25 % of final grade)
- Presentation of written and oral segments of a substantive semester project (50% of final grade)

Textbook, Notes, Readings, and Software

The required textbook for the course, available in the Campus Store, is:

Anderson, T.L., Fracture Mechanics, 2nd Edition, CRC Press, 1995.

Please note that, in my opinion, an excellent textbook for a course such as CEE 770 does not exist. I will use Anderson only as suggested additional reading to supplement extensive course notes (in Powerpoint format) and readings. I have prepared these specific readings for this course:

Ingraffea, A. and Wawrzynek, P., “Crack Propagation” in the ENCYCLOPEDIA OF MATERIALS: SCIENCE AND TECHNOLOGY, 2001 Edition, Elsevier Press.

Ingraffea, A. and Wawrzynek, P., “Finite Element Methods for Linear Elastic Fracture Mechanics”, to appear in COMPREHENSIVE STRUCTURAL INTEGRITY, Vol. 3, R. de Borst and H. Mang, editors, Elsevier Press 2002.

The notes and readings and additional announcements, photos, etc. are available through COURSEINFO. I will also distribute copies of classical and overview papers that are necessary reading for this course.

See the additional handout entitled “Course Hardware and Software” for additional necessary information.

COURSE OUTLINE

A. Motivation and LEFM Review (8/29, 9/3, 9/5, 9/12):

1. Applications of Fracture Mechanics in Various Disciplines and Industrial Settings: Key Issues in Structural Life and Strength Assessment. A taxonomy of approaches to simulation of crack propagation.
2. Classical and Overview Papers in Fracture Mechanics: History of Development of Key Concepts
3. Review of LEFM crack front fields and parameters

Professional Assignments: 1, 2, 3

(There will be at least 3 software training sessions in the ACCEL Facility. Current dates are 9/10, 9/17, and 9/19)

B. Computing LEFM Parameters (9/24, 9/26, 10/1, 10/3, 10/8, 10/10, 10/17):

1. Stress Approach to crack driving and resisting forces: the Stress Intensity Factor (K) Concept

1a. Computing stress intensity factors with the finite element method

2. Energy Approach to crack driving and resisting forces: the Energy Release Rate (G, J) Concept

2a. Computing energy release rate and rates of energy release rate with the finite element method

Professional Assignment: 4

3. Applications of LEFM to fatigue crack growth

3a. Computing crack trajectory/shape and growth rate with the finite element method

Professional Assignment: 5

4. Limitations of LEFM

C. Non-LEFM Concepts (10/22, 10/24, 10/29, 10/31, 11/5, 11/7, 11/12, 11/14):

1. The Elasto-Plastic J-Integral for Initiation of Ductile Crack Growth

1a. Computing the Elasto-Plastic J-Integral

2. The $CTOA_c$ Criterion for Initiation and Propagation of Ductile Crack Growth

2a. Computing the CTOA

Professional Assignment: 6

3. Cohesive Models for Initiation and Propagation of Cracks

3a. Using Cohesive Zone Models within the finite element method

4. Applications on non-LEFM concepts to crack growth problems

Professional Assignment: 7

D. Experimental Fracture Mechanics (11/19, 11/21, 11/26, 12/3, 12/5):

1. ASTM Standards for Measurement of Fatigue and Fracture Parameters

1a. Measuring the fracture toughness of two metallic alloys and a polymer

1b. Measuring fatigue crack growth in a metallic alloy.

Professional Assignment: 8

E. Semester Project Written and Oral Reports, 12/20