AE 560
Fracture Mechanics Laboratory
Spring 2012

Instructor: Prof. John Lambros
310 Talbot Lab
Ph: 333-2242
Fx: 244-0720
lambros@illinois.edu

Course Website: https://netfiles.uiuc.edu/lambros/www/ae560/

Here I will post files that contain copies of the notes to be presented during the lectures as well as instructions for each lab. On occasion I will also post data files that are to be shared among the lab groups.

Class Hours: Tuesday and Thursday 2:00 pm – 3:20 pm, 225A Talbot Lab

Office Hours: None

Required Textbook: None

Course Notes: Notes for the various topics to be discussed in class will be posted on the course website as the semester progresses.

Topics covered include: Various topics will be discussed in depth during the semester. These will concentrate on the experimental and physical aspects of fracture mechanics, and will be on topics that best fit my own areas of expertise. In that sense the course will not be exhaustive in the material covered. Topics to be discussed include Elastic crack tip stress field, Thermoelasticity, Thermoplasticity, Optical Techniques, J-Integral, Toughening Mechanisms, Dynamic Fracture, and Fatigue. Many, but not all, of the topics will have a laboratory, or laboratories, associated with them. Although no exams or homeworks will be associated with the lectures, the lectures will provide both the general background and the specific information needed to conduct the experiments. **Therefore you are expected to attend all lectures.**

Lab Reports: There will be a total of 4 experiments during the semester on a variety of the topics covered in the lectures. A lab report will be required for each of these labs. In each case, your group will have 3 weeks to research the lab topic, carry out the lab, prepare and submit the lab report. You are expected to get references from the library and to learn what needs to be

learned to carry out the experiments. I will teach the essentials in each case, and will be available to guide you, but you must show the initiative that is the hallmark of graduate study. Lab reports are designed to prepare you for publishing in this venue, and are to be prepared in manuscript form, following guidelines typical of technical journals. The basic philosophy of this approach is that you learn by doing, rather than watching. I will be available to help you conduct experiments, interpret results, and assimilate those results into a suitable format for presentation in the lab report, but there will be no specific office hours.

The format to be used for the reports is as if you are preparing a manuscript for submission to one of following journals, as listed per experiment number:

1. International Journal of Fracture
2. Journal of the Mechanics and Physics of Solids
3. Engineering Fracture Mechanics
4. Experimental Mechanics

Grading: Lab Attendance and Reports: 100% (25% each).

NOTE: Lab attendance is mandatory. **No make-up labs are available.**

Course outline

Week	Day	Topic	Reading Assignment
1	**1/17**	Introduction and organization	
	1/19	Technical writing	
2	**1/24**	Elastic crack tip stress fields	(1)
	1/26	Thermo-elastic temperature changes and method for measuring stresses	(2)
3	**1/31**	Experiment # 1: TSA Experiment – 11C Talbot Lab (TLB)	
	2/2	Experiment # 1: TSA Experiment – 11C Talbot Lab (TLB)	
4	**2/7**	Optical Techniques (photoelasticity/moiré)	(3)
	2/9	No class – out of town	
5	**2/14**	Optical Techniques (caustics, CGS, TG, DIC)	(3), (7)
	2/16	CGS Experiment	(3), (10)
6	**2/21**	Experiment # 2: Optical measurement of SIF – 206J TLB	1st Report Due
	2/23	Experiment # 2: Optical measurement of SIF – 206J TLB	
7	**2/28**	Elastic-plastic fracture	(4)
	3/1	Elastic-plastic fracture	
8	**3/6**	Elastic-plastic fracture	(5)
	3/8	J – Testing	ASTM Test Procedure
9	**3/13**	Experiment # 3: Ductile tearing of a polymer – 206J TLB	2nd Report Due
	3/15	Experiment # 3: Ductile tearing of a polymer – 206J TLB	
10	**3/20**	**SPRING BREAK**	
	3/22	**SPRING BREAK**	
11	**3/27**	Dynamic Fracture	(7), (8), (9)
	3/29	Dynamic Fracture	
12	**4/3**	Dynamic Fracture	
	4/5	Dynamic Fracture	
13	**4/10**	Thermoplasticity	
	4/12	Experimental techniques	
14	**4/17**	Experiment # 4: Dynamic Fracture – 9A TLB	3rd Report Due
	4/19	Experiment # 4: Dynamic Fracture – 9A TLB	
15	**4/24**		
	4/26		
16	**5/1**		
	5/3	Reading Day	
17	**5/8**	Exam Week	4th Report Due
	5/10	Exam Week	

References for the course:

(1) *Crack Tip stress Fields:*

Any textbook on Fracture. A good overview text is: Ewalds and Wanhill, Fracture Mechanics, Edward Arnold, 1993.

(2) *Thermoelastic Stress Analysis:*

Harwood and Cummings, Thermoelastic Stress Analysis, Adam Hilger, 1991.

J. M. Dulieu-Barton, Introduction to thermoelastic stress analysis, Strain, Volume 35 Issue 2, Pages 35 – 39, 2008

T.J. Mackin, T.E. Purcell, M.Y. He and A.G. Evans, "Notch sensitivity and stress redistribution in three ceramic-matrix composites", Journal of the American Ceramic Society, Vol. 78, No. 7, pp. 1719-1728, 1995.

Mackin, T. J. and Roberts, M. C., Evaluation of damage evolution in ceramicmatrix composites using thermoelastic stress analysis. Journal of American Ceramic Society, 2000, 83 (2), 337-343

Tomlinson, R. A., Nurse, A. D., Patterson, E. A., 'On determining stress intensity factors for mixed mode cracks from thermoelastic data', Fatigue Fract. Engng. Struct. & Mater., 20(2): 217-226.

Diaz, F.A., Patterson, E.A., Tomlinson, R.A., Yates, J.R., , 'Measuring stress intensity factors during fatigue crack growth using thermoelasticity', Fat & Fract. Engng. Mater. & Structures 27(7):571-584.

(3) *Optical Methods:*

Handbook on Experimental Mechanics, SEM, Edited by A. Kobayashi, Prentice-Hall, Inc., 1987, Chapters 5,6,7, 8, 9, and 10

Experimental Techniques in Fracture, SEM, Edited by J. S. Epstein, VCH, 1993, Chapters 3, 4, 9, 10, 11

(4) *J-integral:*

J. R. Rice, "A Path Independent Integral and The Approximate Analysis of Strain Concentration by Notches and Cracks," *J. Applied Mechanics*, June 1968.

(5) *Toughening mechanisms:*

Fracture in Ceramic Materials, Edited by A. G. Evans, Noyes, 1984.

(6) *Fatigue:*

Fatigue and Fracture, ASM Handbook Number 19.

(7) *General experiments in fracture:*

Experimental Techniques in Fracture, SEM, Edited by J. S. Epstein, VCH, 1993

(8) *Dynamic fracture mechanics:*

General:

L.B. Freund, Dynamic Fracture Mechanics, Cambridge University Press, Cambridge, MA, 1990.

Experimental Techniques in Fracture, SEM, Edited by J. S. Epstein, VCH, 1993

J.W. Dally, "Dynamic photoelastic studies of fracture", *Exp. Mech.*, Vol 19, 1979.

Strain gauges:

S.K. Khanna and A. Shukla, "On the use of strain gauges in dynamic fracture mechanics", *Engineering Fracture Mechanics*, Vol. 51, 1995.

Brazil disk:

Awaji H. and Sato S. (1978), Combined mode fracture toughness measurement by the disk test, Journal of Engineering Materials and Technology, Vol. 100, pp. 175-182.

Jia Z., Castro-Montero A. and Shah S.P. (1996), Observation of mixed mode fracture with center notched disk specimens, Cement and Concrete Research, Vol. 26, No. 1, pp. 125-137.

Johnstone C. and Ruiz C. (1995), Dynamic testing of ceramics under tensile stress, International Journal of Solids and Structures, Vol. 32, No. 17/18, pp. 2647-2656.

Nakano M., Kishida K., Yamauchi Y. and Sogabe Y. (1994), Dynamic fracture initiation in brittle materials under combined mode I/II loading, Journal de Physique III, Vol. 4, pp. C8-695-700.

(9) *Interfacial fracture mechanics:*

J.R. Rice, "Elastic Fracture Mechanics Concepts for Interfacial Cracks", *J. Applied Mechanics*, Vol. 55, March 1988

C.F. Shih, “Cracks on bimaterial interfaces: elasticity and plasticity aspects”, *Materials Science and Engineering*, 1991.

(10) *CGS:*

Tippur, H. V., Krishnaswamy, S. and Rosakis, A. J., A coherent gradient sensor for crack tip measurements : Analysis and experimental results, *International Journal of Fracture*, Vol. 48: pp. 193-204, 1991.

Tippur, H. K., Krishnaswamy, S. and Rosakis, A. J., “Optical mapping of crack tip deformations using the method of transmission and reflection Coherent Gradient Sensing: A study of crack tip K-Dominance”, *International Journal of Fracture*, Vol. 52: pp. 91-117, 1991.