

SE2129 Fracture Mechanics and Fatigue

9 credits, Spring of 2017

1. General information, intended learning outcomes & prerequisites

Fundamental concepts of fracture in linear and nonlinear materials are introduced with the overall aim that the student should obtain a thorough understanding on how cracks affect engineering structures and when an existing crack may start to grow. The student should acquire an operative knowledge on how to design against failure in brittle and ductile materials, and on how to make well informed decisions in situations when a crack is detected in a structure, whether action must be taken to repair the structure or if continued operation can be permitted.

Intended learning outcomes: After the course the student should be able to:

- Identify and list different failure mechanisms in materials and engineering structures.
- Explain how a crack affects an engineering structure and describe the state of stress and strain that may arise in the vicinity of a crack front in different materials.
- Apply different methods to calculate the crack driving force in linear and nonlinear materials and formulate appropriate fracture criteria for stationary and growing cracks in such materials.
- Evaluate fracture toughness data for stationary and growing cracks from linear and nonlinear fracture tests.
- Evaluate crack growth data for materials subjected to cyclic loading in a fatigue test.
- Examine whether a crack will grow in a stable or unstable manner.
- Describe and explain the theoretical background of linear and nonlinear fracture mechanics.
- Analyse well defined fracture mechanics problems for both linear and nonlinear materials subjected to both monotonic and cyclic loading.

Prerequisites: The student should have a good knowledge in strength of materials, mechanics and mathematics. The student should also be able to solve solid mechanics problems numerically by use of the finite element method (FEM).

2. Teachers and course home page

Lecturer and examiner: Jonas Faleskog (faleskog@kth.se; 08-7908977), Room 6458.

Tutorials: MohammadAli Asgharzadeh (asgmoh@kth.se), Room 6457.

Address: KTH Solid Mechanics, Teknikringen 8D, SE-10044 Stockholm.

Course home page (updated during the course): <https://www.kth.se/social/course/SE2129>

3. Literature

The literature is available at the student Office located at Teknikringen 8D, which is open Monday to Friday, 12⁰⁰ - 15⁰⁰.

- Fred Nilsson, “Fracture mechanics — from theory to applications”, KTH Hållfasthetslära (Solid Mechanics), ISBN 91-972860-3-6. 2001. Price: 265 SEK.
- Jonas Faleskog and Fred Nilsson, “Examples in fracture mechanics”, KTH Hållfasthetslära (Solid Mechanics), 2014. Price: 80 SEK.
- Chapters 23 to 25 in “Handbook of Solid Mechanics” (The Handbook is available in both a Swedish and an English version, respectively, 2010. Price: 265 SEK).

Reference literature of interest: T. Anderson, “Fracture mechanics—fundamentals and applications”, 3rd ed., CRC Press, 2005; S. Suresh:” Fatigue of Materials” 2nd edition, Cambridge University Press, 1998.

4. Course requirements, examination and grading

To pass the course, it is required to pass and be approved on the following three course modules: ÖVN (3 credits)—homework assignments (HW); LAB (1 credit)—laboratory work; TEN (5 credits)—written exam. The grade is based on the performance on the written examination (ECTS scale).

Homework assignments, ÖVN (3 credits): The homework assignments (HW) will require a rather large work input as they correspond to one third of the course. A total of five homework assignments must be handed in, and should be carried out by students in groups of two. The HW-solutions should be handed in to one of the teachers in the course, put in the black tin box outside the student office, or sent by E-mail to faleskog@kth.se. The deadlines for these are February 3 (HW1), February 13 (HW2), February 21 (HW3), March 3 (HW4) and March 10 (HW5). If a solution is found to be insufficient, the students will be asked to complement the solution. The assignments will be available on the on the course web site:

<https://www.kth.se/social/course/SE1025/>

Laboratory work, LAB (1 credits): Fracture mechanics testing will be conducted in small groups (less than 10 students) in the laboratory of Solid Mechanics, Teknikringen 8D. The students must sign up for one of the six available times in week 9. The list for signing up will be brought to the lectures. The laboratory work should be reported in written form (two persons per report). The completed report should be handed in to one of the teachers in the course, put in the black tin box outside the student office, or sent by E-mail to faleskog@kth.se. The lab-report should be handed in to one of the teachers no later than March 7, 2017.

Written examination, TEN (5 credits): A written 5-hours exam, covering the whole course material, will take place on Monday, March 13, at 8⁰⁰ to 13⁰⁰, in lecture halls L41, L42 and L43. A second 5-hours exam will take place on Friday, June 9, at 14⁰⁰ to 19⁰⁰ in in lecture halls Q22, Q26 and Q31. To participate, a student must register for the exam on “My pages” (“Mina sidor”). For the original exam registration is open between January 29 and February 26, and for the re-exam, registration is open between April 17 and May 15. The exam consists of six problems that will be given at the most 6 points each. The exam is graded as follows: 0-11 (F); 12-13 (FX); 14-17 (E); 18-21 (D); 22-24 (C); 25-28 (B); 29-36 (A). For those obtaining grade FX, a complimentary examination will be arranged in April, but only in order to reach grade E.

5. Detailed plan for lectures and tutorials

All lectures and tutorial sessions will be held in the Seminar room at the Department of Solid Mechanics, Teknikringen 8D, 2nd floor. Below, **B** refers to the text book by Nilsson and **E** refers to the compendium with examples by Faleskog & Nilsson.

In addition to the problems to be solved during the tutorial sessions, the following examples in “Examples in fracture mechanics” are recommended for own practice:

T2: 8-10, 13; **T3:** 1, 19, 20-22; **T4:** 28, 29, 35, 42-49; **T5:** 42, 44-51, 52-59;

T6-T7: 61-80, 81, 83-85; **T8:** 90, 92, 93, 96-97; **T9:** 98, 88, 89, 100-102, 105;

T10: 99, 116, 119-123, 129

Date	Time	Class, Topic	Literature/Ex.
Jan 17, Tue	13-15	L1: Failure mechanisms, Fracture modes	B :1-9, E :117,118
Jan 18, Wed	15-17	L2: Linear elastic crack tip fields in Mode I, II	B :11-18
Jan 19, Thu	13-15	L3: Mode III, Stress-intensity factors (SIF): K_I, K_{II}, K_{III} , Evaluation of SIF	B :18-23
Jan 23, Mon	10-12	T1: Crack-tip fields, SIF-calculations	E :2,5, 38,39
Jan 24, Tue	10-12	Computer workshop, group 1	
Jan 24, Tue	15-17	Computer workshop, group 2	
Jan 25, Wed	15-17	L4: Potential energy, Energy balance, Energy release rate G	B :25-27
Jan 26, Thu	13-15	L5: Relation $G - \{K_I, K_{II}, K_{III}\}$, SIF-calculations, The J -integral	B :26-34, 36-38
Jan 30, Mon	13-15	T2: Energy release rate calculations	E :6,7,11, 14,15,16
Jan 31, Tue	10-12	L6: Superposition, Weight function	B :34-36, 39-53
Feb 1, Wed	15-17	T3: SIF-calculations by compliance method	E :18,24,36,37,Xtra
Feb 2, Thu	13-15	L7: Linear elastic fracture mechanics (LEFM), LEFM-testing	B :55-62
Feb 6, Mon	10-12	T4: Superposition, weight functions	E :58,53,31,33
Feb 7, Tue	10-12	T5: LEFM	E :54,43,40,57
Feb 8, Wed	15-17	L8: Fatigue	B :87-103
Feb 9, Thu	13-15	L9: Fatigue crack growth	B :87-103
Feb 13, Mon	10-12	L10: Cont'd, Stress corrosion cracking (SCC)	B :105-113; E :61,69
Feb 14, Tue	10-12	T6: Fatigue, Fatigue crack growth	E :74, 77, + S-N-Ex
Feb 15, Wed	15-17	T7: Fatigue crack growth, SCC	E : 76,79,82, 84
Feb 16, Thu	13-15	L11: Crack-tip fields in nonlinear materials, J -integral, NLFM	B :63-67
Feb 20, Mon	10-12	L12: Limit load analysis, Approx. J -evaluation	B :67-72; E : 87
Feb 21, Tue	8-10	T8: J -calculations, Limit load analysis	E :91,95,94
Feb 22, Wed	15-17	L13: R6-method, NLFM-testing	B :72-78
Feb 23, Thu	13-15	L14: Cohesive zones, Stable/unstable crack growth, Constraint, Statistical effects	B :115-119, Handout
Feb 27, Mon	10-12	Laboratory work, Group 1	Handout
Feb 27, Mon	13-15	Laboratory work, Group 2	Handout
Feb 27, Mon	15-17	Laboratory work, Group 3	Handout
Feb 28, Tue	10-12	Laboratory work, Group 4	Handout
Feb 28, Tue	13-15	Laboratory work, Group 5	Handout
Feb 28, Tue	15-17	Laboratory work, Group 6	Handout
Mar 1, Wed	15-17	T9: R6-method	E :103,104,106,116
Mar 2, Thu	13-15	T10: Cohesive zones , Stability	E :108,114,124,121
Mar 6, Mon	10-12	T11: Repetition	Old exam
Mar 13, Mon	8-13	Written Exam in rooms: L41, L42, L43	
June 9, Fri	14-19	Written Re-Exam in rooms: Q22,Q26, Q31	