AE 737: Mechanics of Damage Tolerance

Lecture 12 - Exam 1 Review

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schedule

- 27 Feb - Exam Review, Homework 5 Due
- 3 Mar - Exam 1
- 5 Mar - Stress-based Fatigue
- 10 Mar - Stress-based fatigue

outline

- exam
- stress intensity
- plastic zone
- fracture toughness
- residual strength
- stiffeners
- multiple site damage
- mixed-mode fracture
- review problems

exam

exam format

- Look at the exam and equation sheet posted on Blackboard
- Expect a mixture of quantitative and qualitative questions (some short answer justifications)
- 5 questions (current plan)
- I curve all my exams linearly
- Pay attention to what the question is asking for and be sure to answer all parts of the question
- There will be no T/F section, but those questions in the text can still be useful for review

equation sheet

- The equation sheet for this exam will be the same as the previous equation sheet posted to Blackboard
- Other specific information and formulas (mixed-mode fracture, stiffener data, etc.) will be given in the problem

topics

- Stress Intensity
- Fracture Toughness
- Residual Strength
- Stiffeners
- Multiple Site Damage
- Mixed Mode Fracture

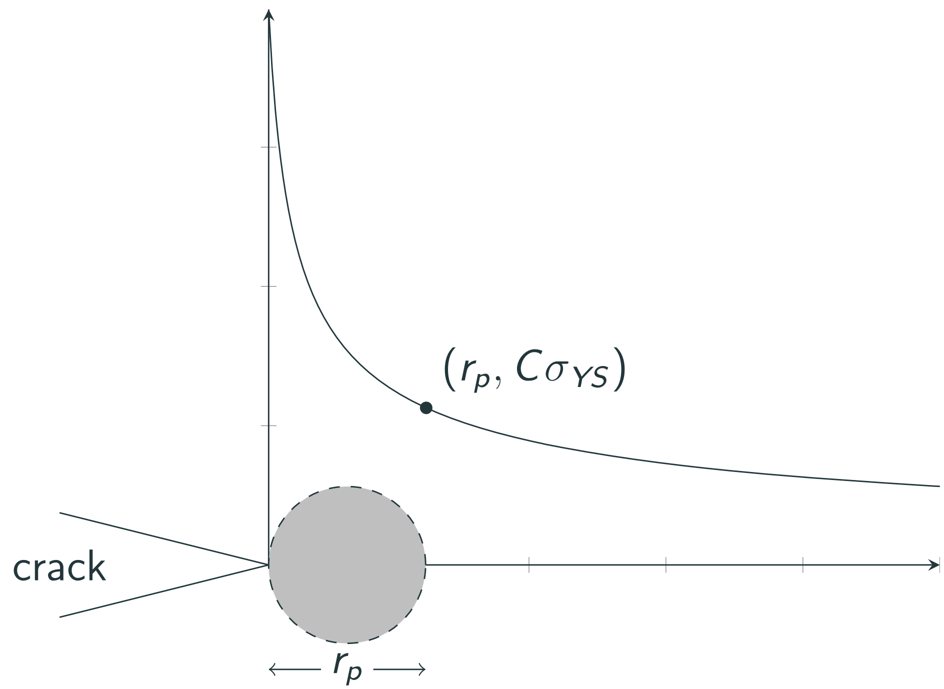
stress intensity

topics

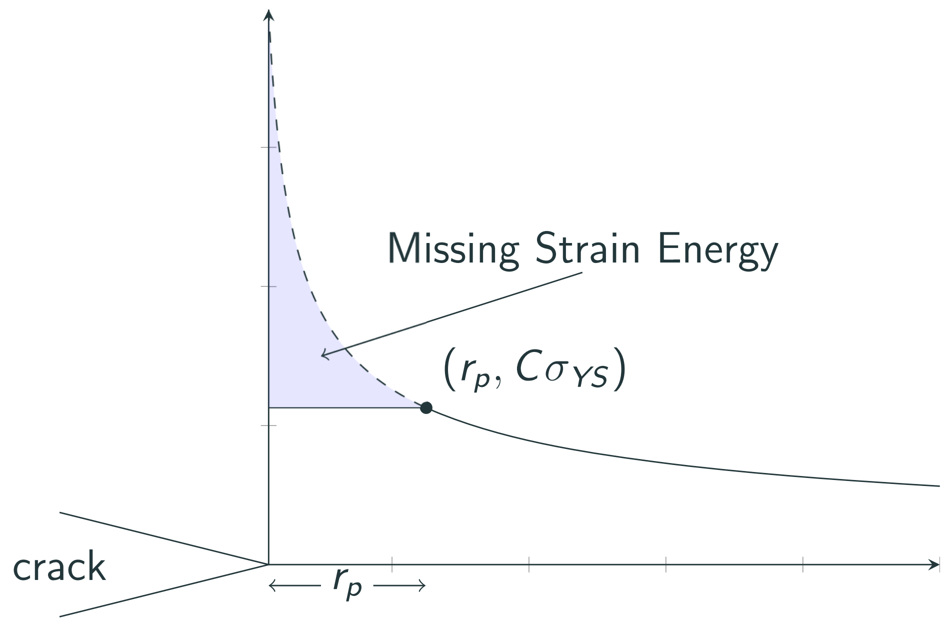
- Stress intensity
- Compounding
- Superposition
- Cracks near curved boundaries

plastic zone

Irwin's first approximation



Irwin's second approximation



fracture toughness

fracture toughness

- The critical load at which a cracked specimen fails produces a critical stress intensity factor
- The “critical stress intensity factor” is known as K_c
- For Mode I, this is called K_{Ic}
- The critical stress intensity factor is also known as fracture toughness

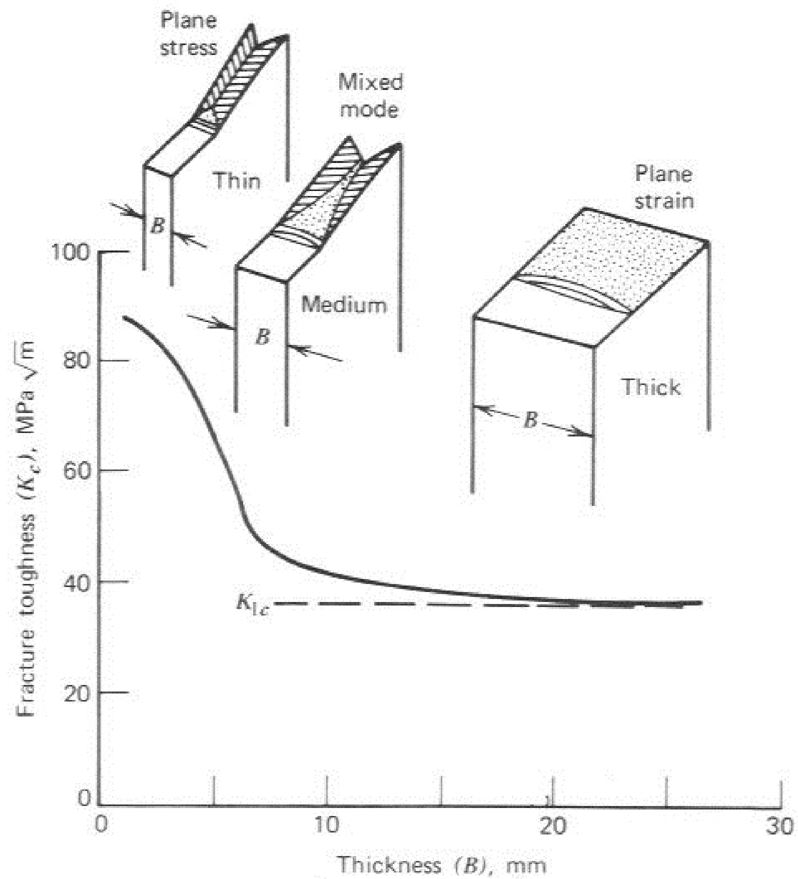
$$K_{IC} = \sigma_c \sqrt{\pi a} \beta$$

- NOTE: “Fracture Toughness” can also refer to G_{Ic}, which is analogous to K_{Ic}, but not the same

fracture toughness

- Fracture toughness is a material property, but it is only well-defined in certain conditions
- Brittle materials
- Plane strain (smaller plastic zone)
- In these cases ASTM E399-12 is used.

fracture toughness



unstable cracks

- Stable crack growth means the crack extends only with increased load
- Unstable crack growth means the crack will continue to extend indefinitely under the same load
- For a perfectly brittle material, there is no stable crack growth, as soon as a critical load is reached, the crack will extend indefinitely

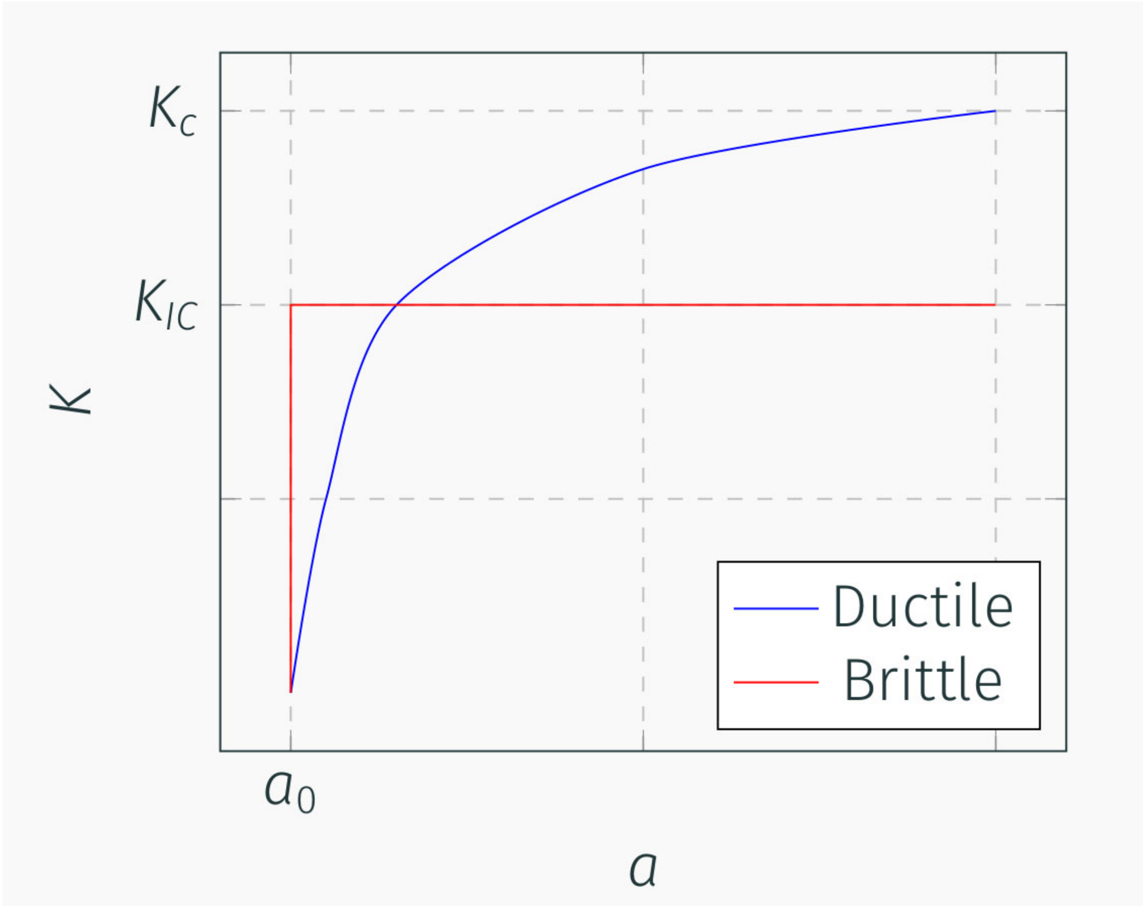
stable cracks

- For an elastic-plastic material, once the load is large enough to extend the crack, it will extend slightly
- The load must be continually increased until a critical value causes unstable crack growth

fracture toughness

- During an experiment, we will record the crack length and applied load (P_i, a_i) each time we increase the load
- We can calculate a unique stress intensity factor K_{Ii} at each of these points
- These are then used to create a “K-curve”, plotting K_I vs. a

K-curve



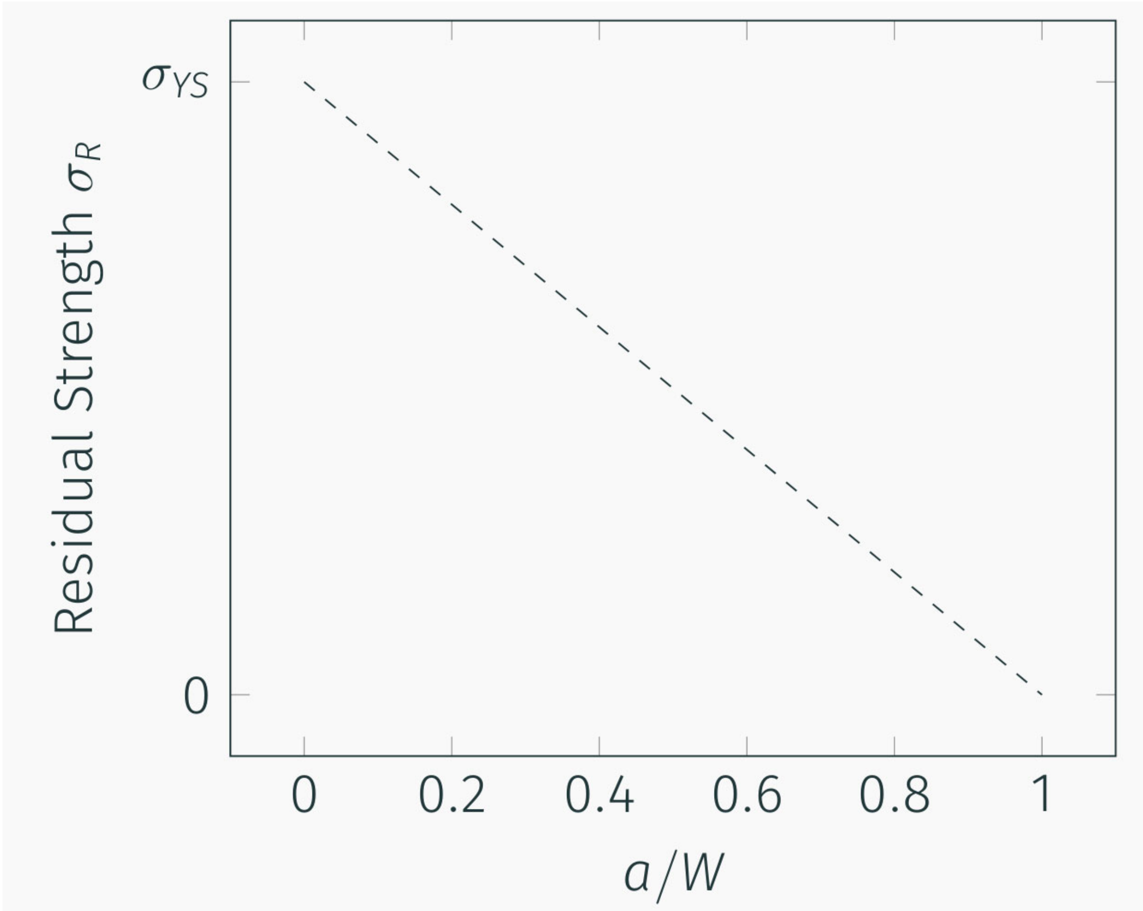
residual strength

residual strength

- In the last chapter we performed some basic residual strength analysis by checking for net section yield
- As the crack grows, the area of the sample decreases, increasing the net section stress
- The residual strength, σ_R is given in terms of the gross area, so as the crack grows the residual strength due to yield decreases
- We can relate the net-section stress to σ_R by

$$\sigma_R = \sigma_{YS} \frac{A_{net}}{A_{gross}}$$

residual strength

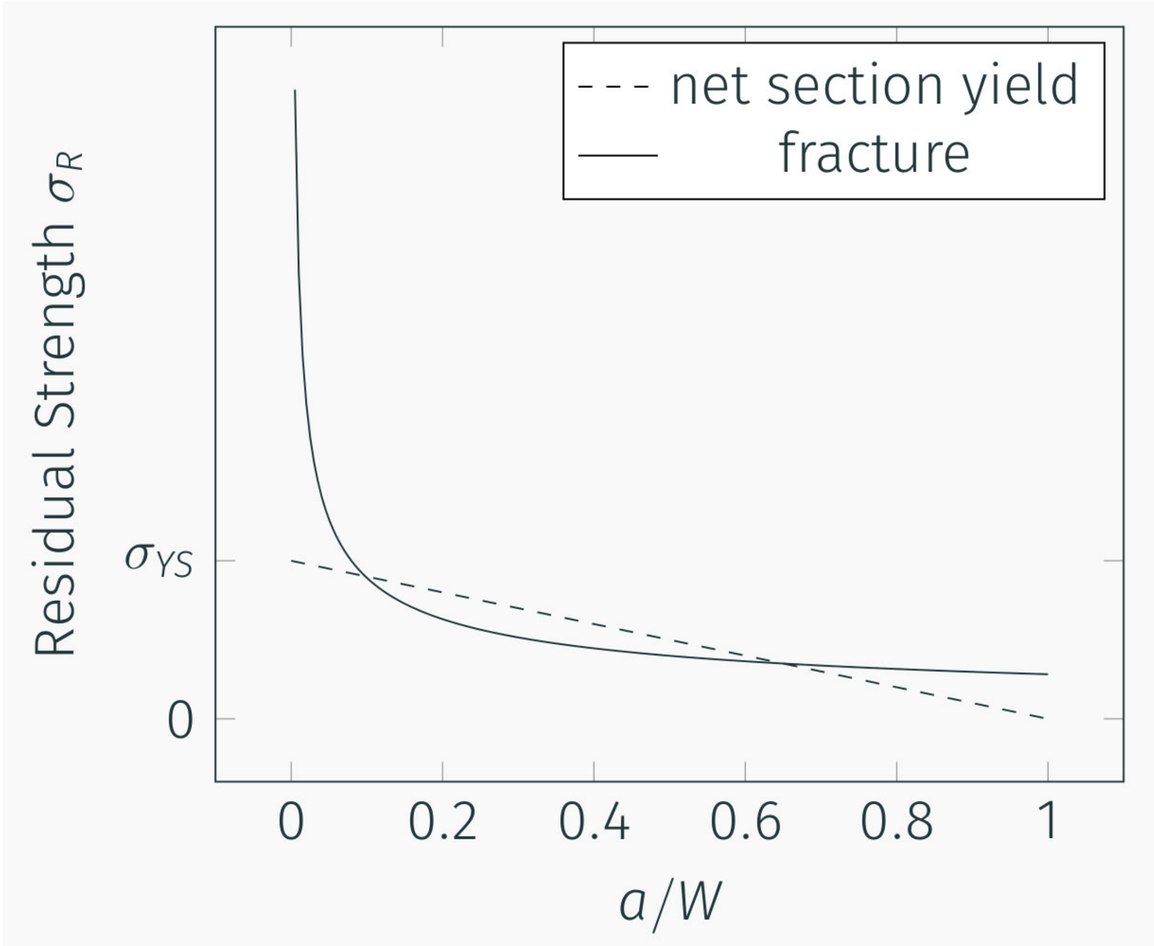


residual strength

- For brittle fracture to occur, we need to satisfy the condition

$$\sigma_R = \sigma_C = \frac{K_C}{\sqrt{\pi a}\beta}$$

residual strength



residual strength

- Within the same family of materials (i.e. Aluminum), there is generally a trade-off between yield stress and fracture toughness
- As we increase the yield strength, we decrease the fracture toughness (and vice versa)

stiffeners

crack growth

- In general, residual strength curves do NOT give any information about crack growth
- When σ_R is exceeded, the panel fails due to unstable crack growth
- Stiffeners reverse this trend to some extent, but causing some sections of residual strength curve to have positive slope
- When the slope of the residual strength curve is positive, crack growth is stable
- Thus in some cases, we can predict some amount of crack growth

critical crack length sketch

residual strength sketch

multiple site damage

mixed-mode fracture

review problems

review problems

review

- p. 415 problem 6
- p. 418 problem 9
- p. 419 problem 10-11
- p. 421 problem 13
- p. 423 problem 17
- p. 424 problem 3
- p. 425 problem 5
- p. 426 problem 1
- p. 427 problem 3
- p. 429 problem 6
- p. 432 problem 9
- p. 433 problem 14
- p. 434 problem 3
- p. 437 problem 8