AE 737 - MECHANICS OF DAMAGE TOLERANCE

Lecture 9

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Last Updated: February 18, 2016 at 2:57pm

Wichita State University, Department of Aerospace Engineering

OFFICE HOURS

- No Office Hours Friday :(
- Raincheck office hours Monday 3:00 - 5:00
- Homework 4 due Thursday, 25 Feb.

SCHEDULE

- 18 Feb - Residual Strength
- 23 Feb - Residual Strength, Multiple Site Damage
- 25 Feb - Multiple Site Damage, Mixed-mode Fracture, Homework 4 Due, Homework 5 Assigned
- 1 Mar - Section 1 Review, Homework 5 Due
- 3 Mar - Section 1 Review, Homework 5 return
- 8 Mar - Exam 1
- 10 Mar - Exam return, Final Project discussion

1. thickness effects

2. fracture toughness review

3. residual strength

4. fedderson approach

5. proof testing

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- The phenomenon is not well-understood

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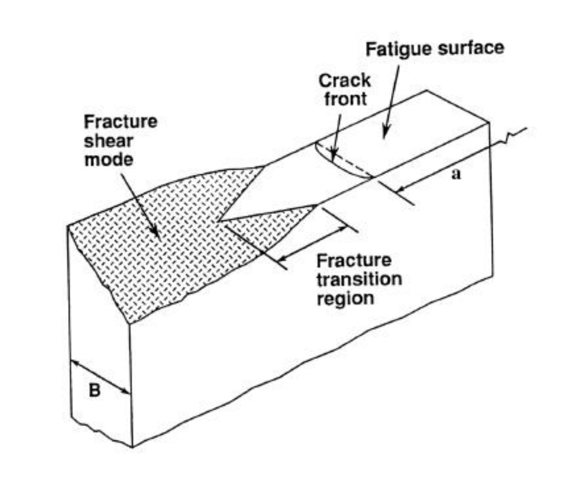
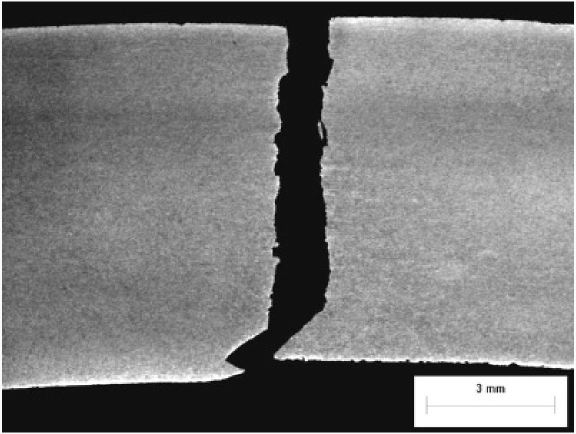
- This is more consistent with pure Mode I

SLANT FRACTURE



SHEAR LIP



FRACTURE TOUGHNESS REVIEW

- Group 1 - Sketch K_R-curve (for ductile material), explain what it means, how to find K_c
- Group 2 - Sketch K_c vs. crack length, explain what's happening
- Group 3 - How can we determine whether a panel is in plane strain or plane stress?
- Group 4 - Sketch K_R-curves for ductile and brittle materials, what is the difference?

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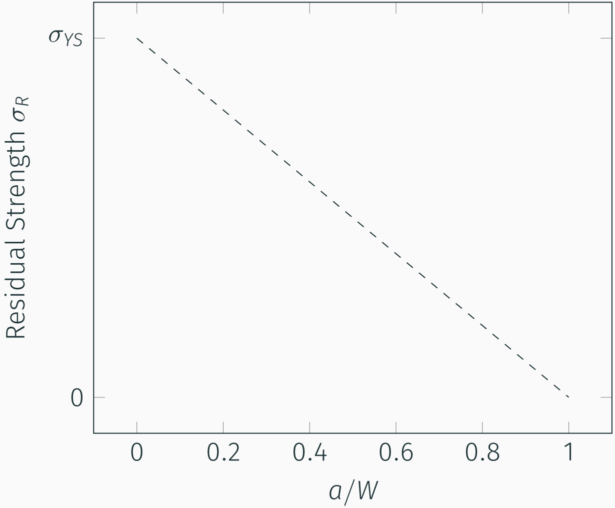
- The residual strength, σ_R is given in terms of the gross area, so as the crack grows the residual strength due to yield decreases
- We can relate the net-section stress to σ_R by

$$\sigma_R = \sigma_{YS} \frac{A_{net}}{A_{gross}} \tag{9.1}$$

RESIDUAL STRENGTH



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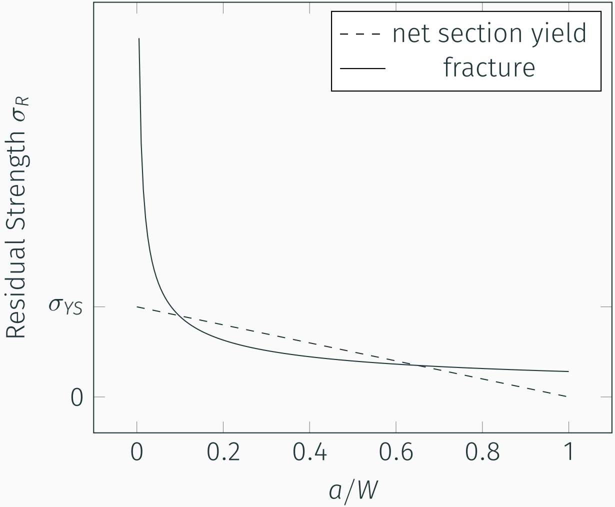
net section yield
fracture
Residual Strength σ_R
σ_{YS}
0
0
0.2
0.4
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    3. 2024-T3, $K_C = 144$ ksi$\sqrt{\text{in.}}$, $\sigma_{YS} = 42$ksi

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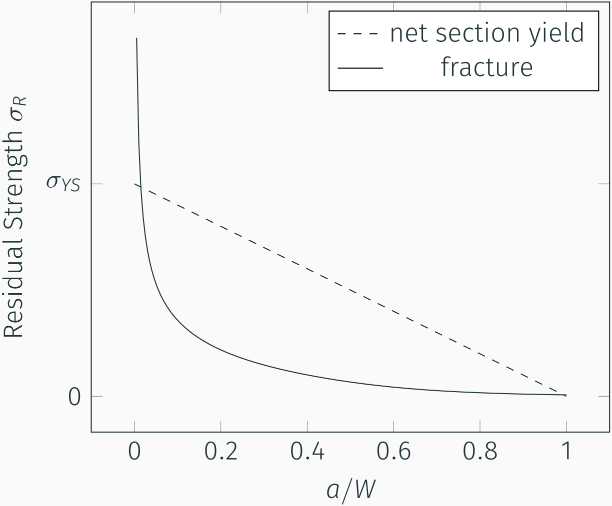
$$\sigma_C = \frac{K_C}{\sqrt{\pi a}\beta}$$

With

$$\beta = 1.12 - 0.231\left(\frac{a}{W}\right) + 10.55\left(\frac{a}{W}\right)^2 - 21.72\left(\frac{a}{W}\right)^3 + 30.39\left(\frac{a}{W}\right)^4$$

7178-T6



net section yield
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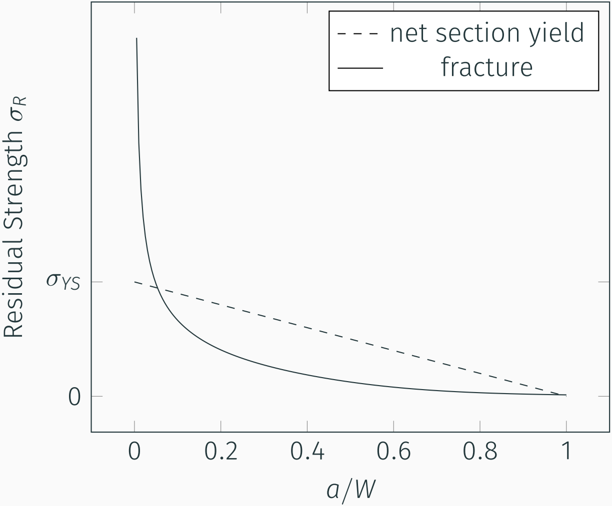

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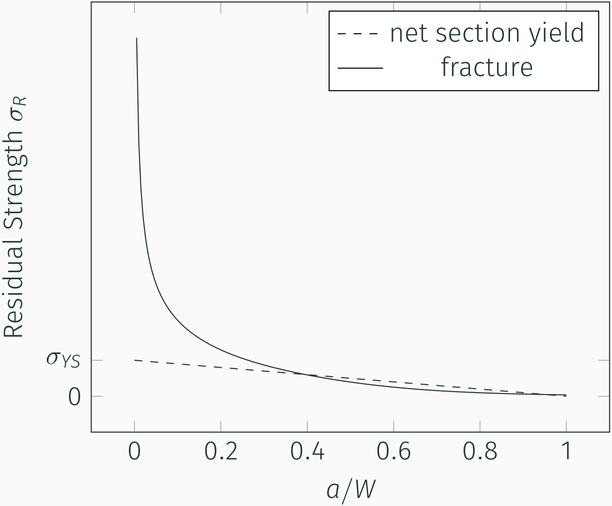

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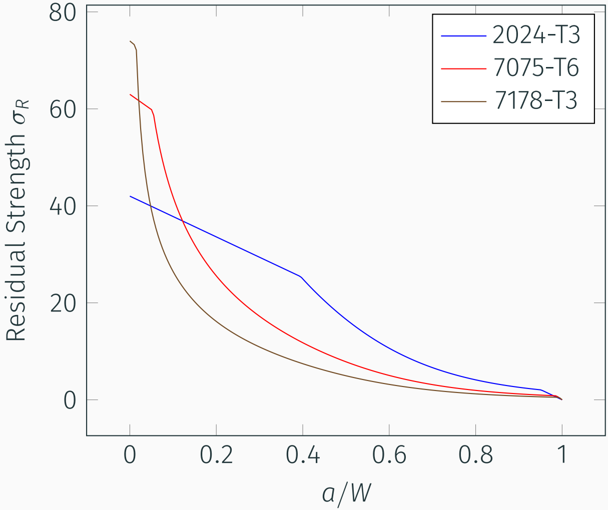

80
60
40
20
0
Residual Strength σ_R
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2024-T3
7075-T6
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- S-Basis - no statistical information available, standard value to be used

USING MIL-HANDBOOK

- F_{tu} - ultimate tensile strength
- F_{ty} - tensile yield strength
- F_{cy} - compressive yield strength
- F_{su} - ultimate shear strength
- F_{bru} - ultimate bearing strength
- F_{bry} - bearing yield strength
- E - tensile Young's Modulus
- E_c - compressive Young's Modulus
- G - shear modulus
- μ - Poisson's ratio

FEDDERSON APPROACH

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- Note: We could do something similar when the crack is very long, but we are generally less concerned with this region (failure will have already occurred)

PROOF TESTING

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- This is the ”proof load”
- If the part does not fail in the proof test, we can assume that the largest flaw in the material is a_0

- Suppose we are concerned about edge cracks in a panel with $\sigma_{YS} = 65\text{ksi}$, $W = 5$''
- We have determined that the largest allowable crack is 0.4"
- The fracture toughness of this panel is $K_c = 140 \text{ ksi}\sqrt{\text{in.}}$
- We can find the proof load

$$\begin{aligned}\sigma_c &= \frac{K_c}{\sqrt{\pi a_0}\beta} \\ &= \frac{140}{\sqrt{\pi 0.4}(1.161)} \\ &= 107.6\end{aligned}$$

- So the proof load would need to induce a gross section stress of 107.6 ksi.