AE 737 - MECHANICS OF DAMAGE TOLERANCE

Lecture 20

Dr. Nicholas Smith

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Wichita State University, Department of Aerospace Engineering

SCHEDULE

- 7 Apr - Crack Growth, Stress Spectrum
- 12 Apr - Retardation, Boeing Commercial Method
- 14 Apr - Exam Review, Homework 8 Due
- 19 Apr - Damage Tolerance
- 21 Apr - Exam 2
- 26 Apr - Exam Solutions, Damage Tolerance

OFFICE HOURS

- I have a meeting this Friday afternoon (4/8)
- Office hours will be Monday 4/11 from 3:00 - 5:00
- As always you can e-mail me to schedule another time, or ask your questions via e-mail

OUTLINE

1. crack growth rate
2. factors affecting crack propagation
3. numerical algorithm

CRACK GROWTH RATE

FRACTURE SURFACE

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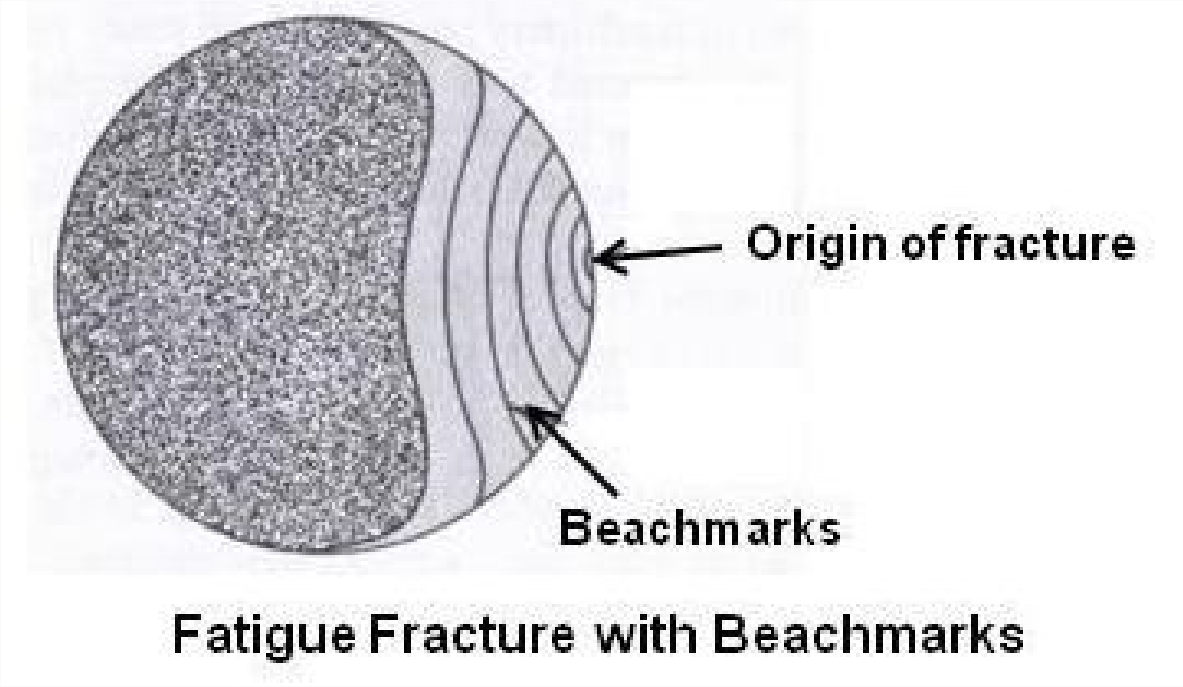

Fatigue Fracture with Beachmarks

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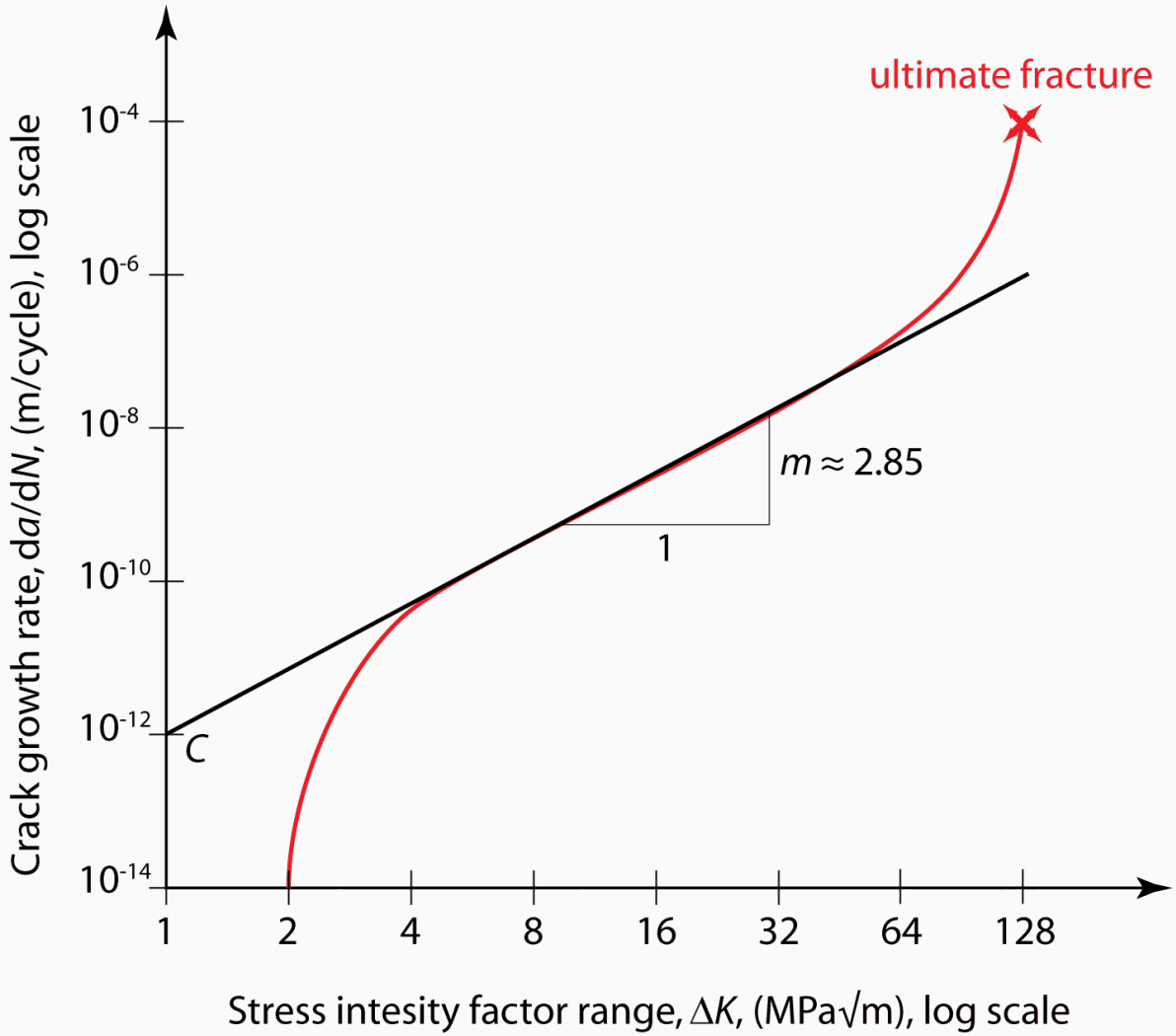
- This chart is then commonly divided into three regions

DA-DN VS K


ultimate fracture
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
10^{-14}
Crack growth rate, da/dN, (m/cycle), log scale
$m \approx 2.85$
1
C
1
2
4
8
16
32
64
128
Stress intesity factor range, ΔK, (MPa$\sqrt{m}$), log scale

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- 3-6 ksi$\sqrt{\text{in}}$ for aluminum

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- Generally linear in the log-log scale

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- Can be significant for parts where we expect high stress and relatively short life

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- The same considerations for thickness apply as with fracture toughness (K_c vs. K_{Ic})
- Is also a function of the load ratio, $R = \sigma_{min}/\sigma_{max}$

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- In general, R dependence vanishes for $R > 0.8$ or $R < -0.3$. This effect is known as the band width

PARIS EXAMPLE

FACTORS AFFECTING CRACK PROPAGATION

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- stress ratio

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- crack orientation
- manufacturer

FACTORS AFFECTING CRACK PROPAGATION

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- stress ratio
- temperature
- environment
- frequency
- crack orientation
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- heat treatment

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- In thin (plane stress) plates, cracks can be treated as through cracks
- In thick plates (plain strain), we generally need to consider the crack shape

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- Q is a shape parameter for elliptical flaws

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- This trend is exactly opposite the trend for K_c
- The effect varies in different materials
- Most materials benefit from slightly lower temperatures, but as temperatures are further decreased the crack growth rate increases again

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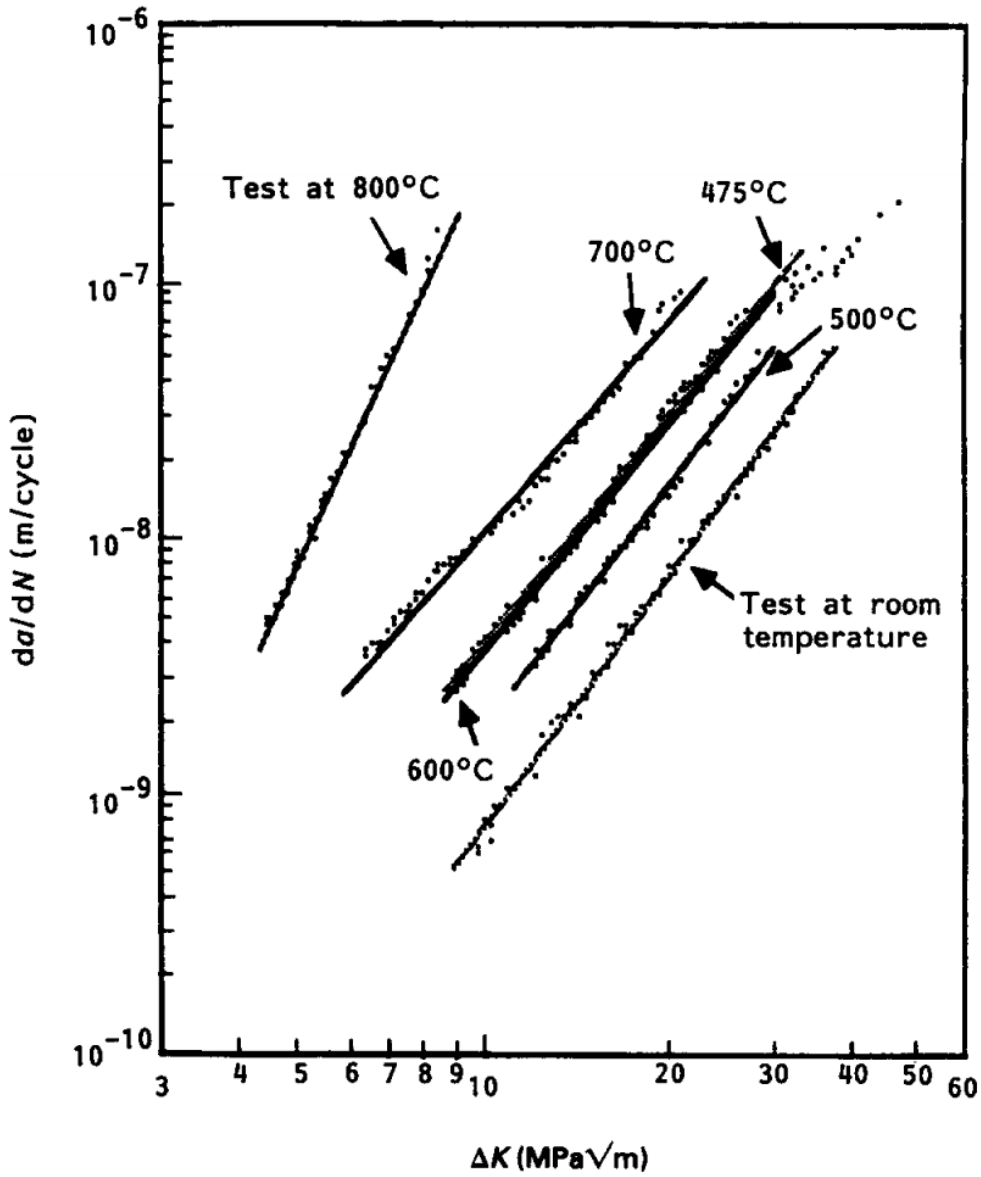

Fig. 2 Mid-range fatigue crack-growth rates with alternating stress intensity factor for 18%Cr–Nb ferritic stainless steel at

TEMPERATURE

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- Instead, materials should be tested at a range of temperatures to establish a range of operating temperatures with corresponding crack growth data

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- These effects have varying strength depending on the material used

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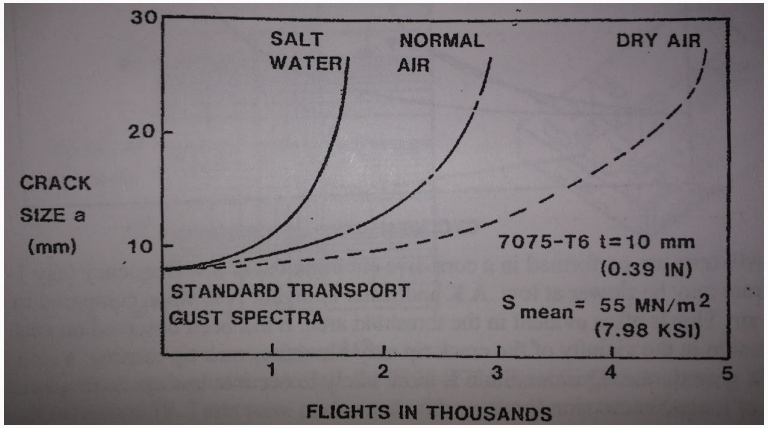

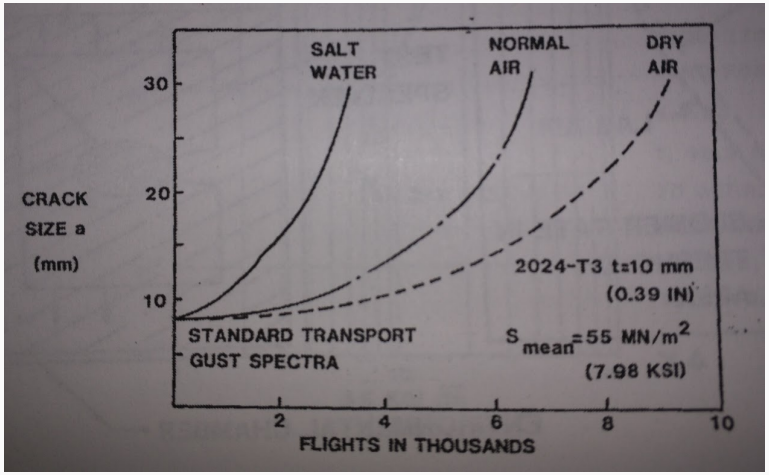

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- Crack growth is faster when the load increases slowly and decreases rapidly
- Crack growth is slower when the load increases rapidly and decreases slowly

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- At low frequencies, a corrosive environment increases the threshold, K^{th}
- However in Region II, crack growth is faster
- This effect can be explained by the corrosive environment blunting the crack tip

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- Some experiments have found a frequency dependence, while others have not
- Many claim that the frequency dependence is due to small amounts of water in air during frequency dependence experiment

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- In many materials, however, the difference between orientations is not significant when compared to scatter, and it is often neglected
- Some materials behave very differently with different crack orientations (i.e. the slope of the paris law curve is different), so care should be taken based on the material used

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- Heat treatment/cold rolling variations

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- But they will also affect the crack growth rate

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- When trying to use large ΔN, check convergence by using larger and smaller ΔN values

BOEING-WALKER EXAMPLE

CONVERGENCE EXAMPLE

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- We will also discuss ”retardation” models next class

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