AE 737: Mechanics of Damage Tolerance

Lecture 23 - Repair

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schedule

- 28 Apr - Repair
- 3 May - Fracture in Composites
- 5 May - Class Canceled
- 9 May - Final Projects Due

outline

- repairing cracked structures
- group problems
- full scale fatigue testing

repairing cracked structures

repair

- Depending on the location and severity of damage, there are a few options for repair
- Replacement
- Stop drilling
- Welding
- Patching
- Oversize fasteners
- Load Reduction/improved analysis
- Residual stresses

stop drilling

- If a crack is not of dangerous length, full repair/replacement is not necessary
- Stop drilling refers to a hole drilled at the crack tip
- This hole removes the crack tip, crack will re-initiate at edge of hole
- Still susceptible to MSD in future
- Some new techniques attempt to change direction of crack growth

welding

- Crack material is machined away
- Empty space is filled with weld
- Can cause distortion
- Sometimes heat treatment is needed

patching

- A patch placed over the crack provides an alternate load path
- Patches can be attached mechanically, with fasteners
- Or bonded with adhesives
- Fasteners introduce new holes, new sites for damage
- Additional fasteners add weight
- Adhesives add less weight, do not introduce new damage, but it can be difficult to ensure the integrity of the bond in-service

oversize fastener

- When crack forms around a fastener hole, the hole can be drilled larger
- The larger hole removes the crack tip
- Fastener is replaced with a larger fastener, appropriate to the drilled hole

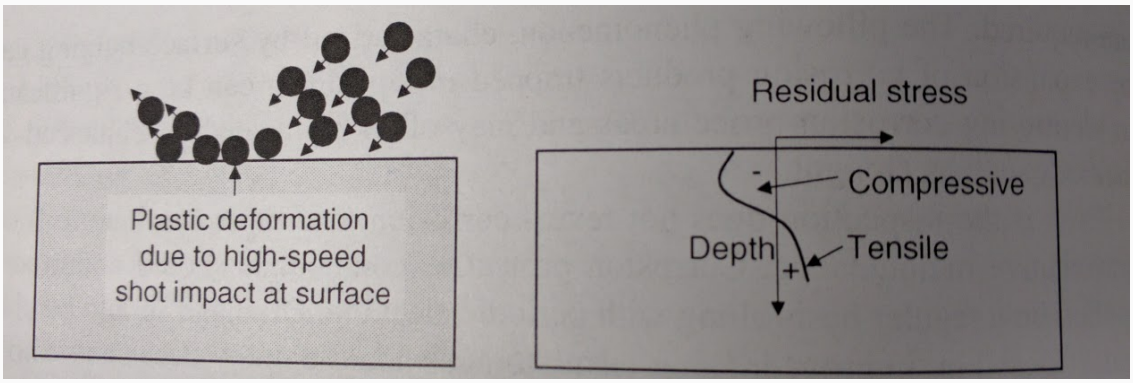
load reduction

- When damaged parts are difficult or expensive to repair, load can be reduced instead
- (e.g. assign a plane to a less rigorous flight path)
- Initial designs are often conservative
- After years of life, more advanced analysis is usually available
- Sometimes repair and load reduction are not necessary if initial design is found to be overly conservative

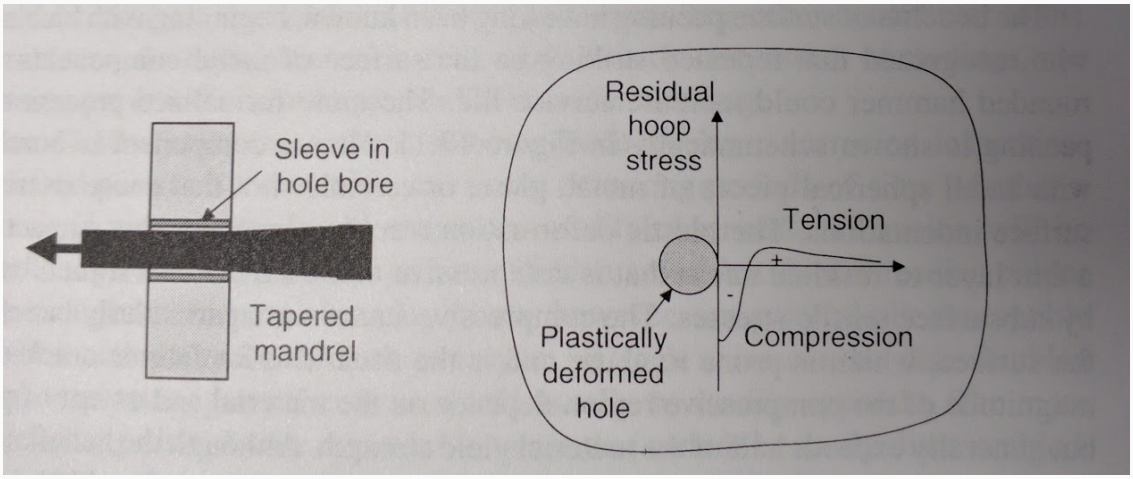
residual stress

- Some repair methods introduce beneficial residual stresses instead of directly addressing the crack
- Surface treatments can introduce compressive residual stresses at the crack tip, which can slow or stop crack growth
- Some common methods used are
- Shot peening
- Low plasticity burnishing
- Laser shock peening
- Hole cold-working

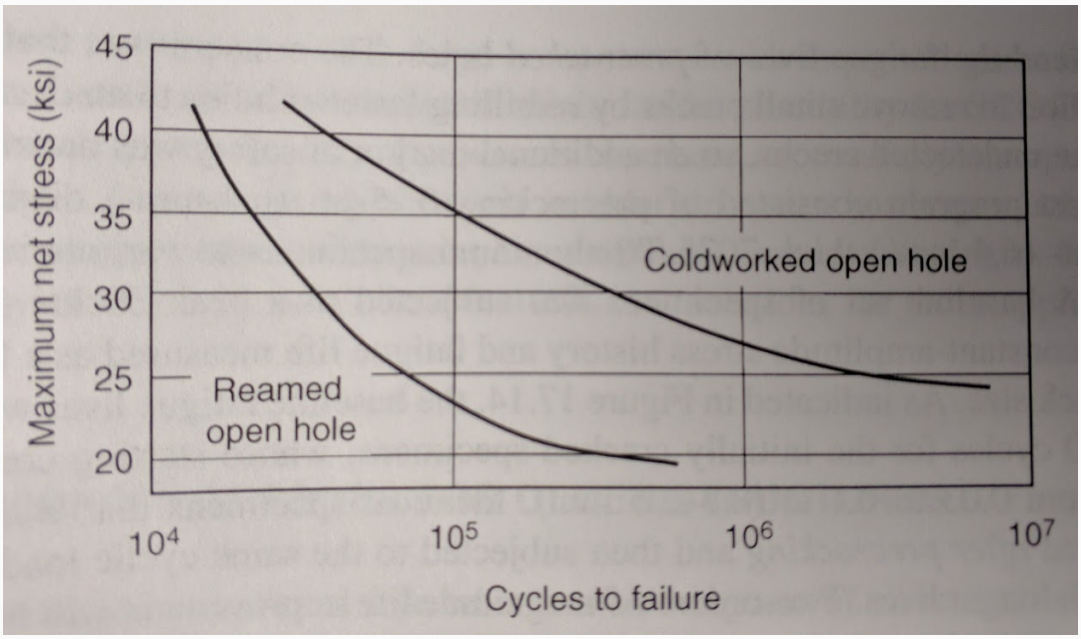
shot peening



hole cold working



hole cold working



which repair method

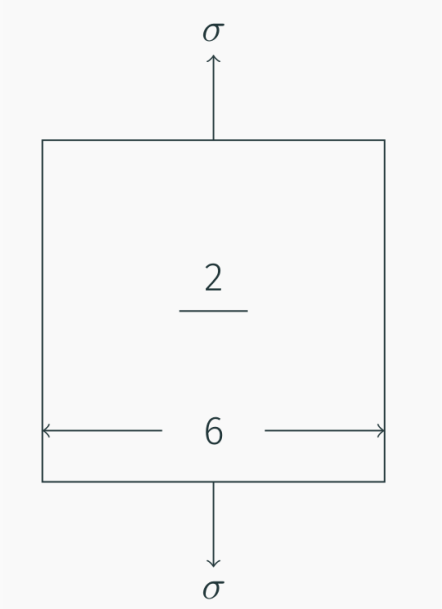
- Which repair method is best?
- Factors that affect decision
- Cost
- Is multiple site damage a concern?
- Fracture vs. net section yield
- Can we reduce K_{max} below K_{th} with residual stresses?

group problems

group 1

- Compare the effectiveness of stop drilling in 2024 and 7075 for the following panel.
- For 2024 use $K_c = 125$ ksi$\sqrt{\text{in}}$ and $\sigma_{YS} = 50$ ksi
- For 7075 use $K_c = 60$ ksi$\sqrt{\text{in}}$ and $\sigma_{YS} = 70$ ksi
- Recall $\beta = \sqrt{\sec(\pi a/W)}$

group 1



group 2

- Due to MSD concerns, we would like to alter a crack path by 15°
- What stresses would need to be added to a 15 ksi tensile load to accomplish this?
- Note: Assume for this problem that $\beta' = \beta$
- Recall

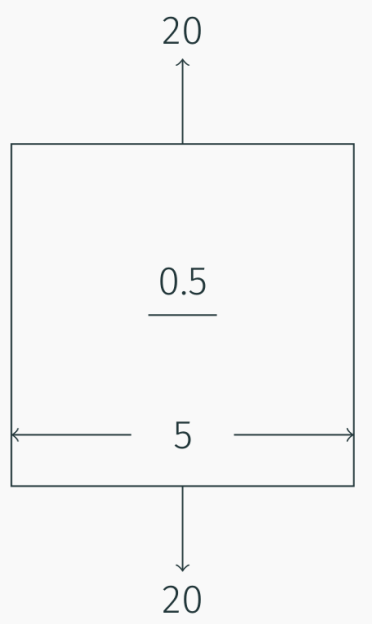
$$K_{II} = \tau\sqrt{\pi a}\beta'$$

$$K_I \sin\theta_p + K_{II}\left(3\cos\theta_p - 1\right) = 0$$

group 3

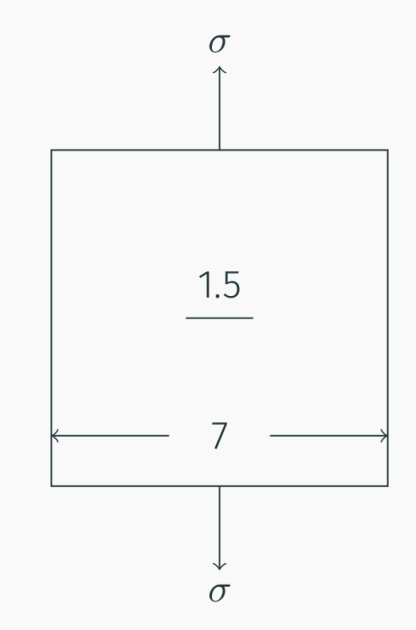
- Compare the amount of residual compressive stress needed stop crack growth for Al 2024 and Al 7075 in the following panel.
- Assume $K_{th} = 4$ ksi$\sqrt{\text{in}}$ for Al 2024
- And $K_{th} = 7$ ksi$\sqrt{\text{in}}$ for Al 7075

group 3



group 4

- Due to damage, an airline decides to move an aircraft to a less strenuous flight cycle.
- Find the effective load for a flight cycle that will last at least 1000 flights for the following cracked panel.
- Note: use $p = 4$ and $M_t = 25.8$
- Assume $K_c = 60$ ksi$\sqrt{\text{in}}$ and $\sigma_{YS} = 70$ ksi
- The largest load of 20 ksi occurs during takeoff and will not change with flight cycle.



full scale fatigue testing

Beoing 787

video[1]

[1] https://www.youtube.com/watch?v=TH9k9fWaFrs

challenges

- Design load cycle
- Apply loading consistent with real-life application
- Frame needs to be rigid relative to test specimen
- Loading needs to be accelerated to be able to use product in reasonable timeframe