

# AE 737 - MECHANICS OF DAMAGE TOLERANCE

## LECTURE 26

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# SCHEDULE

- 5 May - Repair, NDT
- 10 May - Final Project Due by 5:00 pm

- Friday, May 6
- 12:00 - 1:00 pm
- Shocker Hall Multipurpose Room - Honors College
- Pizza (first-come first-served)



**Figure 1:** LASRE on top of SR-71 Blackbird

1. repairing cracked structures
2. group problems

## REPAIRING CRACKED STRUCTURES

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- 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

- 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

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



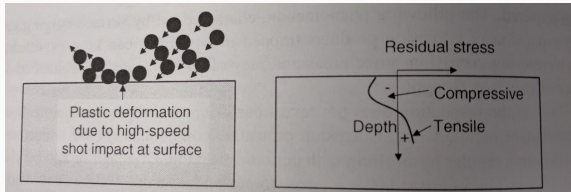
- A patch placed over the crack provides an alternate load path
- Patches can be attached mechanically, with fasteners
- Or bonded with adhesives
- Fasteners introduce new holes, new sites for damage
- Additional fasteners add weight
- Adhesives add less weight, do not introduce new damage, but it can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

- 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

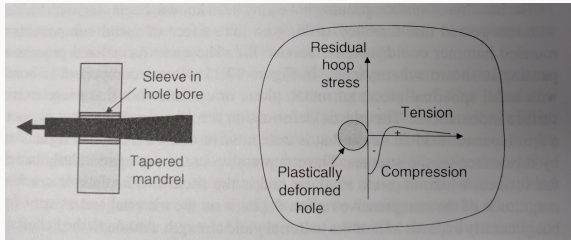
- When damaged parts are difficult or expensive to repair, load can be reduced instead
- (e.g. assign a plane to a less rigorous flight path)
- Initial designs are often conservative
- After years of life, more advanced analysis is usually available
- Sometimes repair and load reduction are not necessary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

- 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

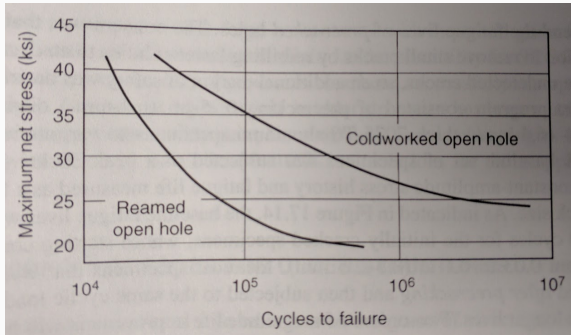
# SHOT PEENING



# 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?

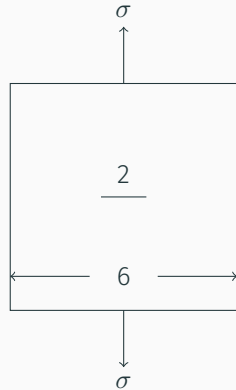


## GROUP PROBLEMS

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## GROUP 1

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

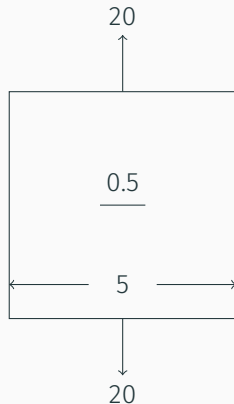


- Due to MSD concerns, we would like to alter a crack path by  $15^\circ$ .
- What stresses would need to be added to a 15 ksi tensile load to accomplish this?
- Note: Assume for this problem that  $\beta' = \beta$
- Recall

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

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

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



## 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  $K_c = 60 \text{ ksi}\sqrt{\text{in}}$  and  $\sigma_{YS} = 70 \text{ ksi}$
- The largest load of 20 ksi occurs during takeoff and will not change with flight cycle.

