University of BRISTOL

Fatigue

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Fatigue

Part-3: Fatigue prevention

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Fatigue life

$$N = N_{stage\text{-}1} + N_{stage\text{-}2} + N_{stage\text{-}3}$$

$$N = N_{initiation} + N_{slow\ propagation} + \cancel{N_{fast\ propagation}}$$

$$\mathbf{N = N_i + N_{SP}}$$

(since fast propagation time is negligible)

Prevent crack initiation / increase Ni

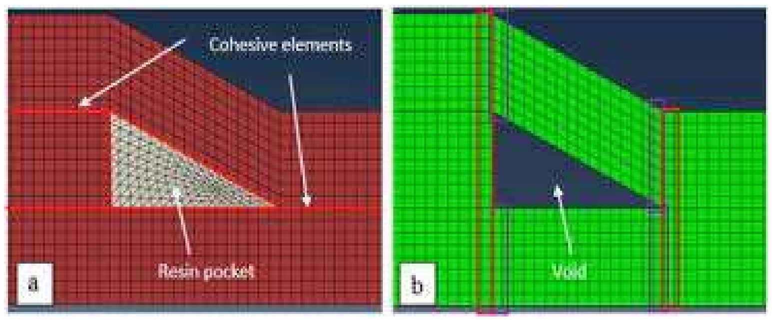
- Crack initiates when S_{local} > YS
- To reduce chance of crack initiation
  - Use material with higher YS
    - Stronger materials
    - Strengthening mechanisms
  - Lower S_{local} by reducing stress concentrations
    - Good surface finish
    - Proper component design (no abrupt changes in cross section, no sharp corners or edges etc.
    - No microscopic defects like porosity, cavity, non-metallic inclusions (use advanced manufacturing like vacuum melting, ESR, prepregs etc.)

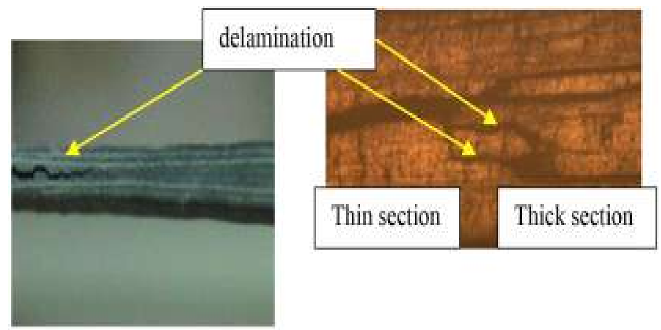
Fatigue notch sensitivity

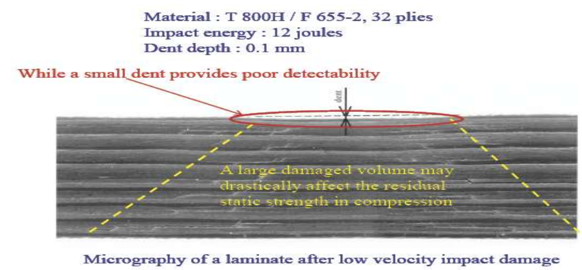
- Notch fatigue strength reduction factor (K_f) = fatigue strength without notch / fatigue strength with notch
  - ≠ Material property (depends on size, shape, stress etc.)

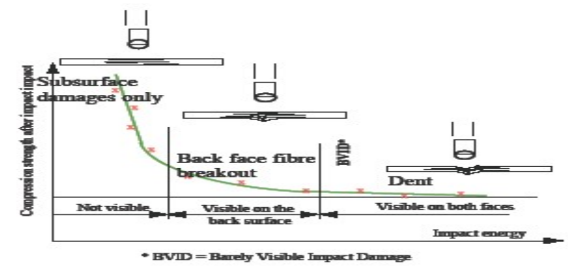
- Fatigue notch sensitivity parameter (q) = (Kf – 1) / (Kt -1)
  - Kt = Monotonic notch concentration factor
  - Highest notch sensitivity (q = 1) when Kf = Kt
  - Least notch sensitivity (q = 0) when Kf = 1
  - Only indicative

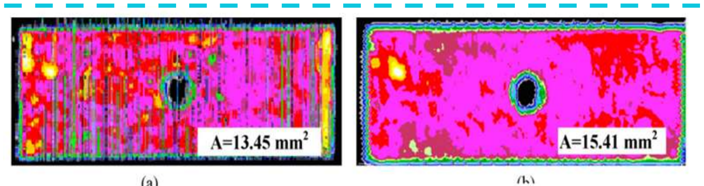
Few unique stress raisers in composites

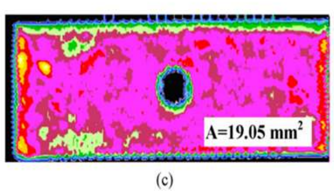


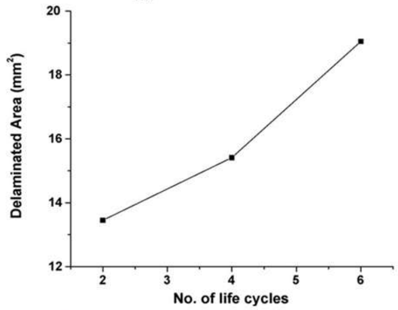


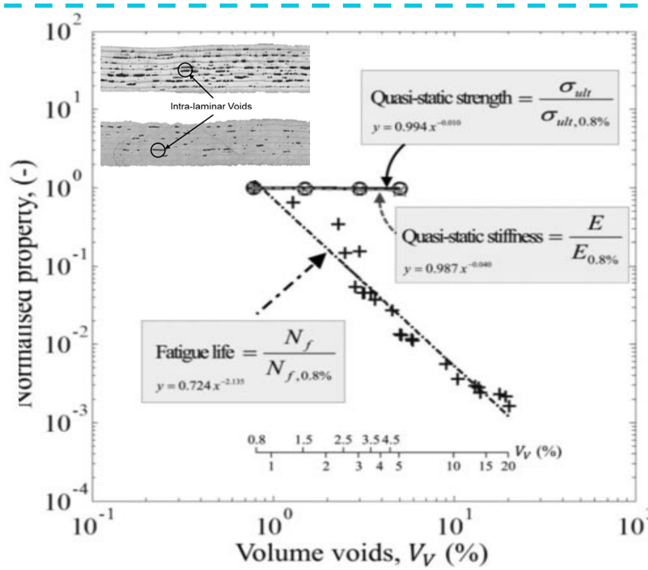


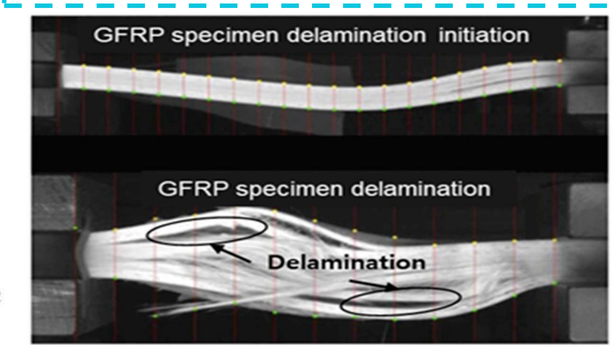












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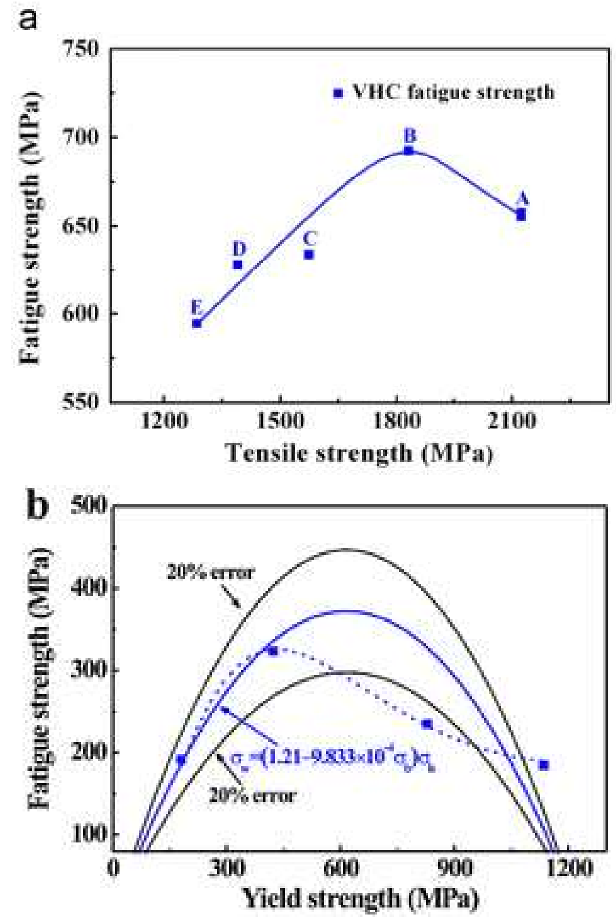
Delay slow propagation of crack / increase N_{SP}

- da/dN = (crack advancement – crack closure)
  - To reduce crack advancement: Higher YS (lower plastic deformation)
  - To increase crack closure: Higher plastic deformation (lower YS)
  - Contradictory requirement needing optimization
    - Surface / case hardening
    - Residual compressive stresses



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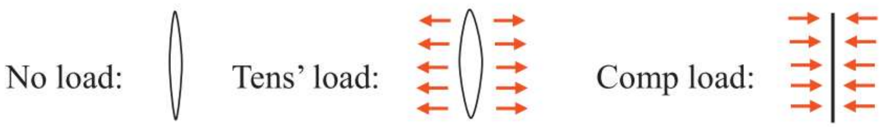
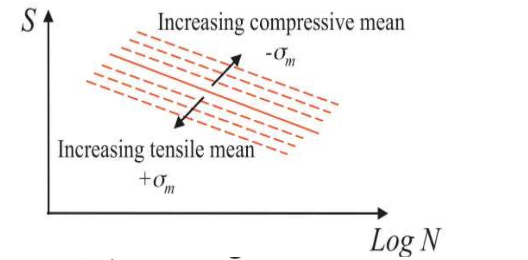
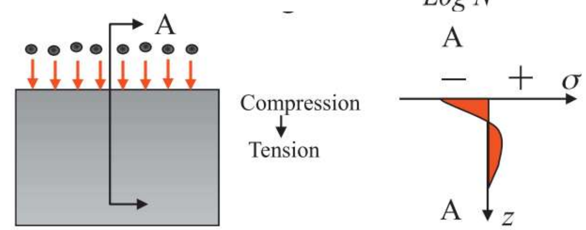
Residual compressive stresses

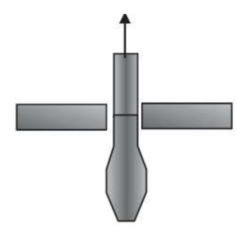
- Recall: Compressive mean stress improves fatigue life
  - Tension: opens up crack
  - Compression: Closes crack

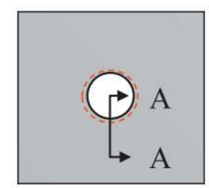




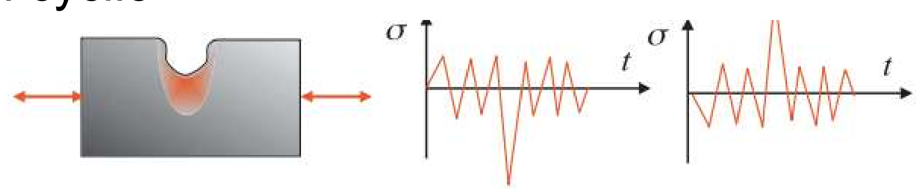
- Residual stress
  - Shot peening / sand blasting (10x fatigue life for mild steel)
  - Cold worked holes (with oversized mandrel pull through)
  - Overloads (tensile overload leaves compressive residues): e.g. freak gust, emergency maneuvers, heavy landings etc.







- Need to be careful about relaxation effects with cyclic loading / heating



End of Part-3

Fatigue

Thank you

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