Workshop 5

Nonlinear Fracture Mechanics Applications

CTOD Application

- CTOD Design curve can be used to get critical crack sizes
- Problem – A hole in a plate with $k_t = 3$, has membrane stress of 350 MPa and residual stress on 0.5 yield strength.
- Yield strength is 600 MPa and E = 210 GPa
- Lecture 13, $\delta_{cr} =$ 0.00438 in = 0.1113 mm

Review of Equations

CTOD Design Curve –

strain calculation

$$\varepsilon = [k_t(\sigma_m + \sigma_b) + Q]/E$$

where,

$\varepsilon/\varepsilon_o$ = strain ratio, horizontal axis

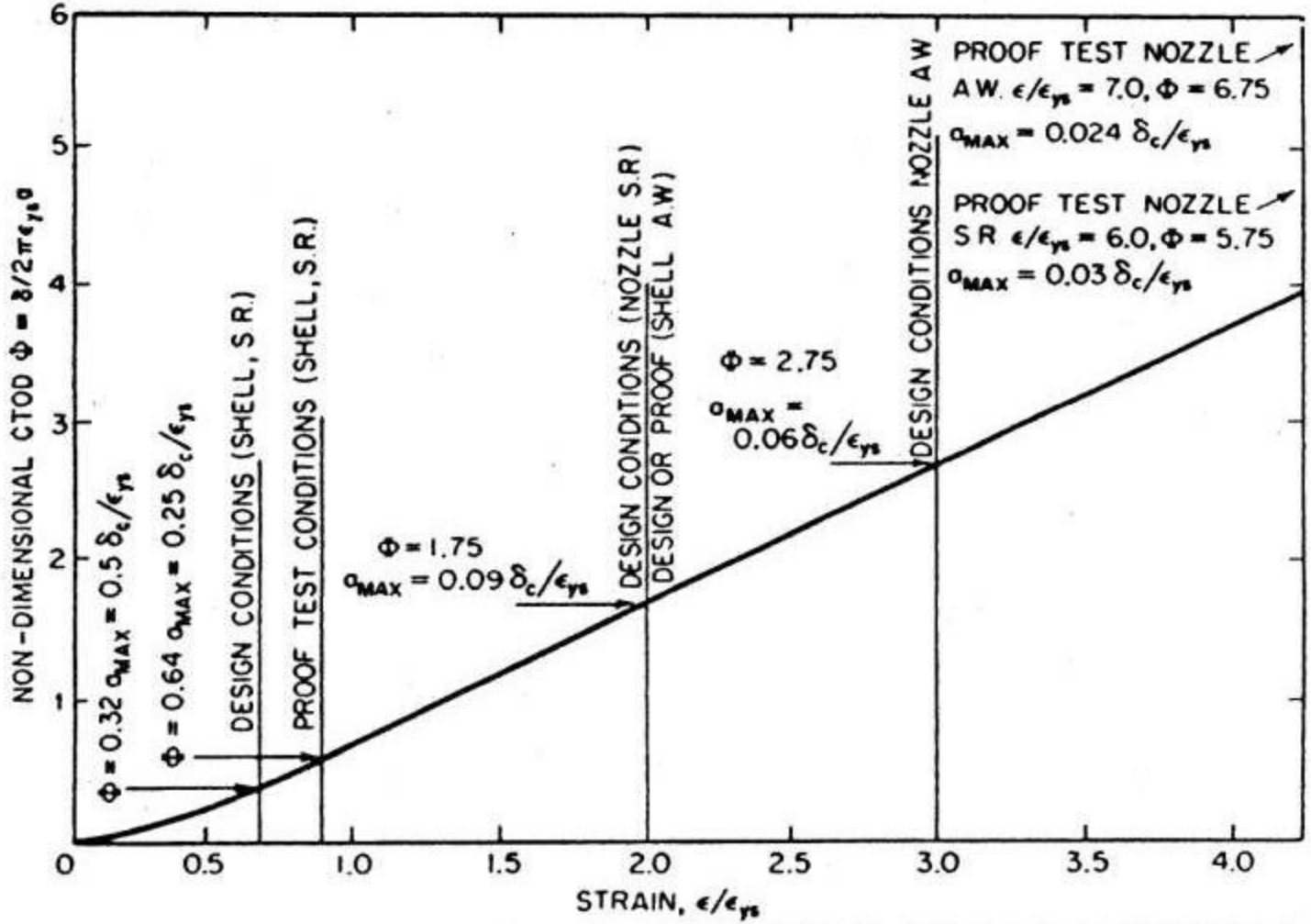
k_t = stress concentration factor

σ_m = primary membrane stress

σ_b = primary bend stress

Q = secondary stress, residual, thermal

$\varepsilon/\varepsilon_o = \varepsilon/(\sigma_{ys}/E)$



(a) DESIGN CURVE FOR CTOD, STRAIN, AND CRACK SIZE RELATIONSHIP AS PROPOSED BY BURDEKIN AND DAWES

Calculations

- $\varepsilon = (3x350 + 0.5x600)/210{,}000 = 1350/210{,}000 = 0.00643$
- $\varepsilon_{ys} = 600/210{,}000 = 0.00286$
- $\varepsilon / \varepsilon_{ys} = 0.00643/0.00286 = 2.25$
- Graph: $\Phi = 2.0 = \delta_{cr}/(2\pi\, \varepsilon_{ys}\, a)$
- $a_{cr} = 0.1113/(2.0x2x\pi x0.00286) = 3.10$ mm

PD 6493 (BSI 710) Problem

- Above problem no hole, no Residual Stress
- Above problem no hole, no Residual Stress
- $\sigma = 350$ MPa, $\sigma_{ys} = 600$, CCT model, $a = 3.1$ mm, $K_{Ic} = 80$ MPa$\sqrt{m}$
- $\sigma = 350$ MPa, $\sigma_{ys} = 600$, CCT model, $a = 3.1$ mm, $K_{Ic} = 80$ MPa$\sqrt{m}$
- $K = \sigma\sqrt{\pi a} = 350\sqrt{(\pi 0.0031)} = 34.5$ MPa$\sqrt{m}$
- $K = \sigma\sqrt{\pi a} = 350\sqrt{(\pi 0.0031)} = 34.5$ MPa$\sqrt{m}$
- $S_r = 350/600 = 0.58 \ll 0.8$
- $S_r = 350/600 = 0.58 \ll 0.8$
- $K_r = 34.5/80 = 0.43 \ll 0.707$
- $K_r = 34.5/80 = 0.43 \ll 0.707$
- Safe at level 1
- Safe at level 1

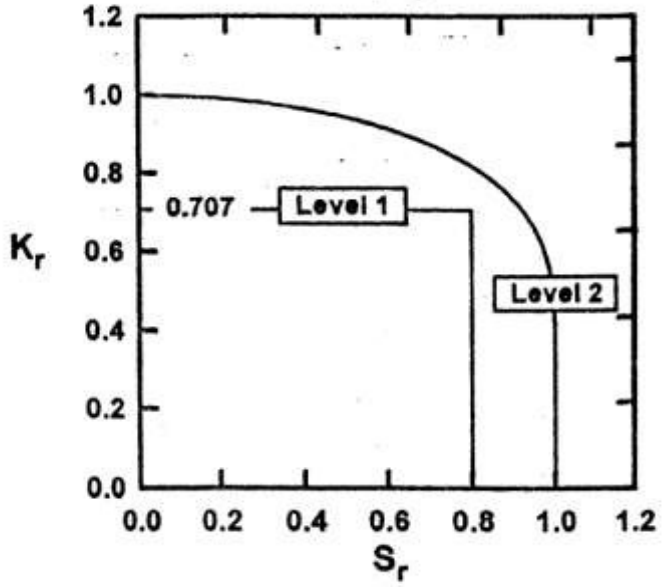
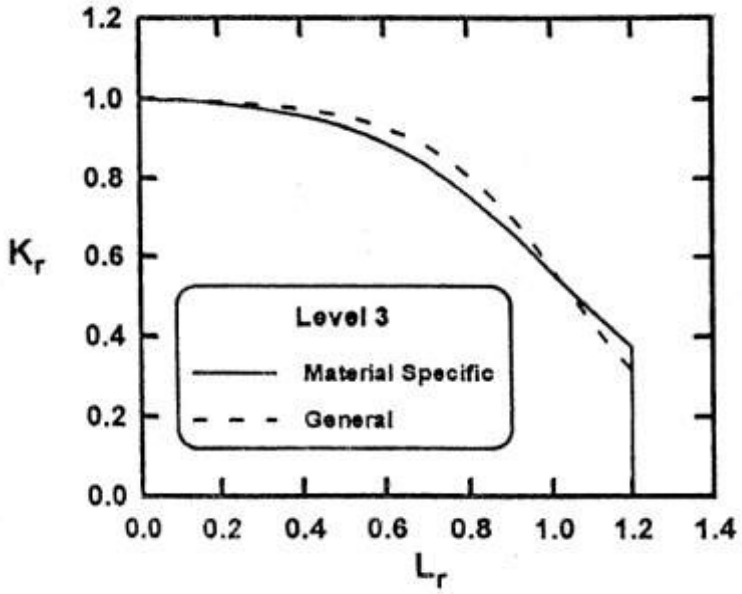


Fig. 17. PD 6493 FAD's, Levels 1 and 2.



Second Problem

- Try with $\sigma = 450$, $a = 6.2$mm
- $K \equiv 450\sqrt{(0.0062\pi)} = 62.8$
- $S_r \equiv 450/600 = 0.75$, just OK
- $K_r = 62.8/80 = 0.785$ not OK

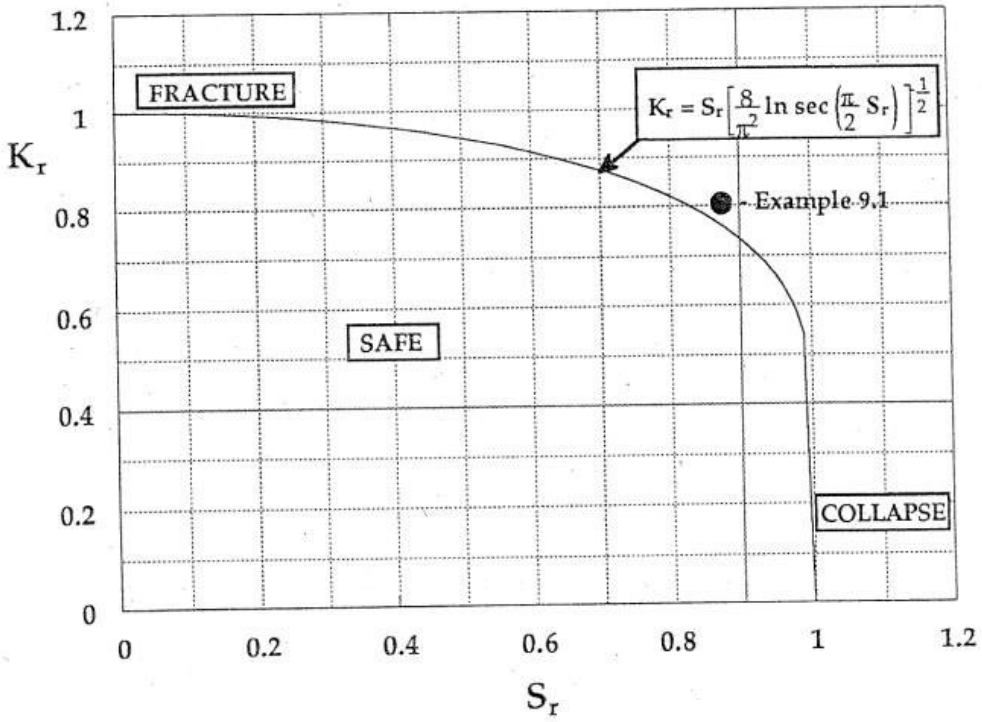
Next Step Level 2

- $K_r = S_r[\frac{8}{\pi^2}\ln\sec(\frac{\pi}{2}S_r)]^{-1/2}$
- $S_r = 0.75$
- Graphical Point, $K_r = 0.85 > 0.785$
- Point is inside R6, okay

Level 2 for a_{cr}

- Level 2 for K = 0.85, K = (0.85x80) = 68.8
- Let $68.8 = 450\sqrt{(a\pi)}$, $a_{cr} = 0.00744$ m
- So a_{cr} = 7.74 mm could be okay by level2
- Do not have level 3 Equations here

Level 2 R-6 Diagram



The strip yield failure assessment diagram [23,24].