MSE C212/ME C225
Deformation and Fracture of Engineering Materials
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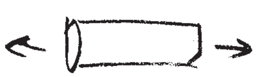
Homework was due: April 11, 2007

Homework No. 3 Solutions

(1) Fracture surfaces/sections (a) smooth bars

(i) High-purity Al – few particles, mostly do not separate from matrix. Expect

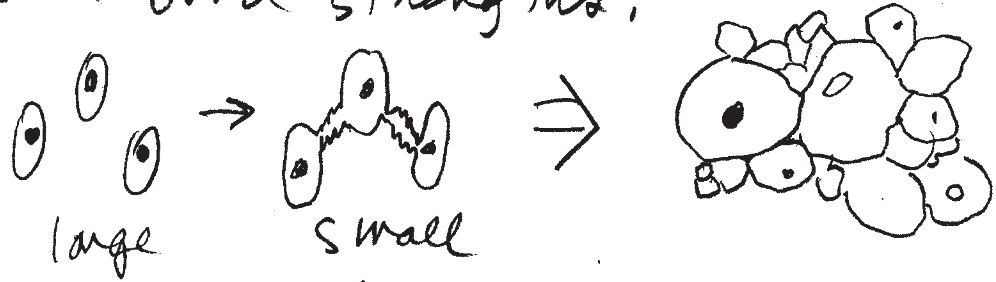
 to  100% RA 

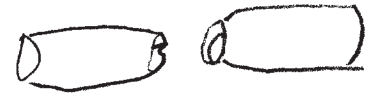
or perhaps a few microvoids at tip →

(ii) At liquid He temp., particles do separate from matrix due to higher flow stress of Al. Still get large RA: 

microvoids  (can be cup-cone)

(iii) Mild steel – lots of particles, all sizes and bond strengths.



and in section, 

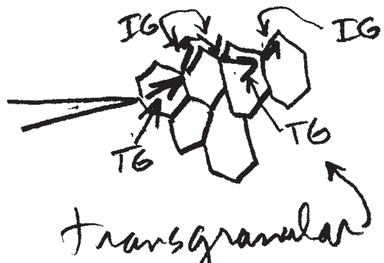
expect cup and cone, moderate RA

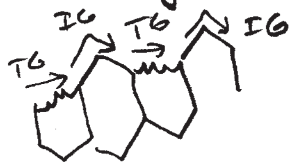
⟹ not intergranular, not cleavage at RT

① (b) Compact tension

(i) Temper-embrittled high-strength steel

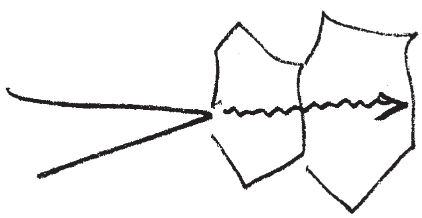
TE weakens grain boundaries; expect IG fracture, usually mixed with MVC





can have varying proportions of IG and TG — okay to show all IG

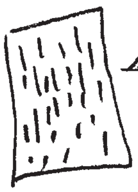
(ii) Copper fatigue



all TG — expect striations to be well formed

may be ~~some~~ MVC at high ΔK

(iii) Al_2O_3 with SiC whiskers



prob. like this (if all whiskers are aligned) — can treat as long fibers

fiber bridging

fibers can crack ahead of crack tip

fibers may pull out

fiber interfaces may separate

matrix material can also micro-crack

(2.) a.) For this thickness, B_{crit} for plane strain is

$$B_{crit} = 2.5\left(\frac{K_{Ic}}{\sigma_y}\right)^2 = 1.276''$$

Since this is very close to the actual thickness of 1.25", and the factor of 2.5 is conservative, <u>plane strain</u> is a safe assumption.

b) From K_{Ic} and $\sigma = 0.5\,\sigma_y$ in <u>service</u>,

$$a_{crit} = \frac{1}{\pi}\left(\frac{K_{Ic}}{1.12(0.5\,\sigma_y)}\right)^2 = 0.52'' \quad [A]$$

This is well above the 0.30" detection limit. But in the proof test $\sigma = 1.5\,(0.5\,\sigma_y) = 0.75\,\sigma_y$ and then the right a_{crit}, for $K_I = K_{Ic}$, is

$$a_{crit} = \frac{1}{\pi}\left(\frac{K_{Ic}}{1.12(0.75\,\sigma_y)}\right)^2 = 0.230'' \quad [B]$$

or <u>less</u> than 0.30" detection limit.

Either way, it is dangerous to risk a failure of a part for a historical machine, with a proof test. Now see part (c).

c) The 0.15" detection limit is far below the value in [A] and below [B] — this is a better risk, but still has danger.

d.) For this $\Delta\sigma$ ($0.5\ \sigma_y$ to zero), $a = 0.15''$,

$\Delta K = 66.6$ ksi$\sqrt{in}$.

For this C, m relation in $\frac{da}{dN} = C(\Delta K)^m$

the <u>initial</u> growth rate is

$$\frac{da}{dN} = 3.2 \times 10^{-7} \text{ in/cycle}$$

For 20,000 cycles at peak power,

$$\Delta a = 5.2 \times 10^{-7} (2 \times 10^4) = 0.0104''$$

Now make an <u>important</u> <u>assumption</u>:
how much Δa to permit prior to next inspection?

For $0.230 - 0.150 = 0.080''$ (proof - inspection)

Assume (<u>my</u> choice) we allow 50% of this crack growth, to be safe, or $0.040''$. This is only <u>3.8 excursions</u>. Probably 4 would be OK.

If assume $0.520 - 0.150 = 0.370$ (service - inspection) and assume 50% growth, get <u>35 excursions</u> but then cannot do proof test without careful inspection. Other choices of numbers give <u>57.2 excursions</u>.