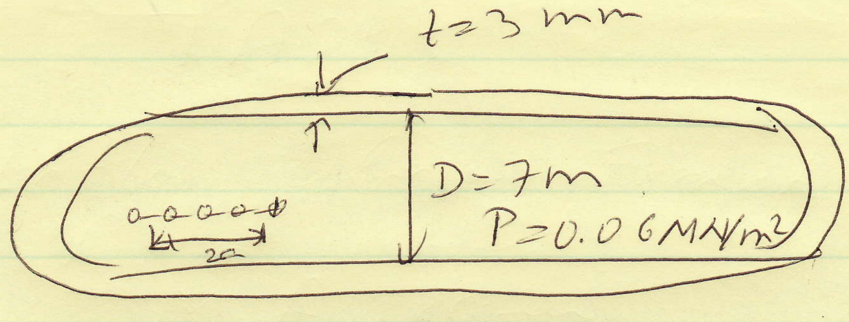
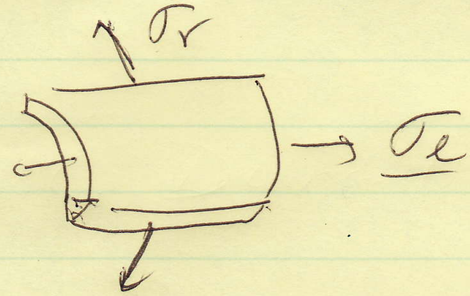
13.3



$r = 3.5\,m$

$K_c = 100\ MN\,m^{-2}$



$$\sigma_r = \frac{Pr}{t}$$

$$\sigma_l = \frac{Pr}{2t}$$

$$\sigma_r = \frac{0.06\,MN}{m^2} \times \frac{3.5}{3 \times 10^{-3}}$$

$$\sigma_r = 0.072 \times 10^3\ \frac{MN}{m^2}$$

$$\boxed{\sigma_r = 72\ MPa}$$

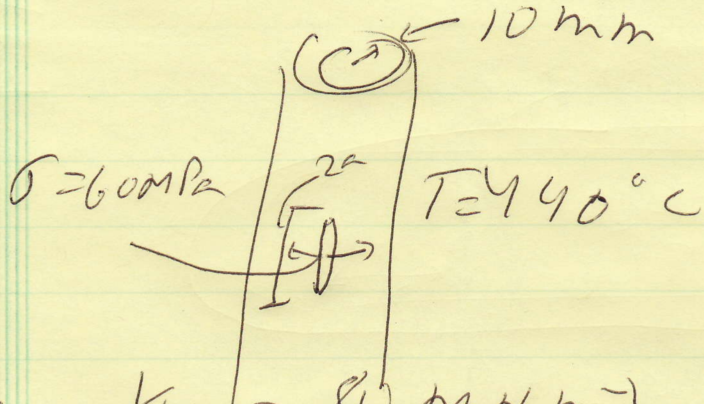
$$K_c = \sigma\sqrt{\pi a}$$

$$\pi a = \frac{K_c^2}{\sigma^2}$$

$$a = \frac{K_c^2}{\pi\sigma^2} = \frac{(100)^2}{\pi \times (72)^2}$$

$$a = \underline{0.65\,m}$$

14.1



new $K_{IC} = 80\ MN\,m^{-2}$

2 years $K_{IC} = 30\ MN\,m^{-2}$

$$K_c = \sigma\sqrt{\pi a}$$

$$a = \frac{K_{IC}^2}{\pi\sigma^2} = \frac{(80)^2}{\pi\, 60^2}$$

$a = 7.95 \times 10^{-2}\ m$

$2a \doteq 16 \times 10^{-2}\ m = \underline{160\ mm}$

14.2

$2a = 20\,mm$

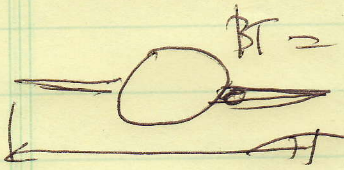
$0.4\,MN/m^2 < \sigma_v < 1\,MN/m^2$

$\sigma_r = 4\,MN/m^2$

$\sigma_T = \sigma_r + \sigma_v = 4 + 1 = 5\,MN/m^2$

$K_c = 1.3\,MN\,m^{-3/2}$

$K_T = 3$



$2a. \quad a = 10\,mm$

$\sigma_M = 3\,\sigma_T = 15\,MN/m^2$

$K_c = \sigma\sqrt{\pi a}$

$a = \frac{K_c^2}{\pi\sigma^2} = \frac{1.3^2}{\pi \times 15^2} = ~~2.8 \times 10^{-2}\,m~~$ 2.4×10^{-2}

$2a = 4.8 \times 10^{-3}\,m = \underline{4.8\,mm}$

$2a >$

So, the crack is larger than the maximum allowable.

Solution: Get a slimmer rod!

14.3) Account for the following observations.

(a) Ductile metals have high toughness whereas ceramics, glasses, and rigid polymers have low toughness.

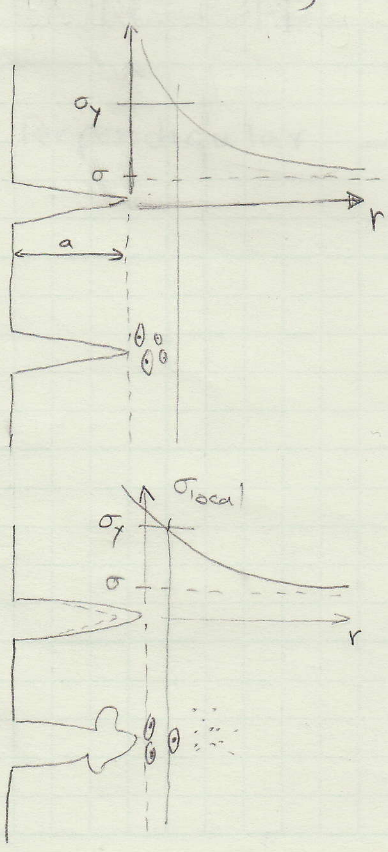
Cracks in Ductile metals have a large plastic zone; cracks in hard ceramics have a small zone, or none at all.

Crack growth by <u>ductile tearing</u> consumes a lot of energy by plastic flow; the bigger the plastic zone, the more energy is absorbed. High energy absorbtion means high (G_c) which equals high (K_c). This is why ductile metals are so tough.

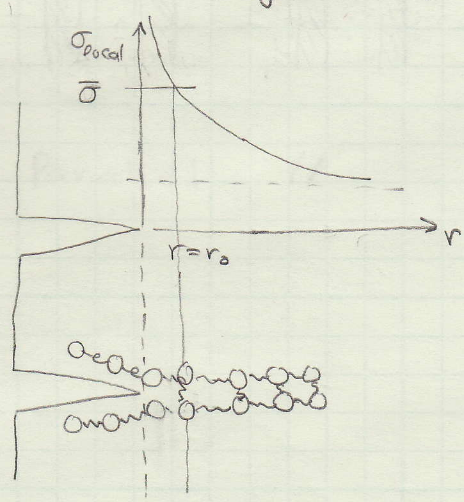
G_c = toughness $\quad$ K_c = fracture toughness

Ceramics give very little plastic deformation at the crack tips. Even allowing for a small degree of crack blunting, the local stress at the crack tip is still in excess of the Ideal strength and is thus large enough to literally break apart the interatomic bonds there; giving rise to <u>cleavage</u>.

Crack Propogation by <u>Ductile Tearing</u>



Crack Popogation by <u>cleavage</u>

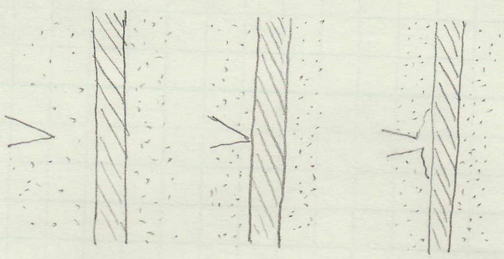


(b) Aligned fiber composites are much tougher when the crack propogates perpendicular to the fibers than parallel to them.

Aligned fiber composites are much tougher when the crack propogates perpendicular to the fibers because they act as crack stoppers. As the crack reaches the fiber, the stress field just ahead of the crack seperates the matrix from the fiber over a small region (a process called debonding) and the crack is blunted so much that its motion is arrested.

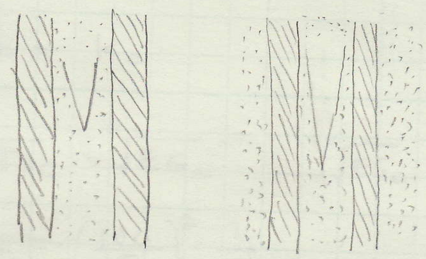
In the case where the crack propogates parrallel to the fibers; the fibers are no longer effective. The crack cannot be stopped.

Crack stopping in Composites



Perpendicular ⊥

Composite : NOT Effective
Crack will continue to grow



Parallel //