University of Portland
School of Engineering
ME 421 – Failure Analysis
Fall 2011

Fracture Mechanics and Fatigue

1. Assume fatigue loading S_{max} = 20ksi and S_{min} = 0. How many cycles are required for the following cracks to grow ¼ inch longer than they start out at and how many cycles are required for them both to grow to a final length of 1 inch? Assume there is an edge-crack and the plate is very wide (small a/W). Use the Paris Law with n = 4 and C = $1X10^{-8}$. Note that this will be very low cycle fatigue and Paris Law is not really valid. Using a spreadsheet, plot crack length verses number of cycles for an edge crack for both (a) and (b) (on the same graph).
   a) original crack length of 0.10 inch
   b) original crack length of 0.25 inch
   c) Repeat the above, except use integration rather than numerical method. Compare the answers.

2. In order to solve future problems (such as problem 3, below) you need to establish an equation governing the steady crack growth. You receive a sample of the same steel that failed in Problem 3 and conduct a test. The test parameters are:

   a) constant sinusoidal stress amplitude
   b) S_{min} is 3ksi and S_{max} is 15 ksi
   c) center cracked panel; W= 6 inches; B = 0.1 inches; yield stress = 48 ksi
   d) K_{IC} = 80 ksi root(inch)

   The following are the results showing crack length (a) after a given number of cycles (N):
   a = 0.05, N=0
   a = 0.2, N=24,000
   a = 0.4, N=54,000
   a = 0.7, N=68,000
   a = 1.0, N =74,000
   a = 2.0, N=77,000

   determine the Paris Law equation for this material. Hint, create a graph (Excel) of log(da/dN) vs. log (ΔK). Throw away any data that does not fit on the straight line (i.e. those that don't obey Paris Law). Fit a straight line through the remaining points. "n" is the slope of the line, log(C) is the y-intercept. Hint, you should get values of n=4 and C = $3.21X10^{-10}$

3. You have received a fractured item from a field failure. You see that the primary mode of failure was high cycle fatigue, which originated from a sharp notch 0.5 inches deep (1/2 inch edge crack – perhaps a quench crack). This can be considered to be an edge-

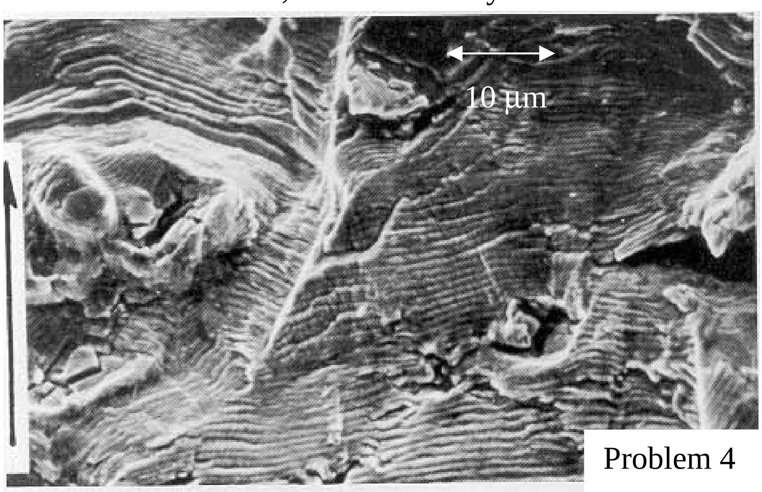
crack in a large wide plate. Using an SEM (scanning electron microscope) you measure the fatigue striations near the starter crack to be about $8X10^{-6}$ inches/cycle. You know that the stress ratio, R, was zero and the stress amplitude was nearly constant. Determine the peak cyclic stress. You must complete Problem 2 before solving this problem.

4. The following fatigue test data was acquired for Inconel X-750 at room temperature (25°C).

ΔK = 18 MPa root-meter, da/dN = $9X10^{-6}$ mm/cycle

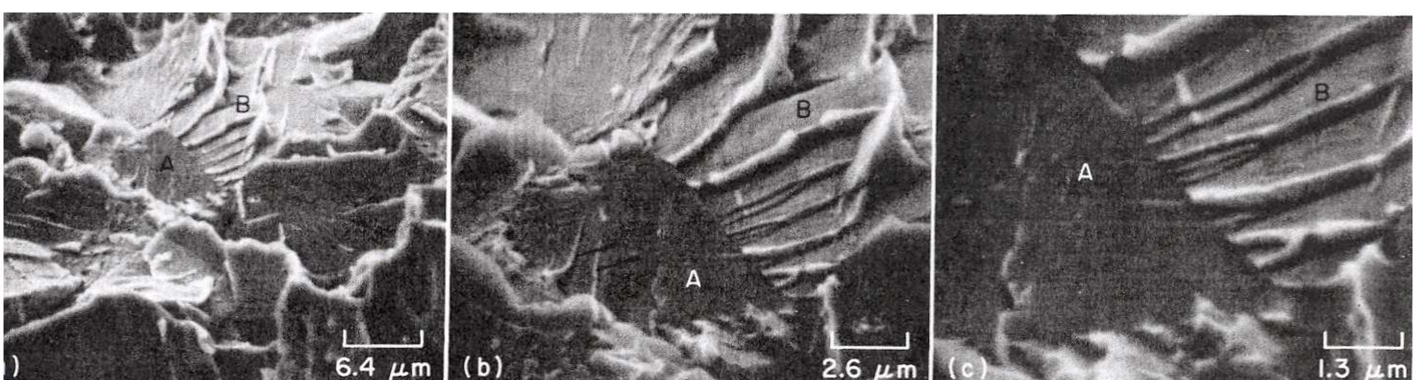
ΔK = 50 MPa root-meter, da/dN = $1X10^{-3}$ mm/cycle

An SEM image of the fracture surface of Inconel X-750 tested at 650°C is shown below. The loading conditions for this specimen was 35 MPa root-meter. Does the fatigue rate for this material increase, decrease or stay the same at 650°C?

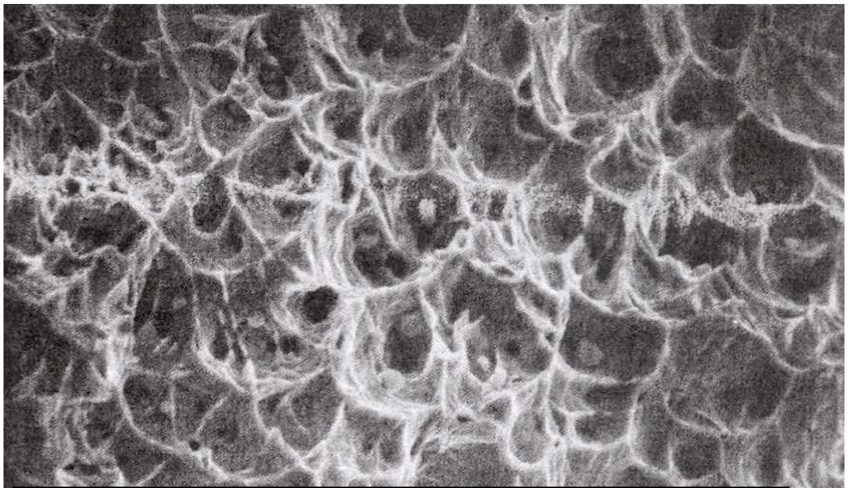


Problem 4

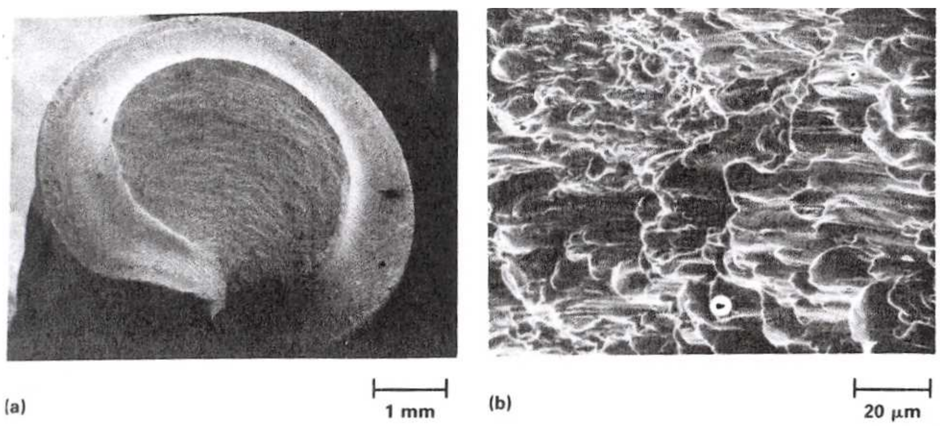
For each of the following sets of photographs (SEM), describe as much as you can. For example, "brittle fracture propagating in the direction shown" *(then include an arrow on the photo indicating fracture direction).* If possible, offer an explanation about what caused the failure.



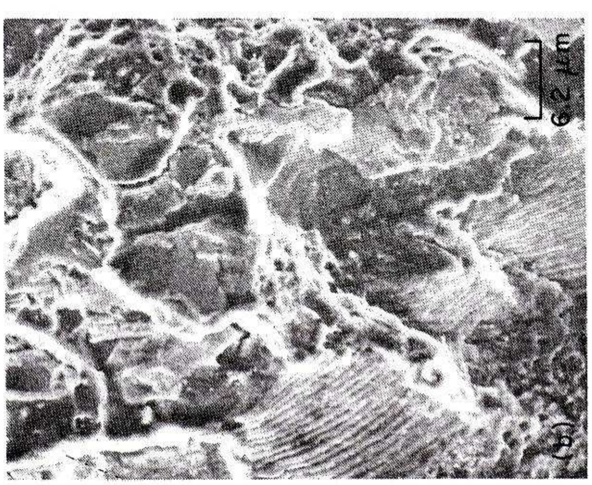
Prob 5 – Fracture surface of hot-rolled AISI 1040 steel. Three images of same location (marked A and B) but at increasing magnification.



Prob 6 – image of fracture surface of copper (750X)



Prob 7 – commercially pure titanium screw.



Prob 8 – aluminum alloy 2024-T851