3.22 Mechanical Properties of Materials
Spring 2008

Problem Set #6
Due: Friday, May 9 by 5:00 PM

1. Describe thoroughly yet concisely three (general) toughening mechanisms in materials. Be sure to include an example of each, and not to confuse (yield) strengthening with toughening. For one mechanism, show a fractograph and briefly note features in the fracture surface that illustrate how the mechanism works.

2. Lowhaphandu and Lewandowski [Scripta Mater. 38, 1811(1998)] studied the effect of crack tip radius on the stress intensity factor at failure for a specific material, as summarized in the graph below. (Note that they call crack tip radius "notch root radius" and stress intensity factor at failure "fracture toughness".)

   (a) Using Inglis' analysis of stress at the tip of an elliptical hole, calculate the stress at the crack tip (as a function of applied stress) for the largest and smallest crack tip radius considered. (This is an single edge-crack with initial crack length a of 25 mm.)

   (b) Are your results from part (a) consistent with the results in the graph below (i.e., consistent with the fact that at the largest crack tip radius we measure has the largest stress intensity factor)? Explain why they are or are not consistent.
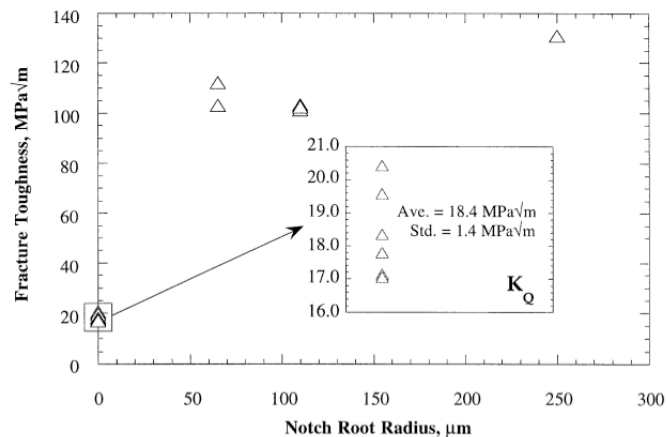
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3. For a single material (which follows Paris Law steady-state crack propagation with $m \neq 2$), you have tested three components with initial crack sizes a_o which failed with final crack sizes a_f (listed in the table below).

   (a) Assume the fatigue conditions of all components are uniaxial loading with $R = -1$ at a maximum stress of 100 MPa and a frequency f of 10 Hz. Draw $\sigma(t)$ for two complete loading cycles, and also draw the representative volume elements and associated stress states at the minimum and maximum $\sigma(t)$.

   (b) Compare the differences in fatigue lifetimes for the three components. Explain your findings in terms of crack growth rates. From this, what do you infer about how growth of cracks should be monitored in a material component put into application?

Component	$a_\circ$	a_f
A	2 mm	10 mm
B	0.5 mm	10 mm
C	2 mm	40 mm

(c) Comment on the average stress applied to this material, and why this is not counter to the reality that fatigue failure still occurs in all of these components.

4. With your special topic group, please prepare slides for a short presentation of your topic to the class, to be delivered on Tuesday, May 13. A template will be posted for your convenience on the wiki. Be as creative as you like, but please adhere to the guidelines to provide uniformity of details and keep to our time constraints.

Reminder that you will need to respond to 2 of 3 wiki questions on the last quiz (i.e., 2 that are not your own special topic). The questions will be based on content delivered in these presentations and related lecture/pset material from the semester. However, you will likely find it helpful and enjoyable to peruse the wiki pages of your colleagues to see more than they will have time to share in class.