MASSACHUSETTS INSTITUTE OF TECHNOLOGY
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2.002 MECHANICS AND MATERIALS II
HOMEWORK # 5

Distributed: Wednesday, April 7, 2004
Due: Wednesday, April 14, 2004

Problem 1

The typical properties of several steels that are being considered for use in bridges in Alaska, and therefore will have service temperatures as low as -60^oF, are as follows:

Steel (ASTM Grade)	Minimum Yield Strength (ksi)	Yield Strength at 60^oF,(ksi)	K_{Ic} at -60^oF, (ksi $\sqrt{\text{in}}$)
A36	36	44	60
A441	50	69	53
A572	50	57	100
A514	100	110	60

For a design stress of 0.6 of the *minimum yield strength* [to be encountered in service], compare the critical crack sizes for fast fracture at the design stress for each steel. Use an edge crack in a large plate for your analysis (note: for this geometry, the numerical value of the configuration correction factor is $Q = 1.12$). With which material would you choose to design? Discuss the tradeoffs you are aware of, including how your inspection technology might influence your decision.

Problem 2

A large thick plate of 7075-T651 aluminum alloy is examined by nondestructive techniques and is found to contain no detectable cracks. In current engineering practice, flaws less than 5 mm in length are not usually reliably detected in large engineering components. Assume that the plate contains an edge crack of length at this limit (5 mm) of detection, and determine if the plate will undergo general yielding or fail by fast fracture before general yielding occurs when subject to tensile loading normal to the presumed crack.

What is the stress at which failure would occur?

$$\sigma_y = 503\,\text{MPa}, \quad K_{Ic} = 27\,\text{MPa}\sqrt{\text{m}}.$$

Problem 3

Dowling text, problem 8.15, page 352 (Second Edition).

Problem 4

A bar of 4340 steel, of thickness $t = 12\,mm$ and width $w = 60\,mm$, is subjected to a cyclic bending moment that ranges from maximum value $M_{(\text{max})} = 4\,kNm$ to minimum value $M_{(\text{min})} = 0.8\,kNm$.

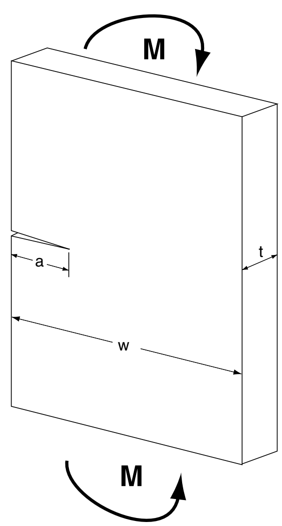

Figure 1: Schematic of edge-cracked specimen under bending.

The steel has Young's modulus $E = 208\,GPa$, Poisson ratio $\nu = 0.3$, tensile yield strength $\sigma_y = 1255\,MPa$, and ultimate tensile strength $UTS = 1295\,MPa$.

After 60,000 cycles of the loading described, the bar fractures, with failure due to a through-thickness edge crack of [failure] length $a_f = 14\,mm$, emanating from the "tensile side" of the bending stress field.

The stress intensity factor for a rectangular beam containing an edge crack of length "a" and subjected to bending moment "M" can be expressed as

$$K_I = Q\,\sigma_b\,\sqrt{\pi a},$$

where σ_b is the peak tensile bending stress in the uncracked beam, subjected to bending moment M, and the configuration correction factor can be taken as constant, $Q = 1.12$, providing the relative crack depth $a/w <\sim 0.3$.

- Estimate the fracture toughness of the 4340 steel.
- Based on your estimate, do you think that final failure took place under small-scale yielding conditions? Under crack-front plane strain conditions? Discuss.