MSE C212/ME C225
Deformation and Fracture of Engineering Materials
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Due: March 7, 2007

Homework No. 2

1. A standard compact tension test specimen has been designed and tested according to the ASTM E399 procedure. Specimen dimensions were W = 10 cm, B = 5 cm, and a = 5 cm. In the test, a smooth (no pop-in) type of load versus displacement test record was obtained, and measures of the maximum load P_{max} and a critical load measurement point P_Q were determined. These values were: P_{max} = 105 kN and P_Q =100 kN. Assuming all other E399 requirements regarding specimen dimensions and the establishment of the fatigue starter crack were met, determine the critical value of the stress intensity. Does this value meet conditions for a valid K_{Ic} test if the material yield strength is 700 MPa? if it is 350 MPa?

   [In the equation $K_Q = Y (P_Q / B \sqrt{W})$, where Y = f(a/W), E399 gives Y = 9.605 for this a/W]

2. You are the materials scientist for a design group which is working on a new, high-speed intercity railroad passenger car. The structural engineer on the project asks you to select a structural material for the car underframe. She has several candidate materials in mind, all of which have adequate yield strength and other properties. She reminds you that in this project, the design stress cannot exceed one-third of the yield strength, and then gives you the following data which her team has collected from handbooks:

Alloy type	Alloy	Product form	σ_y / ρ, inch *	σ_y / E **
Aluminum	A357-T6	Casting	450,000	0.00505
Aluminum	7075-T6	Forging	658,000	0.00725
Titanium	6 Al-4 V	Forging	752,000	0.00746
Steel	4340	Rolled & HT	636,000	0.00602

*ratio of yield strength to density **ratio of yield strength to Young's modulus

The structural engineer remarks to you that you should apply fracture toughness criteria if possible. Your reference materials provide you with the following K_{Ic} values, in ksi√in: 7075-T6, 20; Ti-6-4, 70; A357, 11; 4340, 100. Ultimate tensile strengths in ksi are: 7075, 76; 4340, 215; 6-4, 145; A357, 55 (in each case, for the relevant material condition).
The underframe parts under highest stress will have to have about 0.25-inch thickness. Which material do you recommend? Why? How does your choice affect car weight? What will be the critical crack length in service? What other material characteristics might be important in a choice like this? (You may assume $K_I = \sigma \sqrt{\pi a}$)