MSEG 302 HW #7 Spring 2018

**1. A magnesium oxide (MgO) component must not fail when a tensile stress of 10 MPa is applied. Estimate the maximum allowable surface crack length if the surface energy of MgO is 1.0 J/m2.**

From equation 8.3 in text and from class notes:

c = (2 E / a)1/2

This problem gives c, and asks to solve for the corresponding critical surface crack size a. Squaring and rearranging the equation 8.3 to solve for a gives:

a = 2 E  /  c2

The modulus of MgO is ~225 GPa (Table 12.5 in text, or Wikipedia). Substituting these values, and recognizing that 1 Pa = 1 J/m3 gives:

a = 2 (225 x 109 J/m3) (1 J/m2) / 3.14159 / (10 x 106 J/m3)2 = 0.0014 m = 1.4 mm

**2. A wing component on an aircraft is fabricated from an aluminum alloy that has a plane-strain fracture toughness KIc of 25 MPa m1/2. It has been determined that fracture results at a stress of 110 MPa when the maximum internal crack length is 8 mm. For this same component and alloy, estimate the stress level at which fracture would occur for a critical internal crack length of 6 mm.**

Equation 8.4 gives:

Kc = Y c ( a)1/2

Since this is an internal crack, a = 8 mm / 2 = 4 mm.

So 25 MPa m1/2 = Y (110 MPa) ( 4 x 10-3 m)1/2, so Y = 2.027

solving for c = Kc/(Y ( a)1/2) = 25 MPa m1/2 / 2.027 / ( 3 x 10-3 m)1/2

so c = 127 MPa, which is larger, as expected.

Note: it is also possible to solve this problem using the total internal crack lengths (8 mm and 6 mm in this case) , this will simply change the corresponding value of Y that is determined but will not change the final answer (127 MPa).

**3. A large plate is fabricated from a steel alloy that has a plane strain fracture toughness KIc of 80 MPa m1/2. If the plate is exposed to a tensile stress of 350 MPa during service, determine the minimum length of a surface crack that will lead to failure, assuming a value of 1.0 for Y.**

Solving equation 8.4 for a and substituting values gives:

a = (Kc / Y c)2 / (80 MPa m1/2 / 350 MPa)2/ = 0.0166 m = 16.6 mm

**4. The fatigue data for a steel alloy are given as follows:**

**Stress Amplitude (MPa) Cycles to failure**

**470 104**

**440 3 x 104**

**390 105**

**350 3 x 105**

**310 106**

**290 3 x 106**

**290 107**

**290 108**

**a. Construct an S-N (stress amplitude vs. logarithm of cycles to failure) from these data.**

**b. What is the fatigue limit for this alloy?**

**c. Estimate fatigue lifetimes at stress amplitudes of 415 MPa and 275 MPa.**

**d. Estimate fatigue strengths at 2 x 104 and 6 x 105 cycles.**



a. graph shown above

b. fatigue limit is 290 MPa

c. from graph, at 415 MPa, N ~ 55000 cycles; at 275 MPa, N -> infinity

d. from graph, at 2 x 104 cycles, strength ~ 450 MPa; at 6 x 105 cycles strength ~ 325 MPa

**5. A cylindrical sample is constructed from an S-590 alloy, and is exposed to a tensile load of 20,000 N. What is the minimum diameter required for it to have a rupture lifetime of at least 100 hrs at 925 C?**

From Figure 8.31, this requires stress less than 70 MPa. = F/A, so Amin = F /  = 2.86 10-4 m2. From A =  d2/4 for a cylinder, gives d = 0.019 m = 19 mm

**6. A certain nickel alloy held at a constant temperature of 538 C shows a steady state creep rate of 10-7 hr-1 at a stress level of 22 MPa, and a steady-state creep rate of 10-6 hr-1 at a stress level of 36 MPa. Estimate the stress level at which the steady-state creep rate would be 10-5 hr-1.**

From equation 8.25, K2 n exp(-Qc / RT) = K3 n at a constant T, where K3 is another constant.This means that:

10-7 hr-1 = K3 (22 MPa)n, and 10-6 hr-1 = K3 (36 MPa)n.

Taking log of both sides of the equation gives:

Log[ Log[K3] + n Log[]

so Log[ Log[K3] + n Log[], and Log[ Log[K3] + n Log[], so solving for n:

n = (Log[- Log[/(Log[]-Log[]) = 4.67

Solving for K3 gives K3 = 5.38 x 10-14. So solving 10-5 = K3 n gives = 58.7 MPa