**IET 307: Materials Science**

HW 5 (based on chapter 8), Due by 11.55 PM, October 3’rd, 2010

100 points

1. Explain the S-N curve. What is the endurance limit for aluminum? (10 points)

S-N CURVE: fatigue is the progressive and localized structural damage that occurs when a material is subjected to cyclic loading. The maximum stress values are less than the ultimate tensile stress limit and may be below the yield stress limit of the material.

Aluminum has no endurance limit.

2. Acute angles, small surface cuts and internal macroscopic defects of mechanical components often lead to a premature fracture under material’s actual strength because of “stress concentration” (or so-called “stress raiser”). Please use the singularity of 1/r1/2 to explain the meaning of stress concentration in front of a crack. (10 points)

Stress concentration is directly related to the length of the crack and more importantly the sharpness of the crack. The farther away from the crack the lower the stress will be.

3. A steel plate satisfies a plane strain condition. It has *KIC*=85,000 psi in1/2 and f=1.12. X-ray finds that there exist cracks of up to 0.1 inch inside the steel. What is the maximum tensile stress that the steel can withstand? (10 points)

85000psi2/ (1.12x √.1π ½  ) = 135402 psi

4. Explain in detail brittle and ductile fracture. What is the difference in microscopic morphology between ductile and brittle fractures? (10 points)

The fracture is termed brittle or ductile depending on whether the elongation is large or small.

DUCTILE FRACTURE

* MICROSCOPICALLY: the fracture surface is characteristic of transgranular rupture; it consists of plastic dimples which show substantial plastic deformation during fracture

BRITTLE FRACTURE

* MICROSCOPICALLY: when a fracture occurs along grain boundaries, it has a rocky looking morphology; if it occurs by cutting through grains, it often occurs along close packed atomic planes and shows a Chevron pattern

5. What are the three stages of fatigue? Explain each one of them in detail. (10 points)

NUCLEATION: a small crack nucleates at the weakest point of a component, often at tiny scratches or pits on the surface where the maximum tensile stress appears

CRACK PROPAGATION: the crack propagates step by step under repetitive stress, which makes fracture surface show a beach or clamshell mark morphology

FRACTURE: as the crack grows, the remaining cross sectional area becomes smaller. At a certain point, the remaining area isn’t big enough to support the external stress, which is when the sudden rupture occurs.

6. Please describe the three regimes of creep. Explain each one of them in detail. (10 points)

PRIMARY: a short period in which the strain rate decreases with time; it is a transient period for establishing a steady-state creep

STEADY STATE: a long period in which the strain rate is constant; the most practical and best understood regime

TERTIARY: period in which the strain rate accelerates primarily due to a decrease in the cross-sectional area of the specimen

7. Define endurance limit. Please look at the S-N curve to the right and figure out the endurance limit for this material. Also, if we want the part to work for one million cycles, what maximum tensile stress can we apply? (10 points)

ENDURANCE LIMIT: MPa below which the material never fails, no matter how large the number of cycles is

The endurance limit for the material is at about 150MPa.

The maximum tensile stress that can be applied is about 300MPa.

8. A polystyrene component must not fail when a tensile stress of 1.25 MPa is applied. Determine the maximum allowable surface crack length if the surface energy of polystyrene is 0.50 J/m2. Assume a modulus of elasticity of 3.0 GPa. (10 points)

$$a=\frac{2(3×10^{9})(0.3)}{(3.14)(1.25×10^{6})^{2}}$$

$$a=0.0367 mm$$

9. An aluminum alloy that has a plain strain fracture toughness of 25,000 psi (in.)1/2 fails when a stress of 42,000 psi is applied. Observation of the fracture surface indicates that fracture began at the surface of the part. Estimate the size of the flaw that initiated fracture. Assume that f = 1.1 (10 points).

$$a=\frac{1}{3.14}\left(\frac{25000}{42000\left(1.1\right)}\right)$$

$$a=0.093 in$$

10. Concrete has exceptional strength in compression but it fails rather easily in tension. Explain why this happens in detail. (10 points)

Concrete is a brittle material. It has exceptional compression strength because of the aggregate carrying the compression load. It fails easily in tension because the cement holding the aggregate in place can crack. Reinforcing the concrete with steel bars or adding fiber can help carry the tensile loads.