

- 7-2 A ceramic matrix composite contains internal flaws as large as 0.001 cm in length. The plane strain fracture toughness of the composite is $45 \text{ MPa}\sqrt{\text{m}}$ and the tensile strength is 550 MPa. Will the flaw cause the composite to fail before the tensile strength is reached? Assume that $f = 1$.

Solution: Since the crack is internal, $2a = 0.001 \text{ cm} = 0.00001 \text{ m}$. Therefore

$$a = 0.000005 \text{ m}$$

$$K_{Ic} = f\sigma\sqrt{\pi a} \quad \text{or} \quad \sigma = K_{Ic} / f\sqrt{\pi a}$$

$$\sigma = (45 \text{ MPa}\sqrt{\text{m}}) / (1)\sqrt{\pi(0.000005 \text{ m})} = 11,354 \text{ MPa}$$

63

64 The Science and Engineering of Materials Instructor's Solutions Manual

7-2) \longrightarrow

The applied stress required for the crack to cause failure is much larger than the tensile strength of 550 MPa. Any failure of the ceramic should be expected due to the massive overload, not because of the presence of the flaws.

- 7-3 An aluminum alloy that has a plane strain fracture toughness of $25,000 \text{ psi}\sqrt{\text{in}}$ 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 $f = 1.1$.

Solution: $K_{Ic} = f\sigma\sqrt{\pi a} \quad \text{or} \quad a = (1/\pi)[K_{Ic} / f\sigma]^2$

$$a = (1/\pi)[25,000 \text{ psi}\sqrt{\text{in}} / (1.1)(42,000 \text{ psi})]^2 = 0.093 \text{ in.}$$

3/13/06

7-27 The high-strength steel in Figure 7-21 is subjected to a stress alternating at 200 revolutions per minute between 600 MPa and 200 MPa (both tension). Calculate the growth rate of a surface crack when it reaches a length of 0.2 mm in both m/cycle and m/s. Assume that $f = 1.0$.

Solution: For the steel, $C = 1.62 \times 10^{-12}$ and $n = 3.2$. The change in the stress intensity factor ΔK is

$$\Delta K = f \Delta \sigma \sqrt{\pi a} = \frac{1.0}{1.0} (600 \text{ MPa} - 200 \text{ MPa}) \sqrt{\pi (0.0002 \text{ m})} = 10.02 \text{ MPa}\sqrt{\text{m}}$$

The crack growth rate is

$$da/dN = 1.62 \times 10^{-12} (\Delta K)^{3.2}$$

$$da/dN = 1.62 \times 10^{-12} (10.02)^{3.2} = 2.59 \times 10^{-9} \text{ m/cycle}$$

66 The Science and Engineering of Materials Instructor's Solutions Manual

$$da/dt = (2.59 \times 10^{-9} \text{ m/cycle}) (200 \text{ cycles/min}) / 60 \text{ s/min}$$

$$da/dt = 8.63 \times 10^{-9} \text{ m/s}$$