

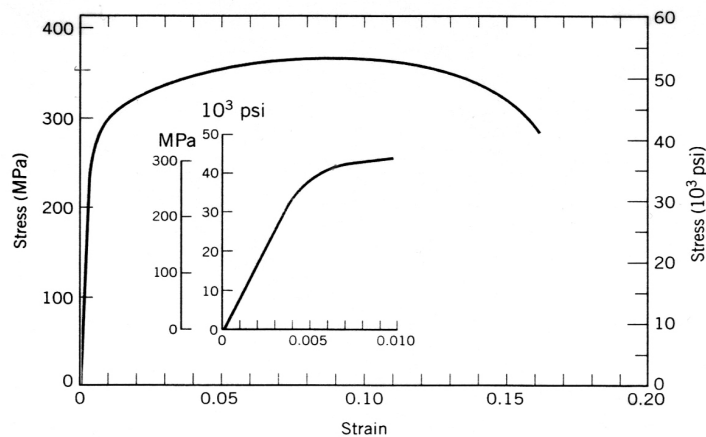
HOMework 1.

solutions



Practice Problems

1. Given the engineering stress-engineering strain diagram for an aluminum alloy initially 11 mm in diameter and 50 mm in length, calculate the following:



Tensile stress-strain behavior for an aluminum alloy.

- a. Percent elongation at fracture

$$\circ \quad \%EL_{\text{at fracture}} = \frac{\Delta l}{l_0} \times 100 = \varepsilon_{\text{max}} \times 100 \cong 16.2\%$$

- b. Percent elongation after fracture

$$\circ \quad \%EL_{\text{after fracture}} = (\varepsilon_{\text{max}} - \varepsilon_{\text{recovered}}) \times 100 \cong 15.7\% \text{ (a little elastic strain is recovered)}$$

- c. True stress at an engineering strain of 0.04

$$\circ \quad \sigma_T = \sigma(1 + \varepsilon) \cong 345 \text{ MPa}(1 + 0.04) = 359 \text{ MPa}$$

- d. True strain at an engineering strain of 0.04

$$\circ \quad \varepsilon_T = \ln(1 + \varepsilon) = 0.039$$

- e. Elongation (Δl) when a load of 25 kN is applied.

$$\circ \quad \text{A load of 25 kN corresponds to a stress of about 263 MPa. At this stress, the engineering strain is about 0.0048, and the elongation is } 0.0048 \times 50 \text{ mm} = 0.24 \text{ mm}$$

2. Askeland (4th ed.) 6-9. Why does silly putty break when you stretch it very quickly?

Silly Putty is a viscoelastic material. As such, the deformation of Silly Putty is significantly affected by strain rate. When Silly Putty is deformed slowly (low strain rate), its polymeric chains are allowed to uncoil, detangle, and move relative to one another, and we observe ductile fracture with great plastic deformation. When Silly Putty is deformed quickly (high strain rate), the polymeric chains are not able to move relative to each other, bonds are broken, and the Silly Putty exhibits brittle fracture.

3. Askeland (4th ed.) 6-25. A force of 100,000 N is applied to a 10 mm x 20 mm iron bar having a yield strength of 400 MPa and a tensile strength of 480 MPa. Determine (a) whether the bar will plastically deform and (b) whether the bar will experience necking.

6-25 A force of 100,000 N is applied to a 10 mm × 20 mm iron bar having a yield strength of 400 MPa and a tensile strength of 480 MPa. Determine (a) whether the bar will plastically deform and (b) whether the bar will experience necking.

Solution: (a) First determine the stress acting on the wire:

$$\sigma = F/A = 100,000 \text{ N} / (10 \text{ mm})(20 \text{ mm}) = 500 \text{ N/mm}^2 = 500 \text{ MPa}$$

Because σ is greater than the yield strength of 400 MPa, the wire will plastically deform.

(b) Because σ is greater than the tensile strength of 480 MPa, the wire will also neck.

4. Askeland (4th ed.) 6-25 (yes, there are two 6-25 problems). Calculate the maximum force that a 0.2 in. diameter rod of Al₂O₃, having a yield strength of 35,000 psi, can withstand with no plastic deformation. Express your answer in pounds and Newtons.

6-25(c) Calculate the maximum force that a 0.2-in. diameter rod of Al₂O₃, having a yield strength of 35,000 psi, can withstand with no plastic deformation. Express your answer in pounds and newtons.

Solution: $F = \sigma A = (35,000 \text{ psi})(\pi/4)(0.2 \text{ in.})^2 = 1100 \text{ lb}$

$$F = (1100 \text{ lb})(4.448 \text{ N/lb}) = 4891 \text{ N}$$

5. Askeland (4th ed.) 6-42. A three point bend test is performed on a block of silicon carbide that is 10 cm long, 1.5 cm wide, and 0.6 cm thick and is resting on two supports 7.5 cm apart. The sample breaks when a deflection of 0.09 mm is recorded. Calculate (a) the force that caused the fracture and (b) the flexural strength. The flexural modulus for silicon carbide is 480 GPa. Assume that no plastic deformation occurs.

6-42 A three-point bend test is performed on a block of silicon carbide that is 10 cm long, 1.5 cm wide, and 0.6 cm thick and is resting on two supports 7.5 cm apart. The sample breaks when a deflection of 0.09 mm is recorded. Calculate (a) the force that caused the fracture and (b) the flexural strength. The flexural modulus for silicon carbide is 480 GPa. Assume that no plastic deformation occurs.

Solution: (a) The force F required to produce a deflection of 0.09 mm is

$$F = (\text{flexural modulus})(4wh^3\delta)/L^3$$

$$F = (480,000 \text{ MPa})(4)(15 \text{ mm})(6 \text{ mm})^3(0.09 \text{ mm}) / (75 \text{ mm})^3$$

$$F = 1327 \text{ N}$$

$$\begin{aligned} \text{(b) flexural strength} &= 3FL/2wh^2 = (3)(1327 \text{ N})(75 \text{ mm})/(2)(15 \text{ mm})(6 \text{ mm})^2 \\ &= 276 \text{ MPa} \end{aligned}$$

6. Askeland (4th ed.) 6-47. What determines or controls the strength of ceramics and glasses?

The strength of ceramics and glasses is determined primarily by the size and distribution of defects in the material. Unlike ductile metals, which can typically undergo ductile fracture even when small (or sometimes large) defects are present, brittle materials such as ceramics and glasses are highly susceptible to fracture due to stress concentrations created by flaws. It's really amazing to estimate the theoretical strength of ceramics and glasses based on interatomic bond energies, then compare these theoretical strength values to actual strengths in manufactured ceramic and glass products. The presence of defects can drop the theoretical strength values by orders of magnitude!

Open-Ended Problems

1. **Liquidmetal.** Go to www.liquidmetal.com, click on the “The Technology” tab, and view the video. Alternatively, check out the physical Liquidmetal demo in the materials science lab. Based on your observations of the behavior of the Liquidmetal and stainless steel cylinders in response to the bearing ball loading, sketch stress-strain curve for both materials (on one set of axes).

Schematic stress-strain curves for Liquidmetal and stainless steel are shown below. For the Liquidmetal to behave the way it does, it needs to be able to absorb a lot of energy from the bearing ball through elastic deformation and give it back to the ball upon recovery of the elastic deformation. We don't expect any plastic deformation in the Liquidmetal, since plastically deforming metal takes energy and isn't recovered. Thus, we expect the Liquidmetal to have a **high yield strength**. The “springiness” of the Liquidmetal comes via a **low modulus of elasticity**. Think about a trampoline with incredibly stiff springs (like those on your car's shock absorbing system) versus one with lower spring constant springs. Which one would send you flying higher? If you prefer, you could think of the properties in terms of the **resilience**, which is defined as the area under the stress-strain curve up to yielding.

Stainless steel exhibits a stress-strain curve characterized by a low yield strength and relatively high modulus. If you look closely at the surface of the stainless steel, you'll notice tiny dents in the metal. This indicates that plastic deformation occurs when the ball hits the stainless steel. The plastic deformation takes energy from the ball, but the energy goes into deforming the stainless steel and is not recovered. The resilience of stainless steel is very low compared to the Liquidmetal.

