Assignment #2

Material and Manufacturing Processes (446.305A) Fall 2014, Prof. Ahn, Sung-Hoon
Out: October 7, 2014 / Due: 6PM, October 14, 2014 (Bldg 301, Room 1405)

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1. The unit cells shown in Figs. 3.2a-c can be represented by hard-ball or hard-sphere models, similar to tennis balls arranged in various configurations in a box. In such an arrangement, the atomic packing factor (APF) is defined as the ratio of the volume of atoms to the volume of the unit cell. Find APF for the bcc structure, fcc structure and hcp structure.

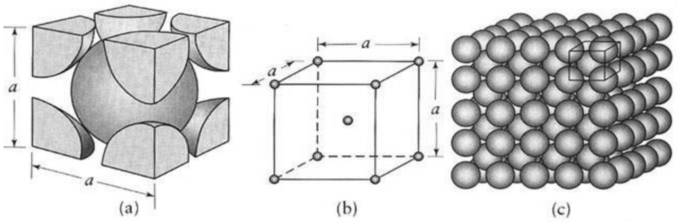


FIGURE 3.2a The body-centered cubic (bcc) crystal structure: (a) hard-ball model; (b) unit cell; and (c) single crystal with many unit cells. *Source*: Courtesy of Dr. William G. Moffatt.

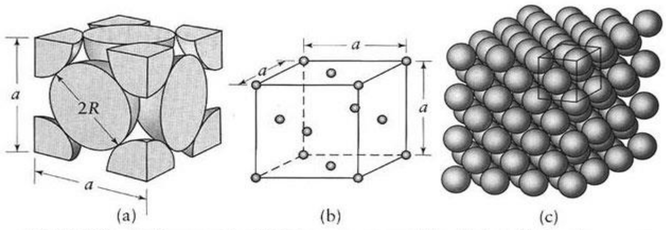


FIGURE 3.2b The face-centered cubic (fcc) crystal structure: (a) hard-ball model; (b) unit cell; and (c) single crystal with many unit cells. *Source*: Courtesy of Dr. William G. Moffatt.

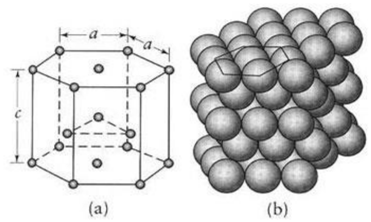


FIGURE 3.2c The hexagonal close-packed (hcp) crystal structure: (a) unit cell; and (b) single crystal with many unit cells. *Source*: Courtesy of Dr. William G. Moffatt.

2. Calculate the theoretical (a) shear strength and (b) tensile strength for aluminum, plain-carbon steel, and tungsten. Estimate the ratios of their theoretical strength to actual strength.

Material	E (GPa)	ν
Aluminum	79	0.34
Plain-carbon steel	200	0.33
Tungsten	400	0.27

3. A strip of metal is reduced in thickness by cold working from 25mm to 15mm. A similar strip is reduced from 25mm to 10mm. Which one of these strips will recrystallize at a lower temperature? Why?

4. Assume that a steel rule expands by 1 % because of an increase in environmental temperature. What will be the indicated diameter of a shaft whose actual diameter is 70.00 mm?

5. In order to make a high-pressure metal gas tank for hydrogen fuel, it is necessary to consider variable properties of material. Select material for spherical tank (diameter = 50cm, thickness of wall = 1cm) which should withstand 160atm, and discuss the reason for your selection. (Search specific properties on the internet)

TABLE 2.1

Typical Mechanical Properties of Various Materials at Room Temperature

	E (GPa)	*Y* (MPa)	UTS (MPa)	Elongation in 50 mm (%)	Poisson's Ratio (ν)
METALS (WROUGHT)					
Aluminum and its alloys	69–79	35–550	90–600	45–5	0.31–0.34
Copper and its alloys	105–150	76–1100	140–1310	65–3	0.33–0.35
Lead and its alloys	14	14	20–55	50–9	0.43
Magnesium and its alloys	41–45	130–305	240–380	21–5	0.29–0.35
Molybdenum and its alloys	330–360	80–2070	90–2340	40–30	0.32
Nickel and its alloys	180–214	105–1200	345–1450	60–5	0.31
Steels	190–200	205–1725	415–1750	65–2	0.28–0.33
Stainless steels	190–200	240–480	480–760	60–20	0.28–0.30
Titanium and its alloys	80–130	344–1380	415–1450	25–7	0.31–0.34
Tungsten and its alloys	350–400	550–690	620–760	0	0.27
NONMETALLIC MATERIALS					
Ceramics	70–1000	–	140–2600	0	0.2
Diamond	820–1050	–	–	–	–
Glass and porcelain	70–80	–	140	0	0.24
Rubbers	0.01–0.1	–	–	–	0.5
Thermoplastics	1.4–3.4	–	7–80	1000–5	0.32–0.40
Thermoplastics, reinforced	2–50	–	20–120	10–1	–
Thermosets	3.5–17	–	35–170	0	0.34
Boron fibers	380	–	3500	0	–
Carbon fibers	275–415	–	2000–5300	1–2	–
Glass fibers (S, E)	73–85	–	3500–4600	5	–
Kevlar fibers (29, 49, 129)	70–113	–	3000–3400	3–4	–
Spectra fibers (900, 1000)	73–100	–	2400–2800	3	–

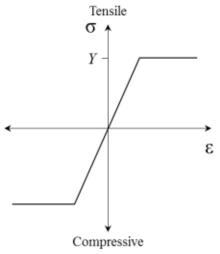
Note: In the upper table, the lowest values for *E*, *Y*, and UTS and the highest values for elongation are for the pure metals. Multiply GPa by 145,000 to obtain psi, and MPa by 145 to obtain psi. For example, 100 GPa = 14,500 ksi, and 100 MPa = 14,500 psi.

TABLE 3.3

Room-Temperature Mechanical Properties and Typical Applications of Annealed Stainless Steels

AISI (UNS)	Ultimate Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)	Characteristics and Typical Applications
303 (S30300)	550–620	240–260	50–53	Screw-machine products, shafts, valves, bolts, bushings, and nuts; aircraft fittings; rivets; screws; studs.
304 (S30400)	565–620	240–290	55–60	Chemical and food-processing equipment, brewing equipment, cryogenic vessels, gutters, downspouts, and flashings.
316 (S31600)	550–590	210–290	55–60	High corrosion resistance and high creep strength. Chemical and pulp-handling equipment, photographic equipment, brandy vats, fertilizer parts, ketchup-cooking kettles, and yeast tubs.
410 (S41000)	480–520	240–310	25–35	Machine parts, pump shafts, bolts, bushings, coal chutes, cutlery, fishing tackle, hardware, jet engine parts, mining machinery, rifle barrels, screws, and valves.
416 (S41600)	480–520	275	20–30	Aircraft fittings, bolts, nuts, fire extinguisher inserts, rivets, and screws.

6. Draw axial stress profile through thickness of a beam under bending. Assume the material follows linear elastic-perfectly plastic stress-strain curve. The beam has rectangular cross section with width b and thickness h.



(a) When maximum stress is lower than yield strength ($\sigma_{\max} < \sigma_Y$)

(b) When maximum stress is in plastic zone, but some parts of the beam are in elastic region

(c) Calculate required bending moment for unloading (Hint: Assume that the end point of elastic range from neutral axis is z_Y.). Draw axial stress profile when bending moment in opposite direction is applied to unload. Compare the stress profile with the profile in problem (b).

(d) Draw residual stress profile through thickness of the beam.