ENGR 145 Fall 2023
Homework Set #6
Due Wednesday, Oct. 18

CR Questions and Problems:

7.7 For a brass alloy, the stress at which plastic deformation begins is 345 MPa (50,000 psi), and the modulus of elasticity is 103 GPa (15.0×10^6 psi).

(a) What is the maximum load that can be applied to a specimen with a cross-sectional area of 130 mm^2 (0.2 $in.^2$) without plastic deformation?

(b) If the original specimen length is 76 mm (3.0 in.), what is the maximum length to which it can be stretched without causing plastic deformation?

7.62 From the stress–strain data for poly(methyl methacrylate) shown in Figure 7.24, determine the modulus of elasticity and tensile strength at room temperature [20°C (68°F)], and compare these values with those given in Tables 7.1 and 7.2.

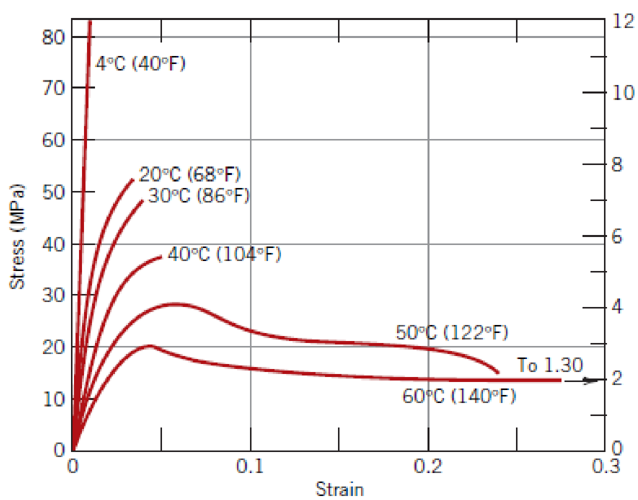

Figure 7.24 The influence of temperature on the stress–strain characteristics of poly(methyl methacrylate). (From T. S. Carswell and H. K. Nason, "Effect of Environmental Conditions on the Mechanical Properties of Organic Plastics," in *Symposium on Plastics,* American Society for Testing and Material Philadelphia, 1944. Copyright, ASTM, 1916 Race Street, Philadelpl PA 19103. Reprinted with permission.)

Table 7.1 Room-Temperature Elastic and Shear Moduli and Poisson's Ratio for Various Materials

	Modulus of Elasticity		*Shear Modulus*		
Material	*GPa*	*10^6 psi*	*GPa*	*10^6 psi*	*Poisson's Ratio*
	Metal Alloys				
Tungsten	407	59	160	23.2	0.28
Steel	207	30	83	12.0	0.30
Nickel	207	30	76	11.0	0.31
Titanium	107	15.5	45	6.5	0.34
Copper	110	16	46	6.7	0.34
Brass	97	14	37	5.4	0.34
Aluminum	69	10	25	3.6	0.33
Magnesium	45	6.5	17	2.5	0.35
	Ceramic Materials				
Aluminum oxide (Al_2O_3)	393	57	—	—	0.22
Silicon carbide (SiC)	345	50	—	—	0.17
Silicon nitride (Si_3N_4)	304	44	—	—	0.30
Spinel ($MgAl_2O_4$)	260	38	—	—	—
Magnesium oxide (MgO)	225	33	—	—	0.18
Zirconia (ZrO_2)[a]	205	30	—	—	0.31
Mullite ($3Al_2O_3$-$2SiO_2$)	145	21	—	—	0.24
Glass–ceramic (Pyroceram)	120	17	—	—	0.25
Fused silica (SiO_2)	73	11	—	—	0.17
Soda–lime glass	69	10	—	—	0.23
	Polymers[b]				
Phenol-formaldehyde	2.76–4.83	0.40–0.70	—	—	—
Poly(vinyl chloride) (PVC)	2.41–4.14	0.35–0.60	—	—	0.38
Poly(ethylene terephthalate) (PET)	2.76–4.14	0.40–0.60	—	—	0.33
Polystyrene (PS)	2.28–3.28	0.33–0.48	—	—	0.33
Poly(methyl methacrylate) (PMMA)	2.24–3.24	0.33–0.47	—	—	0.37–0.44
Polycarbonate (PC)	2.38	0.35	—	—	0.36
Nylon 6,6	1.59–3.79	0.23–0.55	—	—	0.39
Polypropylene (PP)	1.14–1.55	0.17–0.23	—	—	0.40
Polyethylene—high density (HDPE)	1.08	0.16	—	—	0.46
Polytetrafluoroethylene (PTFE)	0.40–0.55	0.058–0.080	—	—	0.46
Polyethylene—low density (LDPE)	0.17–0.28	0.025–0.041	—	—	0.33–0.40

Table 7.2 Room-Temperature Mechanical Properties (in Tension) for Various Materials

Material	Yield Strength		Tensile Strength		Ductility, %EL [in 50 mm (2 in.)][a]
	MPa	ksi	MPa	ksi	
Metal Alloys[b]					
Molybdenum	565	82	655	95	35
Titanium	450	65	520	75	25
Steel (1020)	180	26	380	55	25
Nickel	138	20	480	70	40
Iron	130	19	262	38	45
Brass (70 Cu–30 Zn)	75	11	300	44	68
Copper	69	10	200	29	45
Aluminum	35	5	90	13	40
Ceramic Materials[c]					
Zirconia (ZrO_2)[d]	—	—	800–1500	115–215	—
Silicon nitride (Si_3N_4)	—	—	250–1000	35–145	—
Aluminum oxide (Al_2O_3)	—	—	275–700	40–100	—
Silicon carbide (SiC)	—	—	100–820	15–120	—
Glass–ceramic (Pyroceram)	—	—	247	36	—
Mullite ($3Al_2O_3$–$2SiO_2$)	—	—	185	27	—
Spinel ($MgAl_2O_4$)	—	—	110–245	16–36	—
Fused silica (SiO_2)	—	—	110	16	—
Magnesium oxide (MgO)[e]	—	—	105	15	—
Soda–lime glass	—	—	69	10	—
Polymers					
Nylon 6,6	44.8–82.8	6.5–12	75.9–94.5	11.0–13.7	15–300
Polycarbonate (PC)	62.1	9.0	62.8–72.4	9.1–10.5	110–150
Poly(ethylene terephthalate) (PET)	59.3	8.6	48.3–72.4	7.0–10.5	30–300
Poly(methyl methacrylate) (PMMA)	53.8–73.1	7.8–10.6	48.3–72.4	7.0–10.5	2.0–5.5
Poly(vinyl chloride) (PVC)	40.7–44.8	5.9–6.5	40.7–51.7	5.9–7.5	40–80
Phenol-formaldehyde	—	—	34.5–62.1	5.0–9.0	1.5–2.0
Polystyrene (PS)	25.0–69.0	3.63–10.0	35.9–51.7	5.2–7.5	1.2–2.5
Polypropylene (PP)	31.0–37.2	4.5–5.4	31.0–41.4	4.5–6.0	100–600
Polyethylene—high density (HDPE)	26.2–33.1	3.8–4.8	22.1–31.0	3.2–4.5	10–1200
Polytetrafluoroethylene (PTFE)	13.8–15.2	2.0–2.2	20.7–34.5	3.0–5.0	200–400
Polyethylene—low density (LDPE)	9.0–14.5	1.3–2.1	8.3–31.4	1.2–4.55	100–650

9.14 The tensile strength of brittle materials may be determined using a variation of Equation 9.1. Compute the critical crack tip radius for a glass specimen that experiences tensile fracture at an applied stress of 70 MPa (10,000 psi). Assume a critical surface crack length of 10^{-2} mm and a theoretical fracture strength of $E/10$, where E is the modulus of elasticity.

From your book:

If it is assumed that a crack is similar to an elliptical hole through a plate and is oriented perpendicular to the applied stress, the maximum stress, σ_m, occurs at the crack tip and may be approximated by

$$\sigma_m = 2\sigma_0\left(\frac{a}{\rho_t}\right)^{1/2} \tag{9.1}$$

where σ_0 is the magnitude of the nominal applied tensile stress, ρ_t is the radius of curvature of the crack tip (Figure 9.8*a*), and a represents the length of a surface crack, or half of the length of an internal crack. For a relatively long microcrack that has a small tip radius of curvature, the factor $(a/\rho_t)^{1/2}$ may be very large. This yields a value of σ_m that is many times the value of σ_0.

Also…

The profile of a stress-strain curve varies considerably depending upon the material studied. Using your book, lecture notes and a bit of outside research, sketch stress-strain curve for the following materials with a brief explanation of each: (1) a ductile metal such as copper; (2) a ductile plastic such as polycarbonate; (3) a rubber band; and (4) common window glass.