

Determine the principal stresses for the stress state

$$\sigma_i = \begin{bmatrix} 10 & -3 & 4 \\ -3 & 5 & 2 \\ 4 & 2 & 7 \end{bmatrix}$$

Solution:  $I_1 = 10+5+7=32$ ,  $I_2 = -(50+35+70)+9+4+16 = -126$ ,  $I_3 = 350-48-40-80-63 = 119$ ;  $\sigma^3 - 22\sigma^2 - 126\sigma - 119 = 0$ . A trial and error solution gives  $\sigma = 13.04$ .

Factoring out 13.04,  $\sigma^2 - 8.96\sigma + 9.16 = 0$ . Solving:  $\sigma_1 = 13.04$ ,  $\sigma_2 = 7.785$ ,  $\sigma_3 = 1.175$ .

1-2 A 5-cm. diameter solid shaft is simultaneously subjected to an axial load of 80 kN and a torque of 400 Nm.

a. Determine the principal stresses at the surface assuming elastic behavior.

b. Find the largest shear stress.

Solution: a. The shear stress,  $\tau$ , at a radius,  $r$ , is  $\tau = \tau_0 r/R$  where  $\tau_0$  is the shear stress at the surface  $R$  is the radius of the rod. The torque,  $T$ , is given by  $T = \int 2\pi r \tau^2 dr = (2\pi \tau_0^2 / R) \int r^2 dr = \pi \tau_0^2 R^3 / 2$ . Solving for  $\tau_0 = \tau_{0s}$ ,  $\tau_{0s} = 2T/(\pi R^3) = 2(400\text{N})/(\pi 0.025^3) = 16 \text{ MPa}$

The axial stress is  $16\text{MPa}/(\pi 0.025^2) = 4.07 \text{ MPa}$

$$\sigma_1, \sigma_2 = 4.07/2 \pm [(4.07/2)^2 + (16/2)^2]^{1/2} = 1.029, -0.622 \text{ MPa}$$

b. the largest shear stress is  $(1.029 + 0.622)/2 = 0.925 \text{ MPa}$

A long thin-wall tube, capped on both ends is subjected to internal pressure. During elastic loading, does the tube length increase, decrease or remain constant?

Solution: Let  $y$  = hoop direction,  $x$  = axial direction, and  $z$  = radial direction. —

$$\epsilon_x = \epsilon_z = (1/E)[\sigma - \nu(\sigma_z + \sigma_x)] = (1/E)(\sigma_z - \nu(2\sigma_x)) = (\sigma_z/E)(1-2\nu)$$

Since  $\nu < 1/2$  for metals,  $\epsilon_x = \epsilon_z$  is positive and the tube lengthens.

4 A solid 2-cm. diameter rod is subjected to a tensile force of 40 kN. An identical rod is subjected to a fluid pressure of 3.5 MPa and then to a tensile force of 40 kN. Which rod experiences the largest shear stress?

Solution: The shear stresses in both are identical because a hydrostatic pressure has no shear component.

1-5 Consider a long thin-wall, 5 cm in diameter tube, with a wall thickness of 0.25 mm that is capped on both ends. Find the three principal stresses when it is loaded under a tensile force of 40 N and an internal pressure of 200 kPa.

Solution:  $\sigma_x = PD/4t + F/(\pi D t) = 12.2 \text{ MPa}$

$$\sigma_y = PD/2t = 2.0 \text{ MPa}$$

$$\sigma_z = 0$$

# Metal Forming Solution Manual

**Deborah Wiegand**

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