A 70-mm-diameter solid steel shaft, used as a torque transmitter, is replaced with a 70-mm hollow shaft having a 6-mm wall thickness. If both materials have the same length, what is the percentage reduction in torque transmission? What is the percentage reduction in shaft weight?

SOLUTION:

$$\tau_{max} = \frac{T \cdot c}{J} \qquad J_s = \frac{\pi}{2} \cdot c^4 = 2357176 \text{ mm}^4$$

$$J_H = \frac{\pi}{2} (c_o^4 - c_i^4)$$

$$J_H = 1246182 \text{ mm}^4$$

$$T = \frac{J \cdot \tau_{max}}{c}$$

$$T_s = \frac{2357176 \cdot \tau_{max}}{35}$$

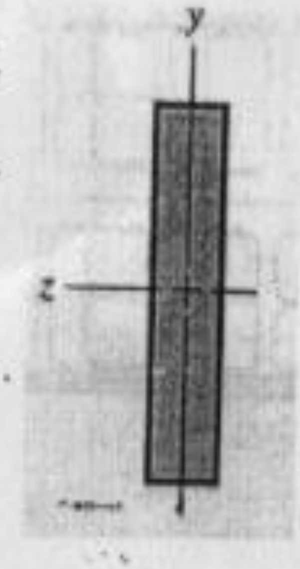
$$T_H = \frac{1246182 \cdot \tau_{max}}{35}$$

$$\frac{T_s - T_H}{T_s} = 0.47 \Rightarrow \%47$$ reduction in torque trans.

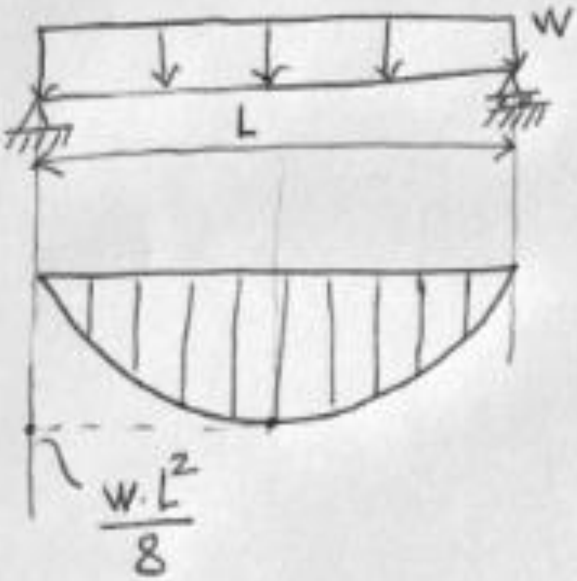
$$\frac{L \cdot \pi \cdot 35^2 - L\pi (35^2 - 29^2)}{L \cdot \pi \cdot 35^2} = 0.69$$

$\Rightarrow \%69$ reduction in weight

The figure illustrates a wood joist section with 30x200 mm and 3 m long. Use an allowable stress of 8 MPa for wood and find the maximum safe uniformly distributed load that the beam can carry if the given length is between simple supports.



SOLUTION:



$$M + w \cdot x \cdot \frac{x}{2} - w\frac{L}{2} \cdot x = 0$$

$$M = \frac{w \cdot x}{2}(L - x)$$

$$M_{max} = \frac{w \cdot L}{4} \cdot \frac{L}{2} = \frac{w \cdot L^2}{8}$$

$$\sigma_{max} = \frac{M_{max}}{I} \cdot c \qquad I = \frac{30 \cdot 200^3}{12} = 20 \times 10^6 \ mm^4$$

$$\sigma_{max} = \frac{\frac{w \cdot 3000^2}{8}}{20 \times 10^6} \cdot 100 \qquad c = 100 \ mm$$

$$\sigma_{max} = 5.625 w = 8 \ N/mm^2$$

$$w = 1.42 \ N/mm = 1420 \ N/m$$

A cylindrical pressure vessel is formed of 1.2 mm cold-drawn AISI 1018 sheet steel. If the vessel has a diameter of 200 mm, estimate the pressure necessary to initiate the yielding. What is the estimated bursting pressure? S_y=370 MPa, S_{ut}=440 MPa.

SOLUTION:

$$\sigma_t = \frac{p.d}{2.t} \qquad \sigma_L = \frac{p.d}{4.t} \qquad \sigma_r = -p$$

$$\sigma_t = \frac{200}{2.(1.2)} p = 83.33\, p$$

$$\sigma_L = 41.67\, p \qquad \sigma_r = -p$$

Von Mises failure hypothesis,

$$\sigma' = \frac{1}{\sqrt{2}}\left[(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2\right]^{1/2} =$$

$$= \frac{1}{\sqrt{2}}\left[(83.33.p-41.67.p)^2+(41.67p+p)^2 + (-p-83.33p)^2\right]^{1/2} = 73.03\, p$$

$$\sigma' = S_y \Rightarrow p = 5.07 \text{ MPa for yield}$$

$$\sigma' = S_{ut} \Rightarrow p = 6.02 \text{ MPa for rupture}$$

A light pressure vessel is made of 2024-T3 aluminum alloy tubing with suitable end closures. This cylinder has a 84 mm OD, a 1.6 mm wall thickness, and $\nu=0.334$. The purchase order specifies a minimum yield strength of 320 MPa. What is the factor of safety if the pressure release valve is set at 4 MPa?

SOLUTION:

$$d_i = 84 - 2\cdot(1.6) = 80.8 \text{ mm}$$

$$\sigma_t = \frac{p\cdot d}{2t} = \frac{4\cdot(80.8)}{2\cdot(1.6)} = 101 \text{ MPa}$$

$$\sigma_L = \frac{p\cdot d}{4\cdot t} = \frac{4\cdot(80.8)}{4\cdot(1.6)} = 50.5 \text{ MPa}$$

$$\sigma_r = -p = -4 \text{ MPa}$$

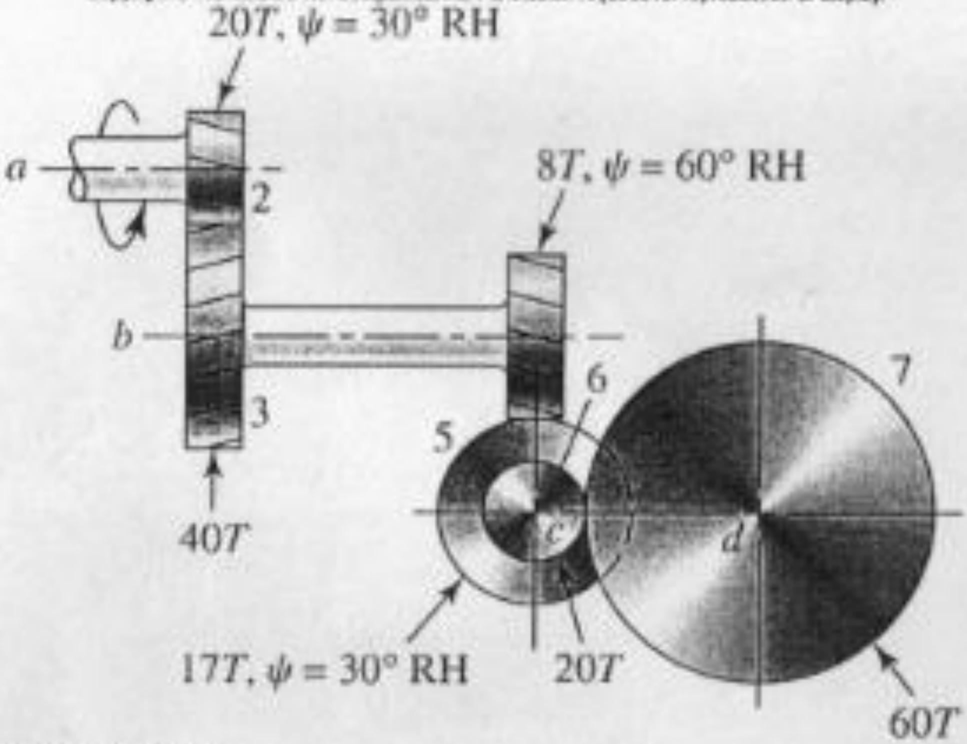
Von Mises failure hypothesis,

$$\sigma' = \frac{1}{\sqrt{2}}\left[(101-50.5)^2 + (50.5+4)^2 + (-4-101)^2\right]^{1/2}$$

$$\sigma' = 90.95 \text{ MPa}$$

$$n = \frac{S_y}{\sigma'} = \frac{320}{90.95} = 3.52$$

Shaft a in the figure rotates at 600 rev/min in the direction shown. Find the speed and direction of rotation of shaft d.

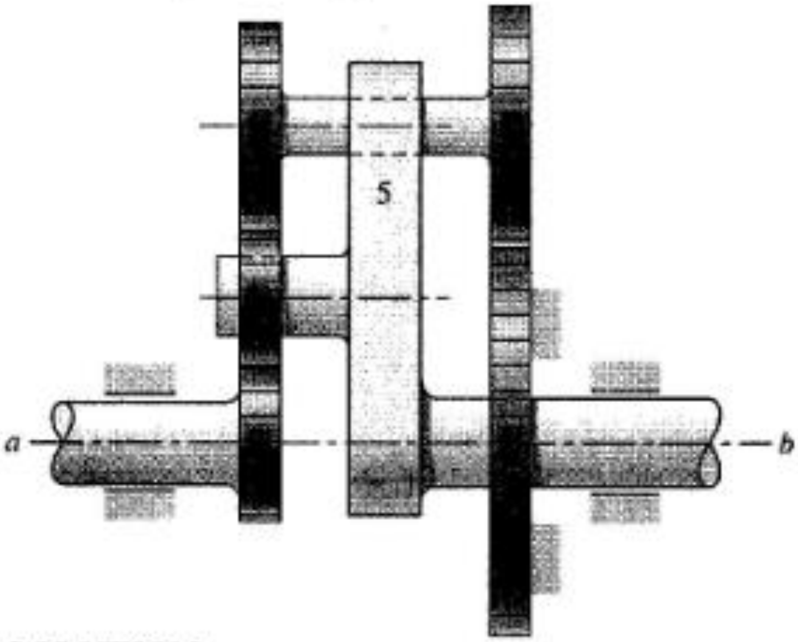


SOLUTION:

$$e = \frac{20}{40}\left(\frac{8}{17}\right)\left(\frac{20}{60}\right) = \frac{4}{51}$$

$$n_d = \frac{4}{51}(600) = 47.06 \text{ rpm}$$

The tooth numbers for the gear train illustrated are $N_2 = 24$, $N_3 = 18$, $N_4 = 30$, $N_6 = 36$, and $N_7 = 54$. Gear 7 is fixed. If shaft b is turned through 5 revolutions, how many turns will shaft a make?



SOLUTION:

$n_F = n_2 \qquad n_L = n_7 = 0$

$$e = \frac{n_L - n_5}{n_F - n_5}$$

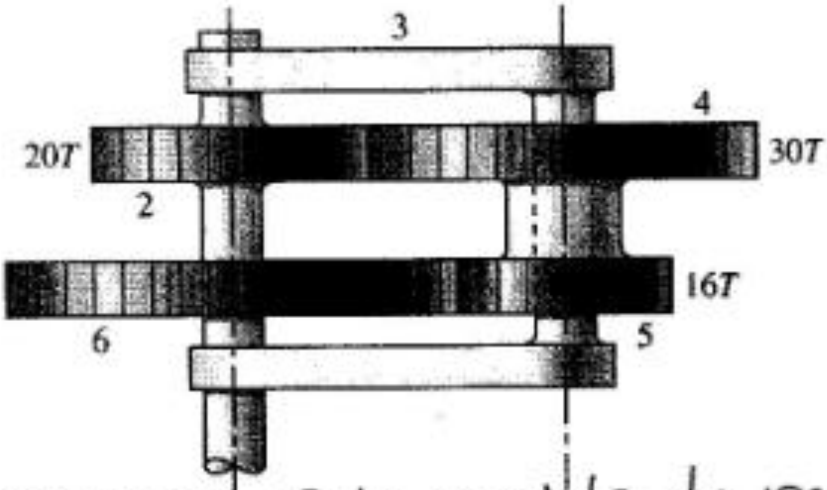
$$e = -\frac{24}{18}\left(\frac{18}{30}\right)\frac{36}{54} = -\frac{8}{15}$$

$$\frac{0-5}{n_2-5} = -\frac{8}{15} \Rightarrow n_2 = 5 + \frac{15}{8}\cdot 5 = 14.375 \text{ rpm}$$

(same direction with a)

So, 14.375 revolutions

In the reverted planetary train illustrated, find the speed and direction of rotation of the arm if gear 2 is unable to rotate and gear 6 is driven at 12 rev/min in the clockwise direction.



SOLUTION: 2 is unable to rotate

$n_F = n_2 = 0 \qquad n_L = n_6 = -12$ rpm

$e = \frac{20}{30} \cdot \frac{16}{34} = \frac{16}{51} \qquad e = \frac{n_L - n_A}{n_F - n_A}$

$\frac{16}{51} \cdot (0 - n_A) = -12 - n_A \Rightarrow n_A = -17.49$ rpm (cw)

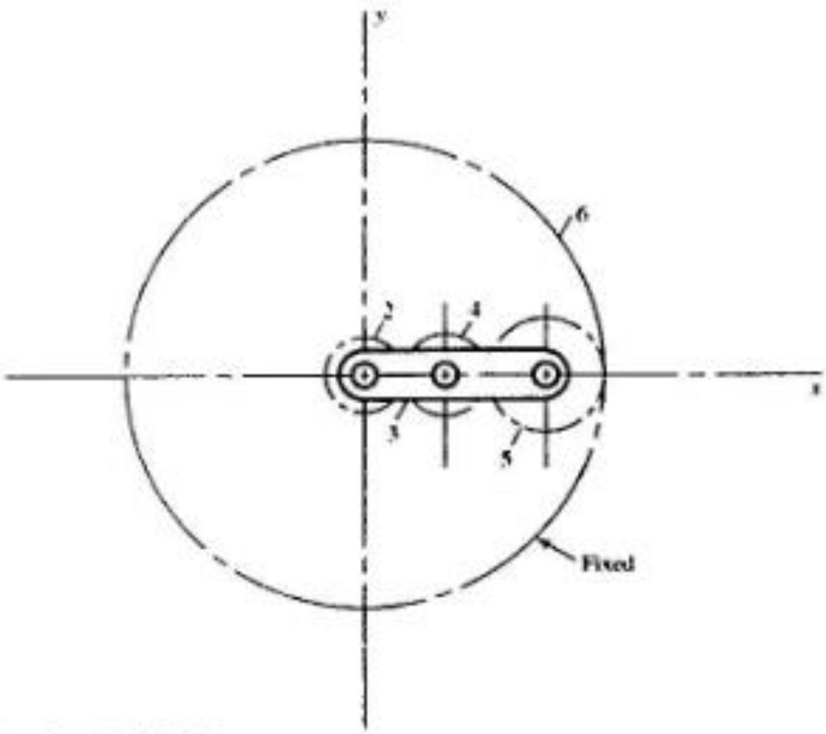
6 is unable to rotate

$n_F = n_2 = -12$ rpm $\qquad n_L = n_6 = 0$

$e = \frac{20}{30} \cdot \frac{16}{34} = \frac{16}{51} \qquad e = \frac{n_L - n_A}{n_F - n_A}$

$\frac{16}{51}(-12 - n_A) = 0 - n_A \Rightarrow n_A = 5.48$ rpm (ccw)

The 12*T*, 4 mm module and 20° pressure angle pinion 2 shown in the figure rotates clockwise at 500 rev/min (rpm) and is driven at a power of 18 kW. Gears 4 and 5 have 24 and 36 teeth, respectively. What is the speed and direction of rotation of arm?



SOLUTION:

$$N_6 = (6 + 24 + 36) \cdot 2 = 132$$

$$e = \frac{12 \cdot \cancel{24} \cdot \cancel{36}}{\cancel{24} \cdot \cancel{36} \cdot 132} = \frac{1}{11}$$

$$e = \frac{n_L - n_A}{n_F - n_A} = \frac{0 - n_A}{500 - n_A} = \frac{1}{11}$$

$$n_A = -50 \text{ rpm}$$

→ ccw

A 20° straight-tooth bevel pinion having 14 teeth and of 4 module drives a 32-tooth gear. The two shafts are at right angles and in the same plane. Find: (*a*) The cone distance. (*b*) The pitch angles, (*c*) The pitch diameters, (*d*) The face width.

SOLUTION:

a) $d_P = 14 \cdot 4 = 56 \text{ mm}$

$d_G = 32 \cdot 4 = 128 \text{ mm}$

$A_o = \sqrt{28^2 + 64^2} = 69.86 \text{ mm}$

b) $\gamma = \tan^{-1}(14/32) = 23.63^\circ$

$\Gamma = \tan^{-1}(32/14) = 66.37^\circ$

c) $d_P = 56 \text{ mm}$

$d_G = 128 \text{ mm}$

d) $\left.\begin{array}{l} b = \dfrac{A_o}{3} = 23.29 \text{ mm} \\ b = 10 \cdot 4 = 40 \text{ mm} \end{array}\right\}$ smaller one $b = 23.29 \text{ mm}$