

Example: Failure of shaft rotating at a constant speed (based on 5-38)

A 1020 CD steel shaft is to transmit 20 hp while rotating at 1750 rpm. Determine the minimum diameter of the shaft such that we have a factor of safety $n=3$. (a) Use MSS theory. (b) Use DE theory. (c) Assume $S_{yt} \neq S_{yc}$, use CM theory.

Solution

MSS theory: $P = T\Omega \Rightarrow T = \frac{P}{\Omega} = \frac{20 \text{ hp}}{1750 \text{ rpm}}$

$$20 \text{ hp} = 20 \cdot 32.572 \frac{\text{ft-lb}}{\text{min}}$$

$$T = 59.25 \text{ ft-lb}$$

Shear stress: $\tau_{\max} = \frac{S_y}{2n}$ MSS failure

$$\tau = \frac{16T}{\pi d^3} \Rightarrow \text{test for failure}$$

$$\frac{16T}{\pi d^3} = \frac{S_y}{2n}$$

$$d = \left(\frac{32nT}{\pi S_y} \right)^{1/3}$$

DE theory: $S_{sy} = 0.577 S_y$

$$\frac{16T}{\pi d^3} = \frac{0.577 S_y}{n}$$