Shafts

A rotating member used to transmit power or motion.

Provides an axis of rotation for gears, pulleys, flywheels, etc.

Stress, deflection, static, and fatigue loading must be considered in shaft design.

Static analysis is always good to perform on a shaft design, if for no other reason than to begin to properly size the shaft for dynamic loads.

Assume shaft is subjected to torsional loading, axial loading, and bending.

$$\sigma_x = \frac{32M}{\pi d^3} + \frac{4F}{\pi d^2}$$

$$\tau_{xy} = \frac{16T}{\pi d^3}$$

Using these expressions in the principal stress formula:

$$\sigma_{1,3} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau^2_{xy}}$$

$$= \frac{1}{2\pi d^2}\left(\frac{32M}{d} + 4F\right) \pm \sqrt{\left(\frac{M}{2\pi d^3} + \frac{4F}{2\pi d^2}\right)^2 + \left(\frac{16T}{\pi d^3}\right)^2}$$

Maximum Shear stress $(\sigma 1 - \sigma 3)/2$
=

$$\tau_{\max} = \frac{2}{\pi d^3}\left[(8M + Fd)^2 + (8T)^2\right]^{1/2}$$

Von Mises' Stress
=

$$\sigma' = \frac{4}{\pi d^3}\left[(8M + Fd)^2 + 48T^2\right]^{1/2}$$

Use these relationships to derive two different expressions for the diameter, d, of the shaft. You may assume that the axial loading component is 0.0. One expression should assume use of the Maximum Shearing Stress Theory and the 2^{nd} expression should be derived using the Distortion Energy Theory.

How would you include a factor of safety in these expressions?

The integral pinion shaft shown is to be mounted in bearings at the locations shown and is to have a gear mounted on the right-hand side. The loading diagram is shown.

Find the diameter of the shaft at the right-hand bearing based upon a material having a yield strength of 66 ksi and a factor of safety of 1.80.