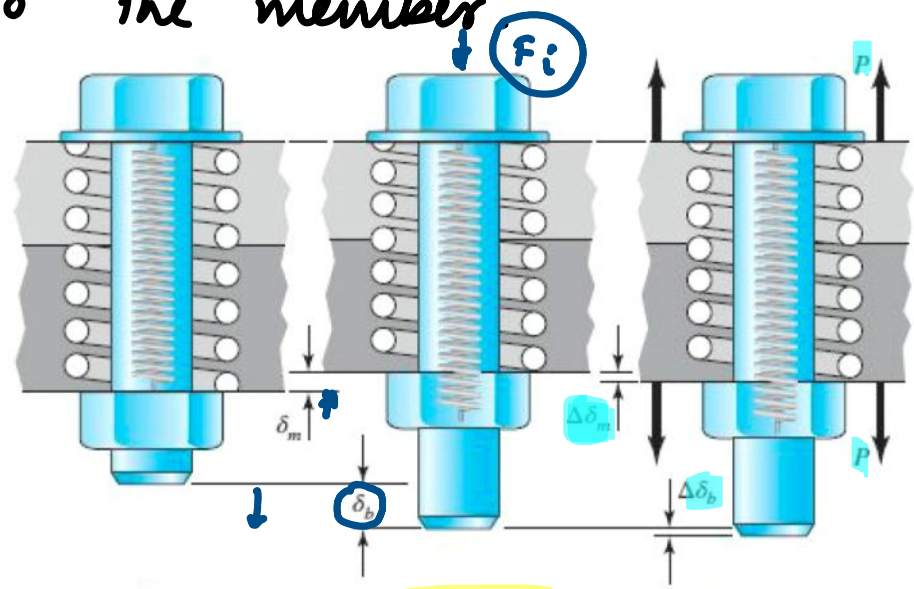
8-7 Tension Joints - The external load.

We have computed joint stiffness and member stiffness individually. We now study the effect of tightening the bolt onto the member



(a) No preload (b) Preload (c) External load

F_i

(a) bolt and nut are not yet tightened

(b) nut is tightened to introduce a preload F_i to the joint. The same force appears at the member. This implies that the joint/member are in series during pre-load.

$$\delta_m = \frac{F_i}{k_m} \quad \text{and} \quad \delta_b = \frac{F_i}{k_b}$$

(c) When an external load P is applied to the members (not directly to the bolt), the bolt elongates by $\Delta\delta_b$ while the member deflection decreases by $\Delta\delta_m$. By inspection it can be seen that these deflections are equal, but the load P is shared.

$$P = P_b + P_m \qquad -\ (1)$$

This indicates that joint / member are in parallel.

$$\Delta\delta_b = \frac{P_b}{k_b} = \Delta\delta_m = \frac{P_m}{k_m} \qquad -\ (2)$$

From (1) and (2)

$$P_b = \frac{k_b P}{k_b + k_m} = CP$$

$$= \frac{k_b}{k_b + k_m}$$

$$P_m = P - P_b = (1 - C)P$$

Summary: $\boxed{P_b = CP, \quad P_m = (1 - C)P \qquad C = \frac{k_b}{k_b + k_m}}$

F_i $\qquad\qquad$ P

Effect of pre-tension and external load.

$$\boxed{\begin{aligned} F_b &= P_b + F_i = CP + F_i \\ F_m &= P_m - F_i = (1-C)P - F_i \end{aligned}}$$

8-8 Relating Bolt Load to Bolt torque

The preload F_i can be related to the torque using raising / lifting the load formula

$$T = \frac{F_i d_m}{2} \underbrace{\left(\frac{l + \pi f d_m \sec\alpha}{\pi d_m - f l \sec\alpha} \right)}_{\text{bolt/screw}} + \underbrace{\frac{F_i f_c d_c}{2}}_{\text{collar}}$$

d_m - average diameter of the screw/bolt
d_c - collar diameter
l - lead
f, f_c - friction in screw / collar respectively
F_i - pre-load
T - torque needed to raise the load

But $\tan\lambda = l / \pi d_m$

$$T = \frac{F_i d_m}{2} \left(\frac{\tan\lambda + f \sec\alpha}{1 - f \tan\lambda \sec\alpha} \right) + \frac{F_i f_c d_c}{2}$$

Assume $d_c = 1.25d$, where d is the major diameter of the screw/bolt

$$T = \left[\left(\frac{d_m}{2d}\right)\left(\frac{\tan\lambda + f\sec\alpha}{1 - f\tan\lambda\sec\alpha}\right) + 0.625 f_c\right] F_i d$$

This is usually written as

$$\boxed{\begin{gathered} T = K F_i d \\ \text{where } K = \left[\left(\frac{d_m}{2d}\right)\left(\frac{\tan\lambda + f\sec\alpha}{1 - f\tan\lambda\sec\alpha}\right) + 0.625 f_c\right] \end{gathered}}$$

a) geometry d_m, d, λ

b) friction

Q3

A fully threaded bolt with a lead of (1/16) in, major diameter of 0.75 in is subjected to a load of 6 kip in a tension joint. The initial bolt tension is 25 kip. The bolt and member stiffnesses are kb = 6.5 M-lbf/in and km = 13.8 M-lbf/in. The area of the threaded portion of the bolt is At = 0.373 in^2, the area of the minor diameter Ar = 0.351 in^2

F_i $\quad$ F_i, P

(a) Compute the preload and service load stress in the bolt.
(b) Compute the torque needed to develop the preload assuming that that the constant K = 0.2
(c) Compute the torque needed to develop the preload assuming that f = fc = 0.15, alpha = 30 degrees

$l = 1/16$ in

$d = 0.75$ in

$P = 6$ kip

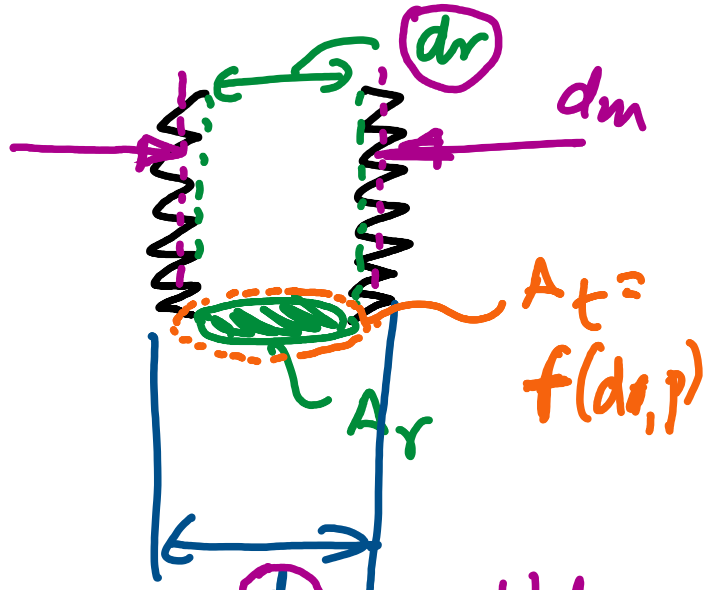
$F_i = 25$ kip

$A_r = 0.351\ in^2 = \dfrac{\pi d_r^2}{4}$

$k_b = 6.5$ Mlbf/in

$k_m = 13.8$ Mlbf/in

$A_t = 0.373\ in^2$



② $d_m = \frac{1}{2}(d + d_r)$

① $d_m = d - p$ $\quad$ p = pitch

$d_m = d - p = p/T\sigma\alpha$

(a) Preload stress σ_i

$$\sigma_i = \frac{F_i}{A_t} = \frac{25}{0.373} \qquad \boxed{\sigma_i = 67.02 \text{ kpsi}}$$

Service stress σ_b

$$\sigma_b = \frac{F_b}{A_t} = \frac{CP + F_i}{A_t}$$

$$C = \frac{k_b}{k_b + k_m} = \frac{6.5}{6.5 + 13.8} = 0.32$$

$$\sigma_b = \frac{(0.32)(6) + 25}{0.373} \qquad \boxed{\sigma_b = 72.17 \text{ kpsi}}$$

(b) $T = K F_i d$

$$T = (0.2)(25)(10^3)(0.75)$$

$$\boxed{T = 3750 \text{ lbf-in}}$$

(c)

$$\boxed{K = \left[\left(\frac{d_m}{2d}\right)\left(\frac{\tan\lambda + f\sec\alpha}{1 - f\tan\lambda\sec\alpha}\right) + 0.625 f_c\right]}$$

$f = f_c = 0.15$

$\alpha = 30^\circ$

$d = 0.75\,in$

$\tan\lambda = \left(\frac{l}{\pi d_m}\right)$

(iii) $\tan\lambda = \frac{1/16}{\pi(0.7093)} = 0.028$

(ii) $d_m = \frac{1}{2}(d + d_r) = \frac{1}{2}(0.75 + 0.6685) = 0.7039$

(i) $A_r = \frac{\pi d_r^2}{4} \Rightarrow d_r = \sqrt{\frac{4A_r}{\pi}} = \sqrt{\frac{4(0.351)}{\pi}}$

$d_r = 0.6685\,in$

$$K = \frac{0.7093}{2(0.75)}\left[\frac{0.028 + 0.15(1.15)}{1 - 0.75(0.028)(1.15)}\right] + (0.625)(0.15)$$

$T = K F_i d$

$$\boxed{T = 3551\ lbf \cdot in}$$