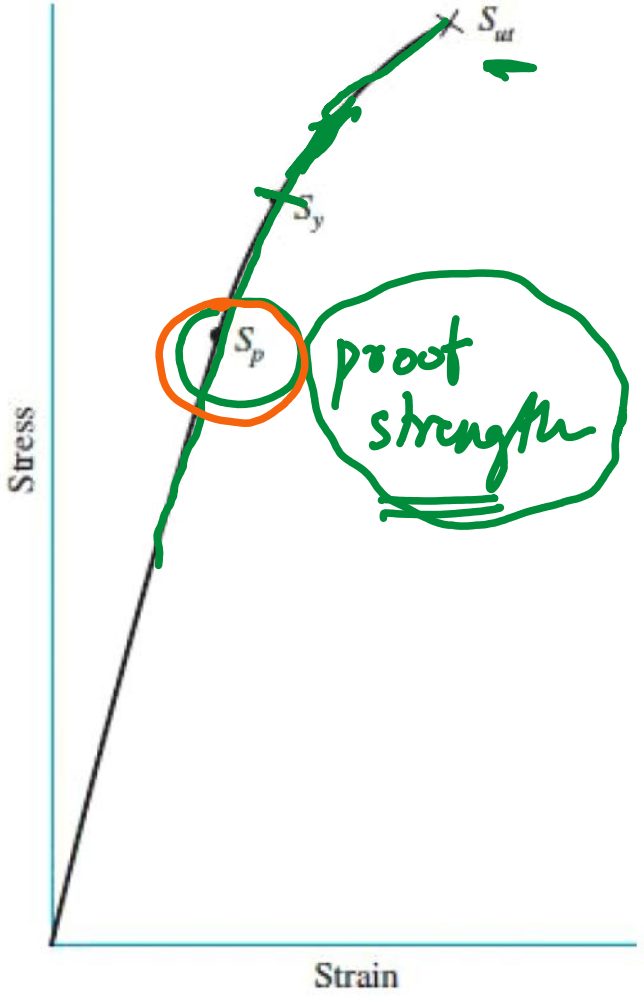
8-9 Statically loaded tension joint with preload



- stress-strain curve for bolt is shown
- proof strength S_p is the maximum force the bolt can withstand without experiencing permanent deformation.
- If S_p is not given use $S_p = 0.85 S_y$

If F_p is the proof load and A_t is the cross-sectional area of the threads then

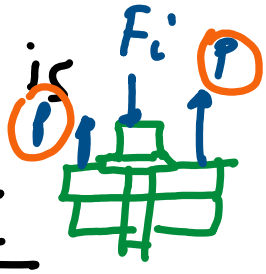
$$F_p = A_t S_p$$

specification

There are recommendation for preload F_i as follows

$$F_i = \begin{cases} 0.75 F_p & \text{non permanent connections or reused fasteners} \\ 0.9 F_p & \text{permanent connections} \end{cases}$$

The tensile stress in a bolt σ_b is



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

The yielding factor of safety is n_p

(1) $$n_p = \frac{S_p}{\sigma_b} = \frac{S_p A_t}{CP + F_i}$$

Bolts are loaded close to proof strength hence n_p is close to 1

We defined a load factor n_L that scales the load as $n_L P$. We now solve for n_L such that the bearing stress (σ_b) equals the proof strength (S_p) such that $n_p = 1$

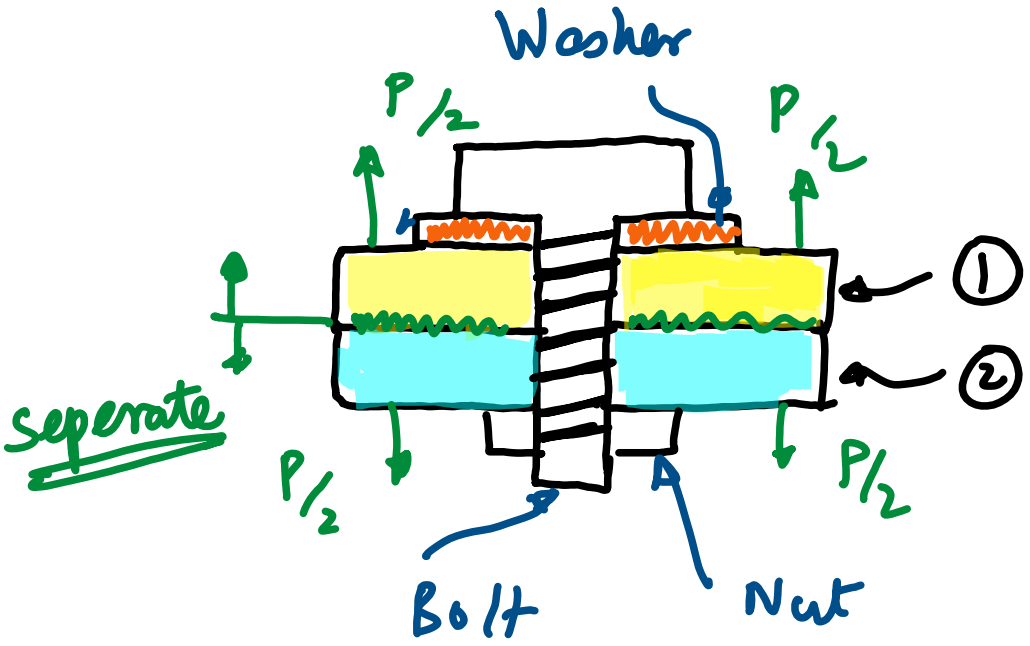
$$S_p = \sigma_b = \frac{F_b}{A_t} = \frac{C\, n_L P + F_i}{A_t}$$

($\sigma_b = S_p$ when $n_p = 1$)

Solve for n_L

(2)

$$\boxed{n_L = \frac{S_p A_t - F_i}{CP}}$$



The external load P should be such that the members ① and ② will not separate. In this case all the load is taken by the bolt

The condition is that the force in the member. $F_m \leq 0$ see Lec 29

At separation $F_m = 0$.

$$F_m = P_m - F_i = (1-C)P_o - F_i = 0$$

Solving for load $\boxed{P_o = F_i/(1-C)}$

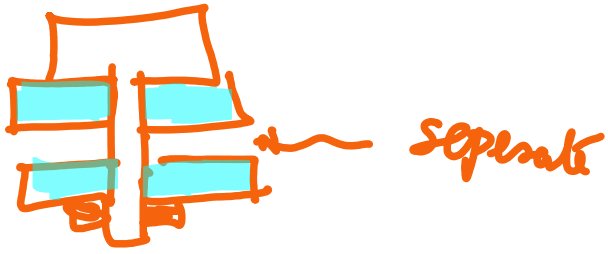
We can define a factor of safety for joint separation (n_o)

$$n_o = \frac{P_o}{P}$$

But $P_o = F_i / (1-C)$

(3)

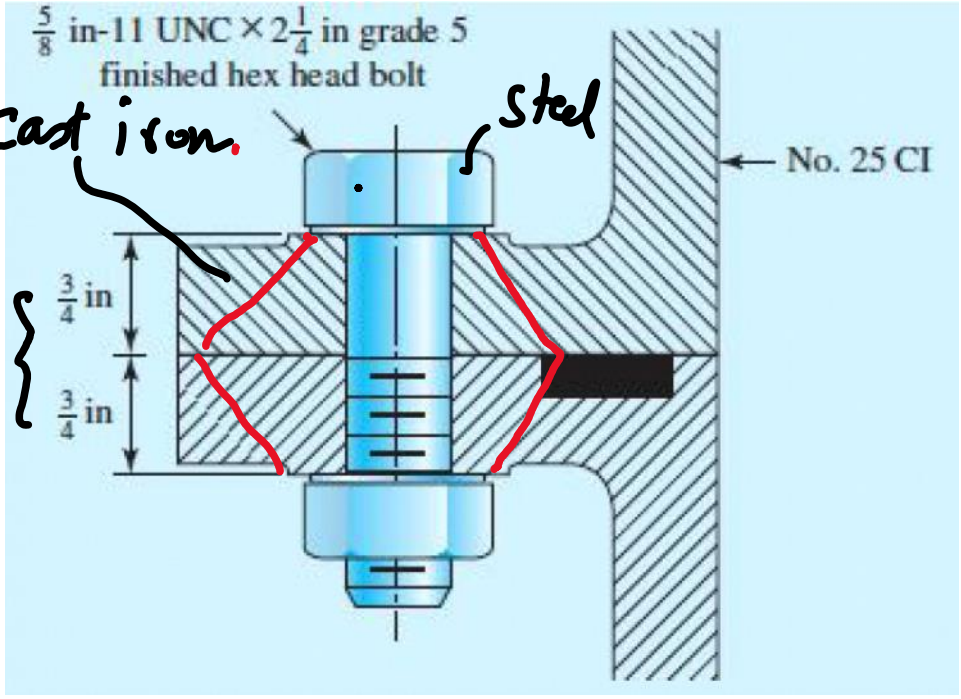
$$n_o = \frac{F_i}{P(1-C)}$$



Q4

The figure below shows a cross-section of cast-iron pressure vessel. The maximum diameter of the steel bolt is 0.625 in, the threaded length is 0.75in, the unthreaded length is 0.75 in, the area of threaded portion is At = 0.226 in^2. A total of N bolts are to be used to resist a separating force of 36 kip. Assume E=14 Mpsi for cast iron and E=30 Mpsi for steel, proof strength Sp = 85 kpsi

(a) Compute kb, km, C.
(b) Compute the number of bolts, N, required for a load factor of 2 when the bolts maybe reused when the members are taken apart.
(c) Using the the value of N above, determine the realized load factor for overload, the yielding factor of safety, and the load factor for member (or joint) separation.



$l_t = 0.75$

$l_d = 0.75$

$A_t = 0.226$

$P_{total} = 36 kips$

$A_d = \frac{\pi d^2}{4}$

$= \frac{\pi (0.625)^2}{4}$

$A_d = 0.3068$

(a)

$$k_b = \frac{A_t A_d E}{A_t l_d + A_d l_t}$$

$$= \frac{(0.326)(0.3068)(30)}{(0.326)(0.75) + (0.3068)(0.75)}$$

$$k_b = 5.21 \text{ Mlbf/in}$$

$$k_m = \frac{0.5774 \pi E d}{2 \ln \left[5 \frac{0.5774 l + 0.5d}{0.5774 l + 2.5d} \right]}$$

$d = 0.625$; $l = 1.5$; $E = 14$

$$k_m = 8.95 \text{ Mlbf/in}$$

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

$$C = 0.368$$

(b)

$$n_L = \frac{S_p A_t - F_i}{C P}$$

$n_L = 2$; $C = 0.368$;

$A_t = 0.226$; $S_p = 85$ kpsi ;

$F_i = 0.75 F_p = 0.75 S_p A_t$

$F_i = (0.75)(85)(0.226) \Rightarrow F_i = 14.4$ kip

$P = P_{total} / N = 36/N$

$$2 = \frac{(85)(0.226) - 14.4}{(0.368)(36)/N}$$

Solve for N: $N = 5.52$ $\boxed{N = 6}$

(c)

$$n_L = \frac{S_p A_t - F_i}{CP}$$

$$n_L = \frac{(85)(0.226) - 14.4}{(0.368)\left[\frac{36}{6}\right]}$$

$n_L = 2.18$

yield factor of safety

$$n_p = \frac{S_p}{\sigma_b} = \frac{S_p A_t}{CP + F_i}$$

$$= \frac{(85)(0.226)}{(0.368)\left(\frac{36}{6}\right) + 14.4} \Rightarrow n_p = 1.16$$

Load factor guarding from separation

$$n_o = \frac{F_i}{P(1-C)} = \frac{14.4}{\left(\frac{36}{6}\right)(1-0.368)}$$

$n_o = 3.8$

$F \leq (3.8)\left(\frac{36}{6}\right)$