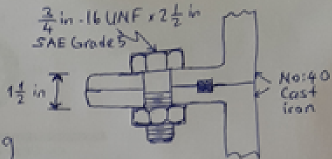
Problem 8.60

The section of the sealed joint shown in the figure is loaded by a force cycling between 4 and 6 kips. The members have E = 16 Mpsi. All bolts have been carefully preloaded to F_i = 25 kip each.



a) Determine the yielding factor of safety.
b) Determine the overload factor of safety.
c) Determine the factor of safety based on joint separation.
d) Determine the fatigue factor of safety using the Goodman criterion.

Solution:

From the bolt notation; $d = \frac{3}{4}$ in = 0.75 in

From the figure, the grip length $l = 1\frac{1}{2}$ in = 1.5 in

For cast iron E = 16 kpsi

For hexagon head bolts $d_w = 1.5d$ and since the members are same, equation 8.22 is used for the member stiffness:

$$k_m = \frac{0.5774\pi E d}{2\ln\left[5\frac{0.5774l+0.5d}{0.5774l+2.5d}\right]} = \frac{0.5774\pi(16)0.75}{2\ln\left[5\frac{0.5774(1.5)+0.5(0.75)}{0.5774(1.5)+2.5(0.75)}\right]}$$

$$k_m = 13.32 \text{ Mlbf/in}$$

Concider bolt; from eqn. 8.13 (or from Table 8.7)

It is evident from the figure that total bolt length L in less than 6 in (It is also given by the bolt notation anyway).

Therefore; $L_T = 2d + \frac{1}{4}$ in $= 2(0.75) + (0.25) = 1.75$ in.

$l = 1.5$ in.

$l_d = L - L_T = 2.5 - 1.75 = 0.75$ in $\quad l_t = l - l_d = 1.5 - 0.75 = 0.75$ in

Using Table 8.2, $A_t = 0.373 \text{ in}^2$

$A_d = \frac{\pi d^2}{4} = \frac{\pi}{4}(0.75)^2 = 0.442 \text{ in}^2$

From Table A.5 for steel bolt, $E = 30$ Mpsi

Using eqn. 8.17 for bolt stiffness,

$$k_b = \frac{A_d A_t E}{A_d l_t + A_t l_d} = \frac{(0.442)(0.373)\,30}{(0.442)(0.75) + (0.373)(0.75)} = 8.09 \text{ Mlbf/in}$$

The stiffness constant of the joint is,

$$C = \frac{k_b}{k_b + k_m} = \frac{8.09}{8.09 + 13.32} = 0.378$$

Alternating stress σ_a is (from eqn. 8.35):

$$\sigma_a = \frac{C(P_{max} - P_{min})}{2A_t} \qquad P_{max} = 6 \text{ kips} \qquad P_{min} = 4 \text{ kips (given)}$$

$$\sigma_a = \frac{0.378(6-4)}{2(0.373)} = 1.013 \text{ kpsi}$$

Mean stress σ_m is (from eqn. 8.36)

$$\sigma_m = \frac{C(P_{max} + P_{min})}{2A_t} + \frac{F_i}{A_t} = \frac{0.378(6+4)}{2(0.373)} + \frac{25}{0.373}$$

$$\sigma_m = 72.09 \text{ kpsi}$$

a) For yielding factor of safety eqn. 8.51 is used

$$n_p = \frac{S_p}{\sigma_m + \sigma_a}$$

From Table 8.9 for Grade 5 bolt $S_p = 85$ kpsi

$$n_p = \frac{85}{72.09 + 1.013} \rightarrow \boxed{n_p = 1.16} \text{ — Ans}$$

b) For overload factor of safety eqn. 8.29 is used

$$n_L = \frac{S_p A_t - F_i}{C P_{max}} = \frac{85(0.373) - 25}{(0.378)(6)} \rightarrow \boxed{n_L = 2.96} \text{ — Ans.}$$

c) For joint separation factor of safety eqn. 8.30 is used

$$n_o = \frac{F_i}{P_{max}(1-C)} = \frac{25}{(6)(1-0.378)} \rightarrow \boxed{n_o = 6.70} \text{ ... Ans.}$$

d) For factor of safety based on Goodman criterion eqn. 8.38 is used;

$$n_f = \frac{S_e(S_{ut} - \sigma_i)}{S_{ut}\sigma_a + S_e(\sigma_m - \sigma_i)}$$

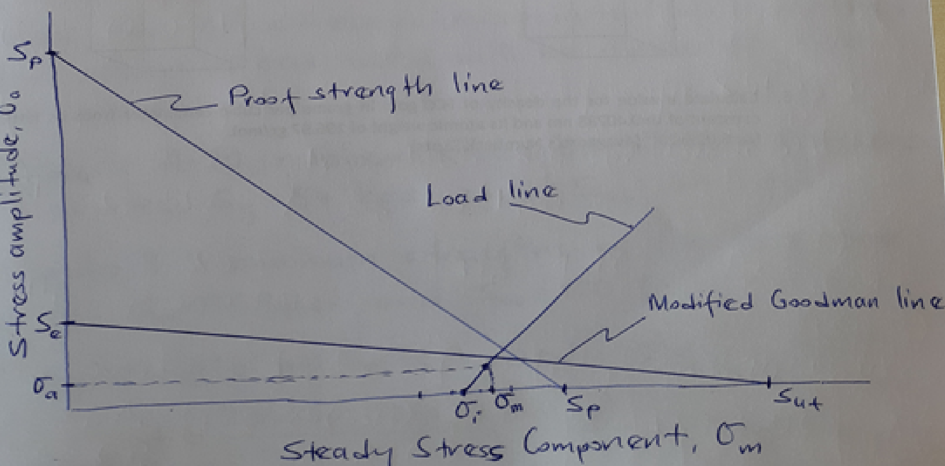
From Table 8.17 for SAE 5, $S_e = 18.6$ kpsi

From Table 8.9 for Grade 5, $S_{ut} = 120$ kpsi

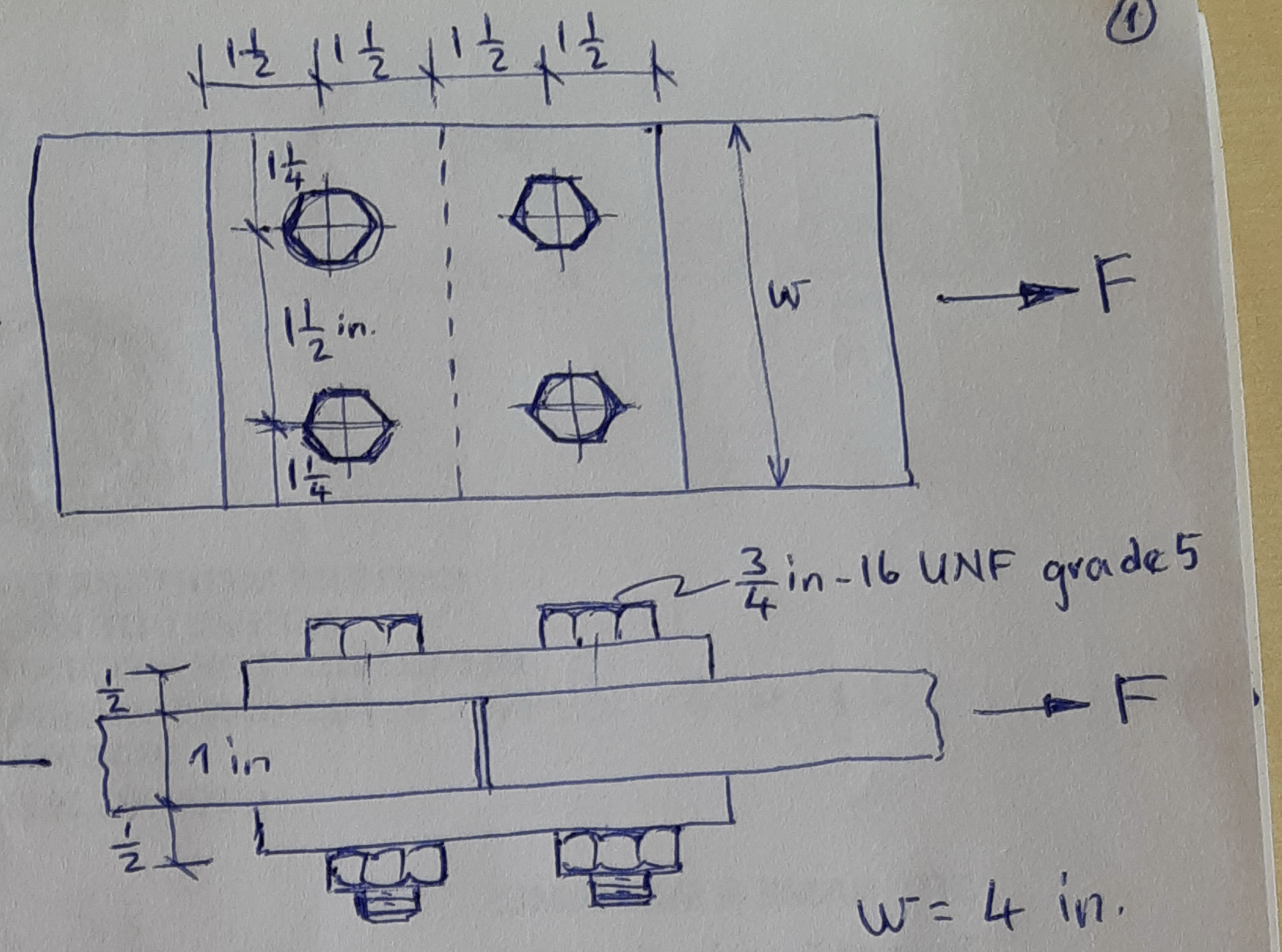
The preload stress is $\sigma_i = \frac{F_i}{A_t} = \frac{25}{0.373} = 67$ kpsi

Substituting these into eqn. 8.38

$$n_f = \frac{18.6(120-67)}{(120)(1.013) + 18.6(72.09-67)} \rightarrow \boxed{n_f = 4.56} \text{ ... Ans.}$$



Problem 8.67



Two 1 by 4 in cold-rolled steel bars are butt-spliced with two $\frac{1}{2}$ by 4 in 1018 cold-rolled splice plates using four $\frac{3}{4}$ in-16 UNF grade 5 bolts as depicted in the figure.
For a design factor of $n_d = 1.5$ estimate the static load F that can be carried if the bolts lose preload.

Solution:

Half of the static load (F/2) is transmitted by each of the splice plates, but since the areas of the splice plates are half those of the center bars, the stresses associated with the plates are the same. So fr stresses associated with plates, the force and areas used will be those of the center plates.

From Table A-20, minimum strengths of the members are found as; $S_y = 54$ kpsi and $S_{ut} = 64$ kpsi.

From Table 8-9 minimum strengths of the bots are found as; $S_p = 85$ kpsi and $S_{ut} = 120$ kpsi.

Bearing in bolts, all bolts loaded : $\sigma = \dfrac{F}{2td} = \dfrac{S_p}{n_d}$

$t = 1.0$ in

$d = \frac{3}{4}$ in $= 0.75$ in

$$F = \frac{2 t d S_p}{n_d} = \frac{2(1)(0.75)(85)}{1.5} \rightarrow F = 85 \text{ kip}$$

Bearing in members, all bolts active

$$\sigma = \frac{F}{2td} = \frac{(S_y)_{mem}}{n_d} \rightarrow F = \frac{2td(S_y)_{mem}}{n_d} = \frac{2(1)(0.75)\,54}{1.5}$$

$$F = 54 \text{ kip}$$

Shear of bolts, all bolts active

If the bolt threads do not extend into the shear planes of four shanks:

$$\tau = \frac{F}{4\frac{\pi d^2}{4}} = 0.577\frac{S_p}{n_d}$$

$$F = 0.577\,\pi d^2 \frac{S_p}{n_d} = 0.577\pi(0.75)^2\frac{85}{1.5} \rightarrow F = 57.8 \text{ kip}$$

If the bolt threads extend into a shear plane:

$$\tau = \frac{F}{4A_r} = 0.577\frac{S_p}{n_d}$$

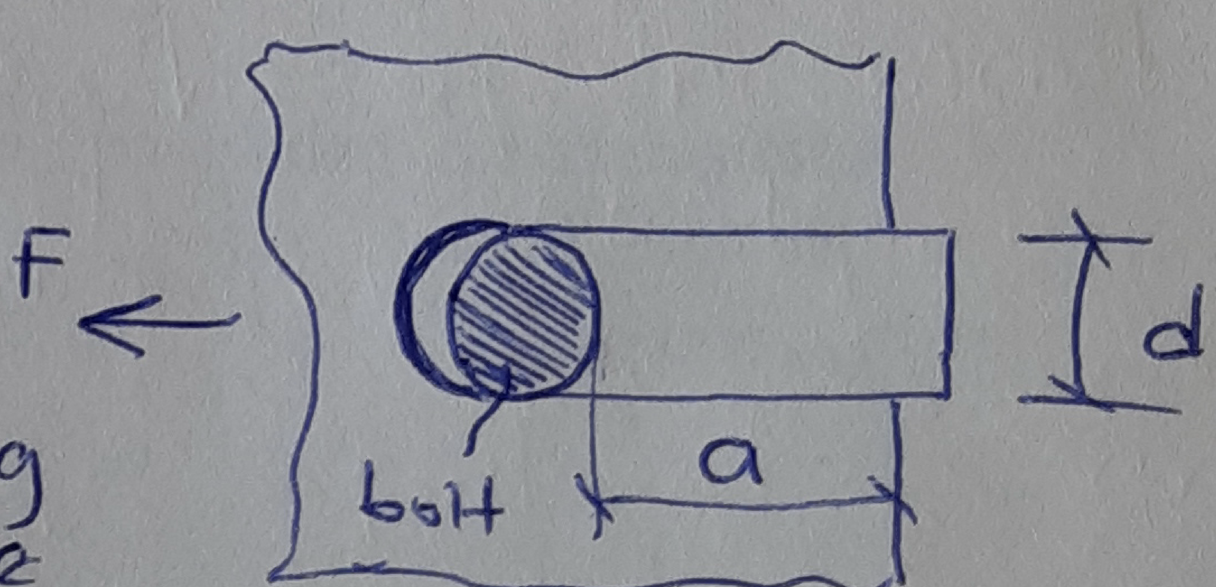
A_r: Minor diameter.
From Table 8-2 $A_r = 0.351 \text{ in}^2$

$$F = \frac{0.577(4)A_r S_p}{n_d} = \frac{0.577(4)(0.351)(85)}{1.5} \rightarrow F = 45.9 \text{ kip}$$

Edge shearing of member at two margin bolts:

$$\tau = \frac{F}{4at} = \frac{0.577(S_y)_{mem}}{n_d} \rightarrow F = \frac{4at\,0.577(S_y)_{mem}}{n_d}$$

$$F = \frac{4(1.125)(1)0.577(54)}{1.5} \rightarrow F = 93.5 \text{ kip.}$$



On the basis of bolt shear, the limiting value of the force is 45.9 kip, assuming the threads to extend into a shear plane. However it would be poor design to allow the threads to extend into shear plane. So, assuming a good design based on bolt shear, the limiting value of the force is 57.8 kip. For the members, the bearing stress limits the load to 54 kip. The solution is:

$$\boxed{F = 54 \text{ kip}}$$