The University of Tennessee at Martin

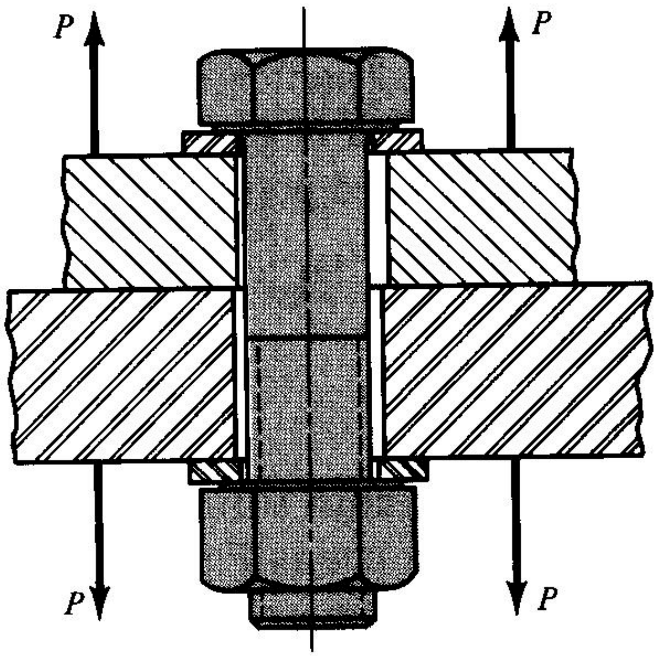
MARTIN School of Engineering

Mechanical Fasteners –
Tension Connections

Lecture 29

Engineering 473
Machine Design

Tension Connection



- A threaded fastener connection has clearance gaps that are used to assemble the connection.
- A connection can be loaded in either tension/compression or shear.
- Because of the clearance gaps, dowel pins are often used for accurately positioning of mating parts.

Shigley, Fig. 8-12

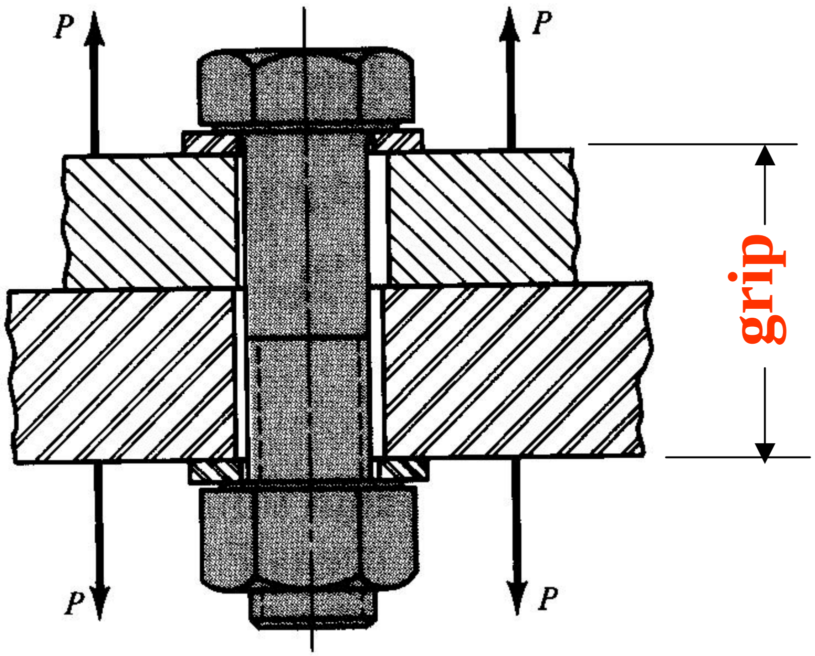
Proof Load & Proof Stress

Proof Load : Maximum force that a fastener can withstand without acquiring a permanent set.

Proof Stress: Proof Load divided by the tensile-stress-area of the fastener.

The proof stress is slightly less than the yield stress of the material due to stress concentrations in the threads.

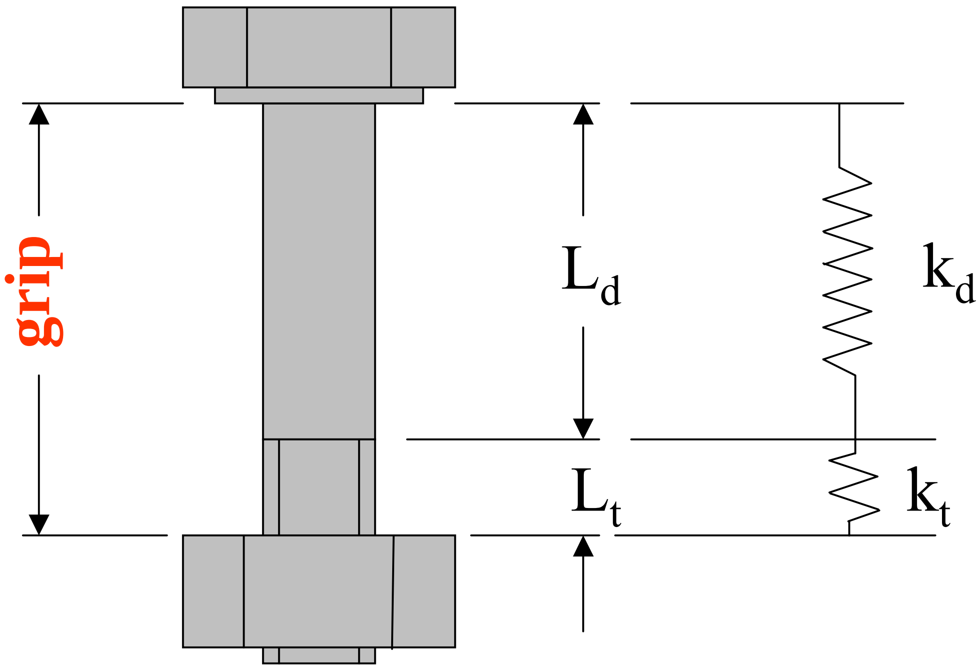
Bolt Preload



- Purpose of bolt is to clamp two parts together.
- Turning the nut on the threads will stretch the bolt to create a clamping force.
- The clamping force will impart a compressive force on the mating parts.
- The clamping force is called preload or initial tension.

Shigley, Fig. 8-12

Bolt Stiffness



$$\delta = \delta_d + \delta_t$$

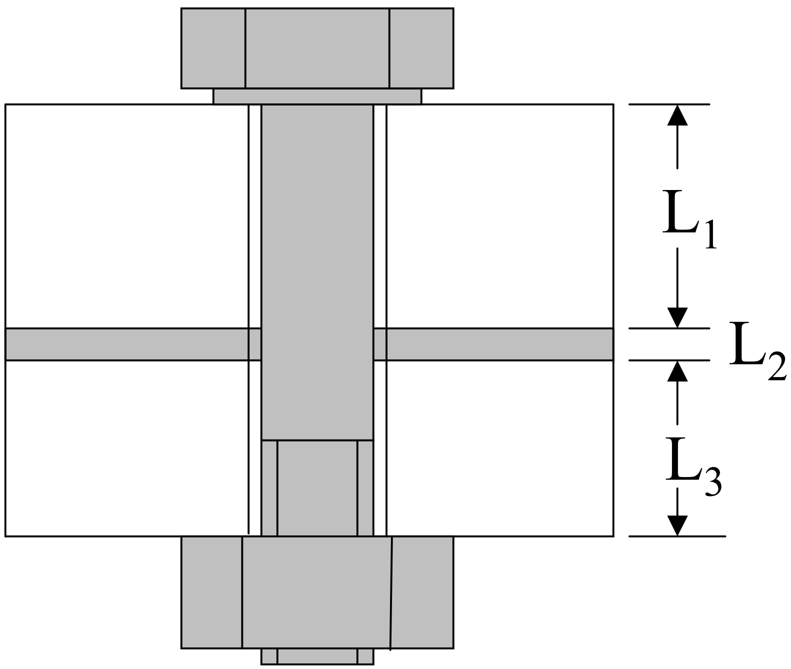
$$\delta_d = \frac{F_i}{k_d}$$

$$\delta_t = \frac{F_i}{k_t}$$

$$F_i = \frac{k_d k_t}{k_d + k_t}\delta$$

$$F_i = k_b \delta$$

Clamped Part Stiffness



$$F_i = k_m \delta$$

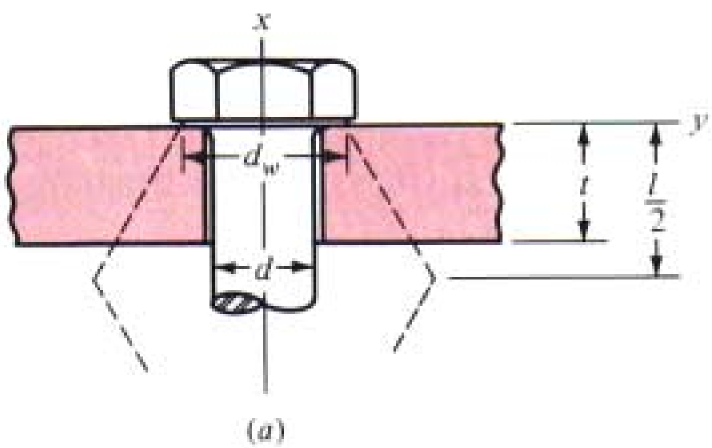
$$\frac{1}{k_m} = \frac{1}{k_1} + \frac{1}{k_2} + \frac{1}{k_3}$$

$$k_1 = A_1 E / L_1$$

$$k_2 = A_2 E / L_2$$

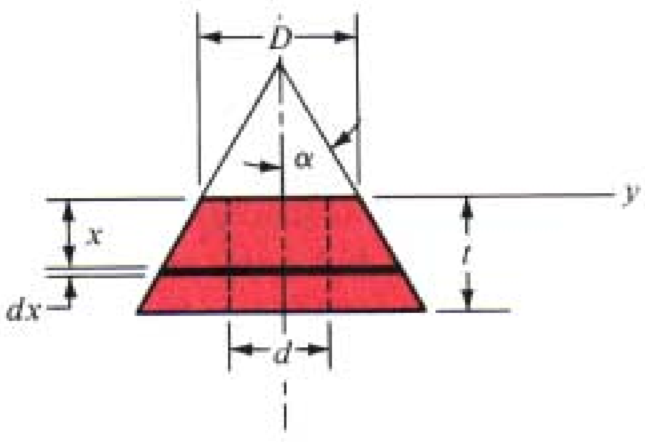
$$k_3 = A_3 E / L_3$$

Pressure-Cone Equations



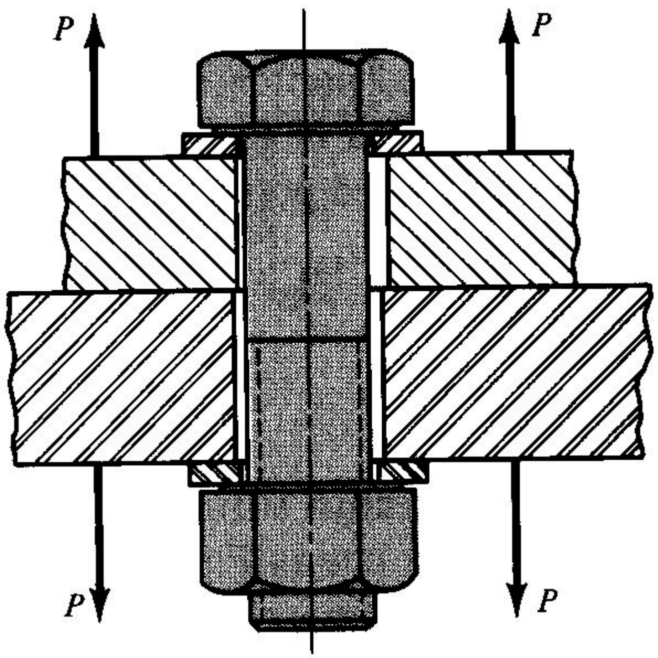
Reference Shigley, page 339-340 for derivation

$$k = \frac{0.577\pi \cdot Ed}{\ln\left(\frac{(1.15t + D - d)(D + d)}{(1.15t + D + d)(D - d)}\right)}$$



Shigley, Fig. 8-14

External Load Interaction – Preloaded Connection



$$\delta = \frac{P_b}{k_b} = \frac{P_m}{k_m}$$

$$P_b = P_m\left(\frac{k_b}{k_m}\right)$$

$$P = P_b + P_m$$

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

$$F_b = P_b + F_i$$

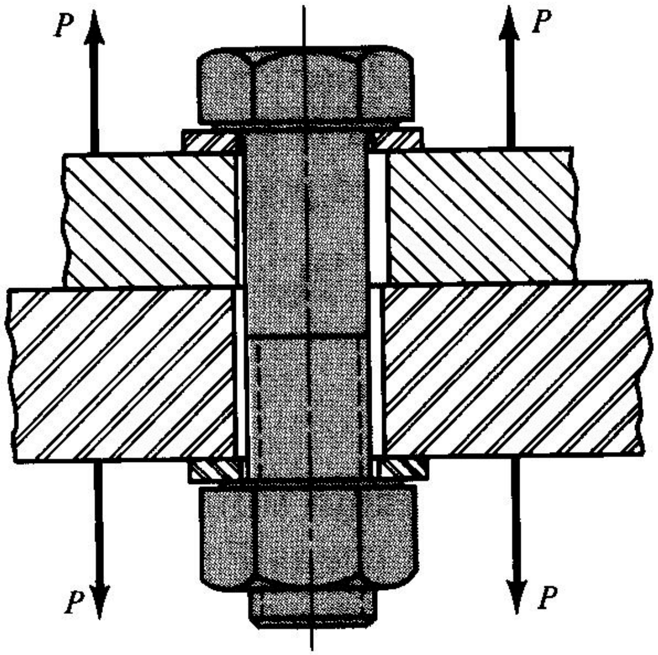
$$F_b = \frac{k_b P}{k_b + k_m} + F_i$$

$$F_m = \frac{k_m P}{k_b + k_m} - F_i$$

$$F_m < 0$$

Shigley, Fig. 8-12

External Load Interaction – Preloaded Connection



Let $C = \dfrac{k_b}{k_b + k_m}$

$$F_b = CP + F_i$$

$$F_m = (1 - C)P - F_i$$

C is the ratio of the bolt stiffness to the total stiffness (bolt plus clamped material).

Sample Data

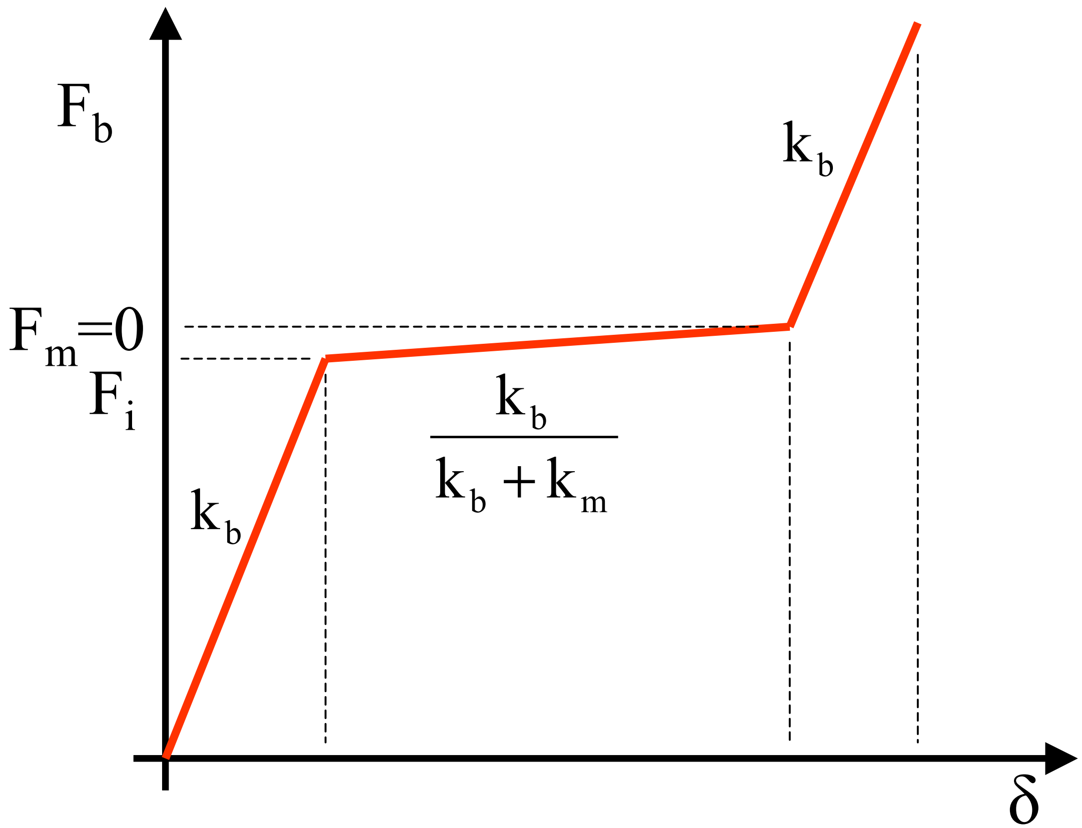
Bolt: ½-13 UNC-2A
Material: Steel

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

Bolt Grip (in)	k_b (Mlb/in)	k_p (Mlb/in)	C	1-C
2	2.57	12.69	0.168	0.832
3	1.79	11.33	0.136	0.864
4	1.37	10.63	0.114	0.886

- Most of the external load, P, is carried by the mating parts.
- Making the grip longer decreases the bolt's share of the the load.

Bolt Force – Displacement Diagram



When the mating parts and bolt are made from the same material, an external load will not cause an appreciable increase in the bolt’s total force until separation of the mating parts occurs.

Recommended Preload

$$F_p = S_p \cdot A_t$$

Disassembly Required

$$F_i = 0.75 \cdot F_p$$

Permanent Connection

$$F_i = 0.90 \cdot F_p$$

F_p – Bolt proof load
S_p – Bolt proof strength
A_t – Tensile stress area
F_i – Bolt preload

These recommendations assume that the nut or threaded part has sufficient shear strength in the threads (i.e. steel bolts and steel nuts).

Bolt Failure Criteria

$$F_b = CP + F_i$$

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

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

$$S_p = \frac{CnP}{A_t} + \frac{F_i}{A_t}$$

$n \equiv$ Load Factor

$S_p \equiv$ Proof Stress

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

Connection Separation Criteria

$$F_m = (1 - C)P - F_i$$

At separation, $F_m = 0$

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

$$P_o = \frac{F_i}{1 - C}$$

$P_o \equiv$ External load that will cause separation

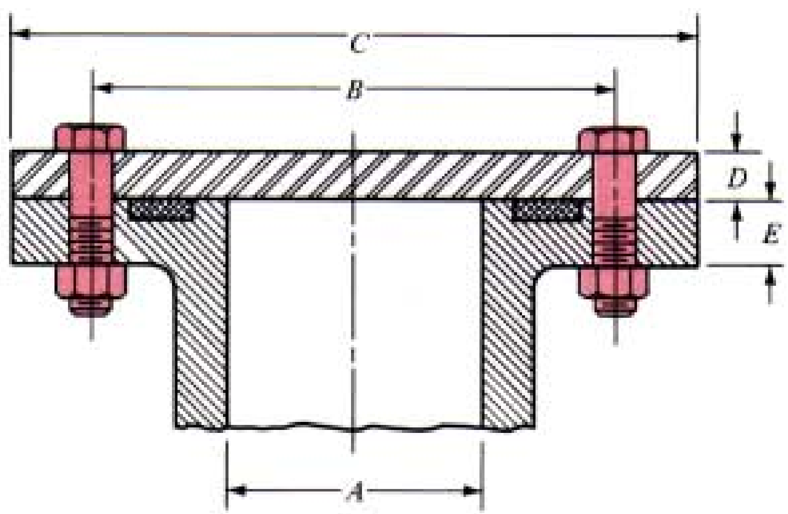
Let $P_o = nP$, where n is a load factor, then

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

It is necessary to check both bolt stress and connection separation when designing a tension connection. Separation often occurs first.

Assignment

In the figure, the bolts have a diameter of ½ inch and the cover plate is steel, with D=1/2 inch. The cylinder is cast iron, with E=5/8 inch and a modulus of elasticity of 18 Mpsi. The ½ inch SAE washer to be used under the nut has OD=1.062 inch and is 0.095 inch thick. Find the stiffness of the bolt and the mating members and the joint constant.



Assignment
(Continued)

In addition to the information given in problem 1, the dimensions of the cylinder are A=3.5 inch and an effective seal diameter of 4.25 inch. The internal static pressure is 1,500 psi. The outside diameter of the head is C = 8 inch. The diameter of the bolt circle is B = 6 inch, and a bolt spacing in the range of 3 to 5 bolt diameters would require 8 to 13 bolts. Select ten SAE grade 5 bolts and find the resulting load factor n.