The University of Tennessee at Martin

MARTIN School of Engineering

Connections Loaded in Shear and Tension

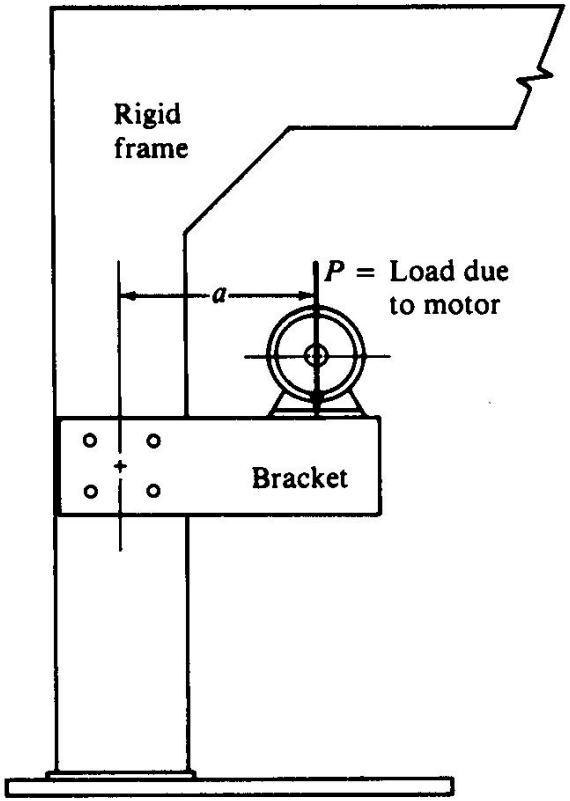
Lecture 32

Engineering 473

Machine Design

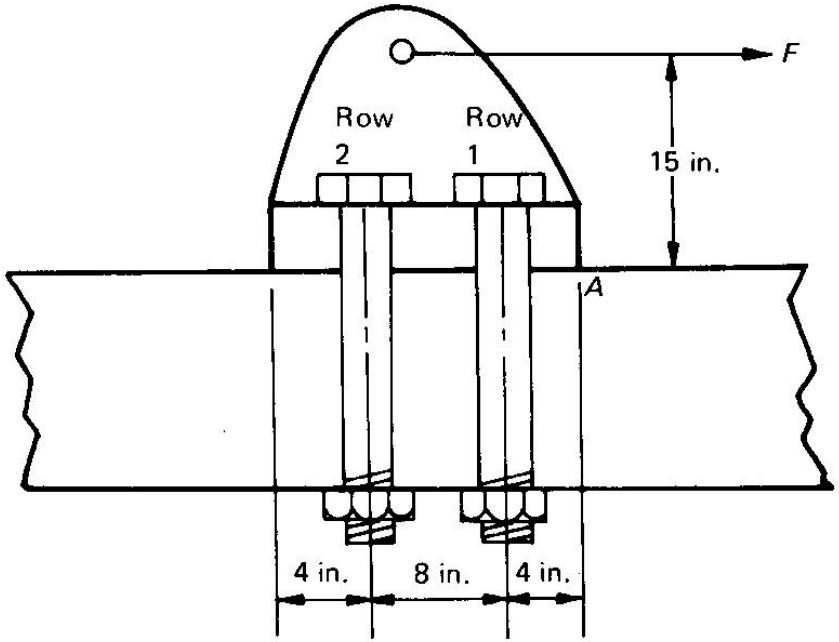
MARTIN

Eccentric Loads



Load Lying in Shear Plane

Mott, Fig. 20.4

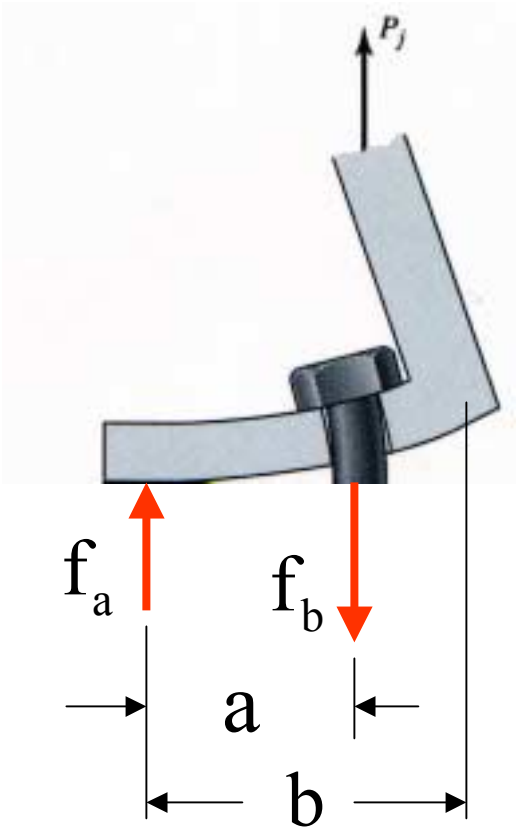


Load Offset from Shear Plane

Deutschman, Fig. 16-17

Prying Forces

Exaggerated Deformation in Joint



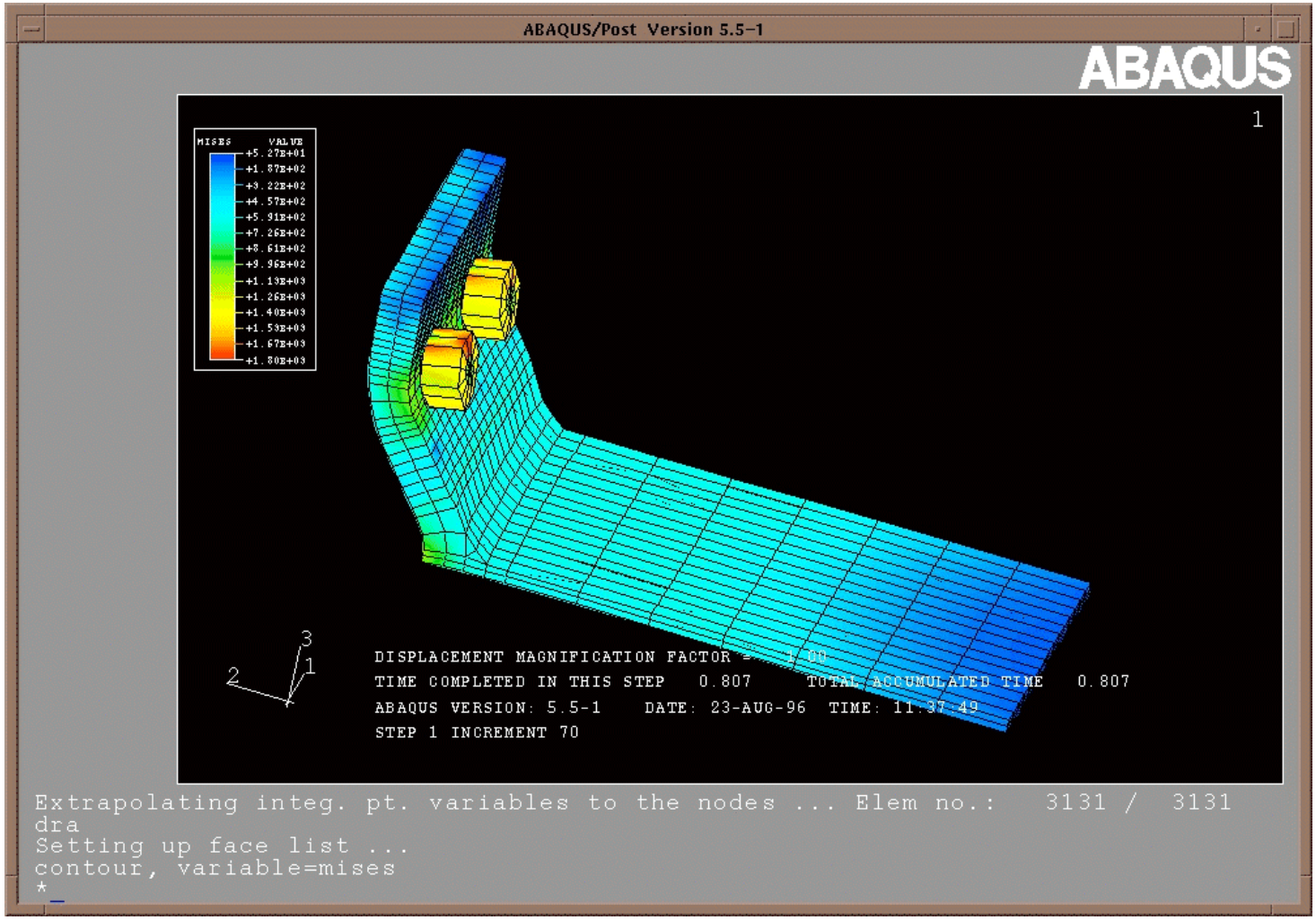
Free-Body Diagram

$$f_b = \left(\frac{b}{a}\right) P_j$$

$$f_a = f_b - P_j$$

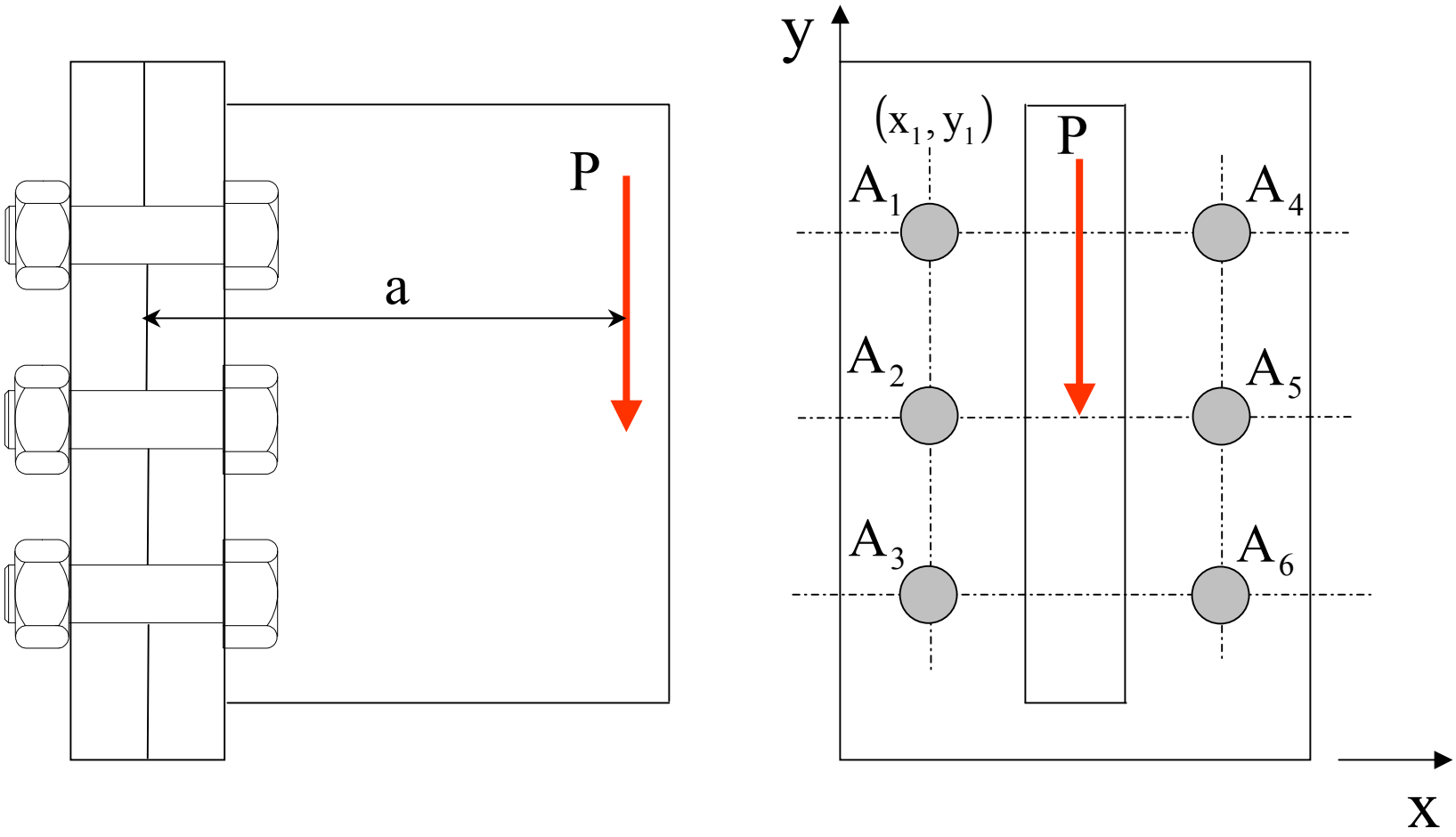
- Prying in a connection increases the bolt force.
- Prying is a joint separation phenomena.

Finite Element Analysis Showing Joint Deformation



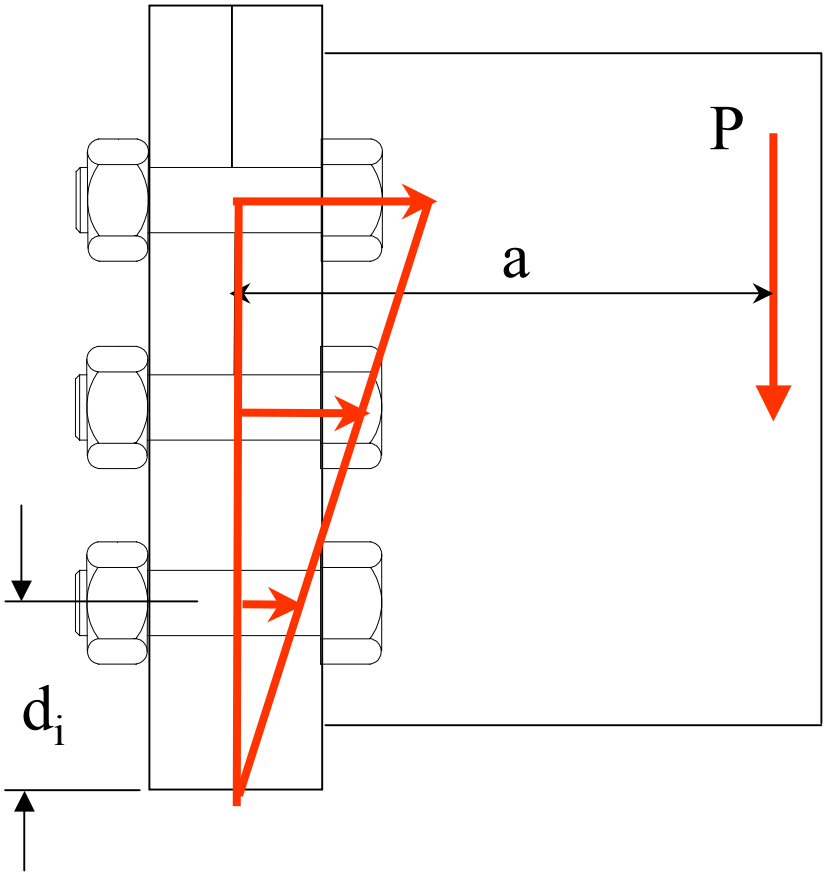
http://river.tay.ac.uk

Separation Example



Preload is not sufficient to prevent separation.

Connections With Separation



$$M = Pa = \sum_{i=1}^{n} f_i d_i$$

$$\frac{f_1}{d_1} = \frac{f_2}{d_2} = \frac{f_i}{d_i}$$

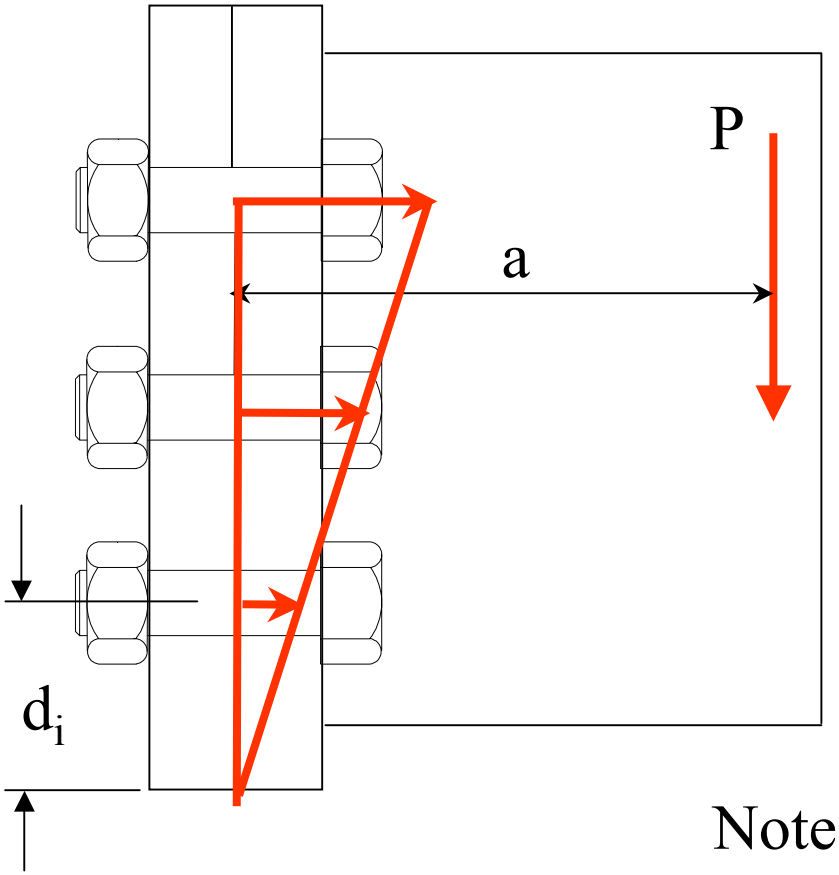
$$f_i = \frac{(d_i)}{d_1} f_1$$

$$M = \frac{f_1}{d_1} \sum_{i=1}^{n} d_i^2$$

$$f_1 = \frac{M d_1}{\sum_{i=1}^{n} d_i^2}$$

$d_i \equiv$ distance from pry point to ith fastener

Connections With Separation
(Continued)

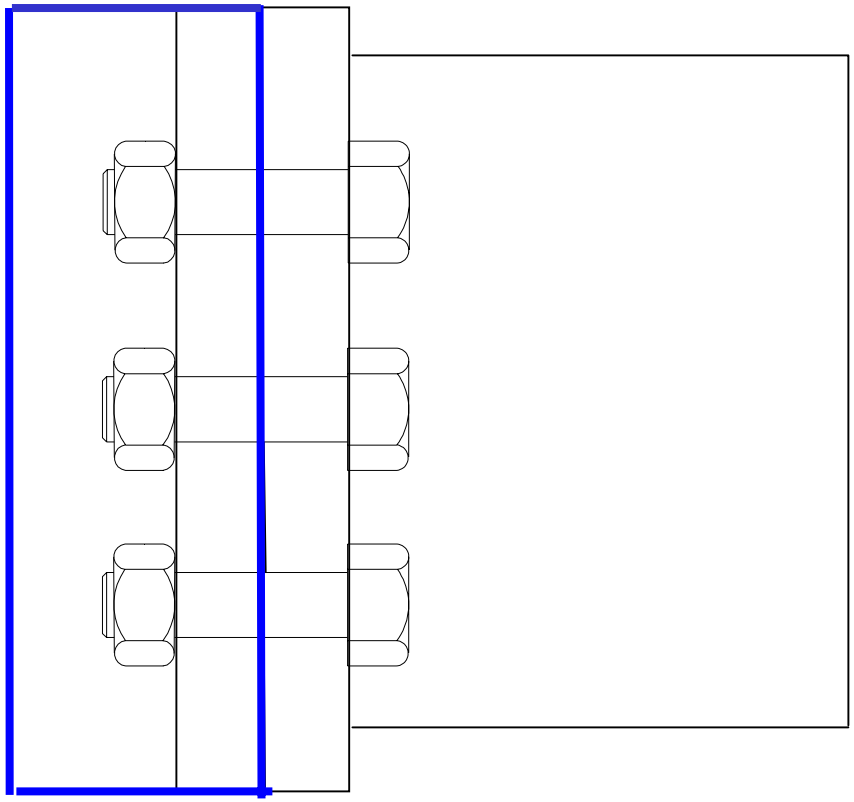


$$f_i = \frac{Md_i}{I}$$

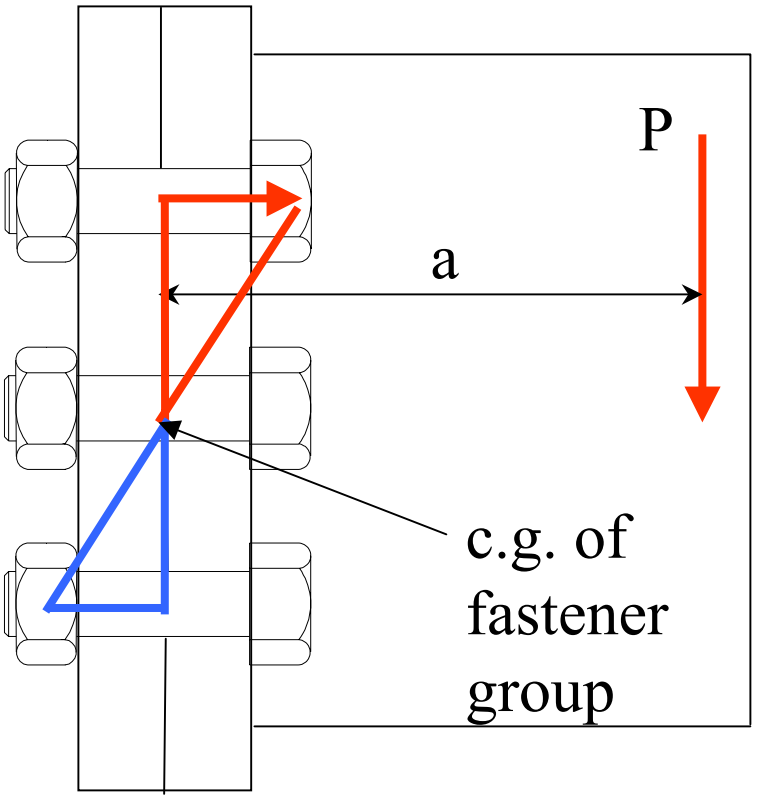
$$I = \sum_{j=1}^{n} d_j^2$$

Note that assumptions about the stiffness of the connection plate are required to estimate the location of the pry point.

Connections With Significant Preload



Compressive Mating Force Due to Preload



Force Proportionality Point (AISC Standard Practice)

Connections With Significant Preload
(Continued)

Bolt Force

$$f_{i,ext} = \frac{Mc_i}{I}$$

$f_{i,ext} \equiv$ axial force in ith fastener due to external moment.

$c_i \equiv$ distance from c.g. to ith fastener

$I \equiv$ moment of inertia of fastener group

$M \equiv$ eccentric moment

Location of C.G.

$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$

Moment of Inertia

$$I_{xx} = \sum_{i=1}^{n} \left(y_i - \bar{y}\right)^2$$

These formulas must be applied for both the x and y-directions if the connection is eccentrically loaded in both directions.

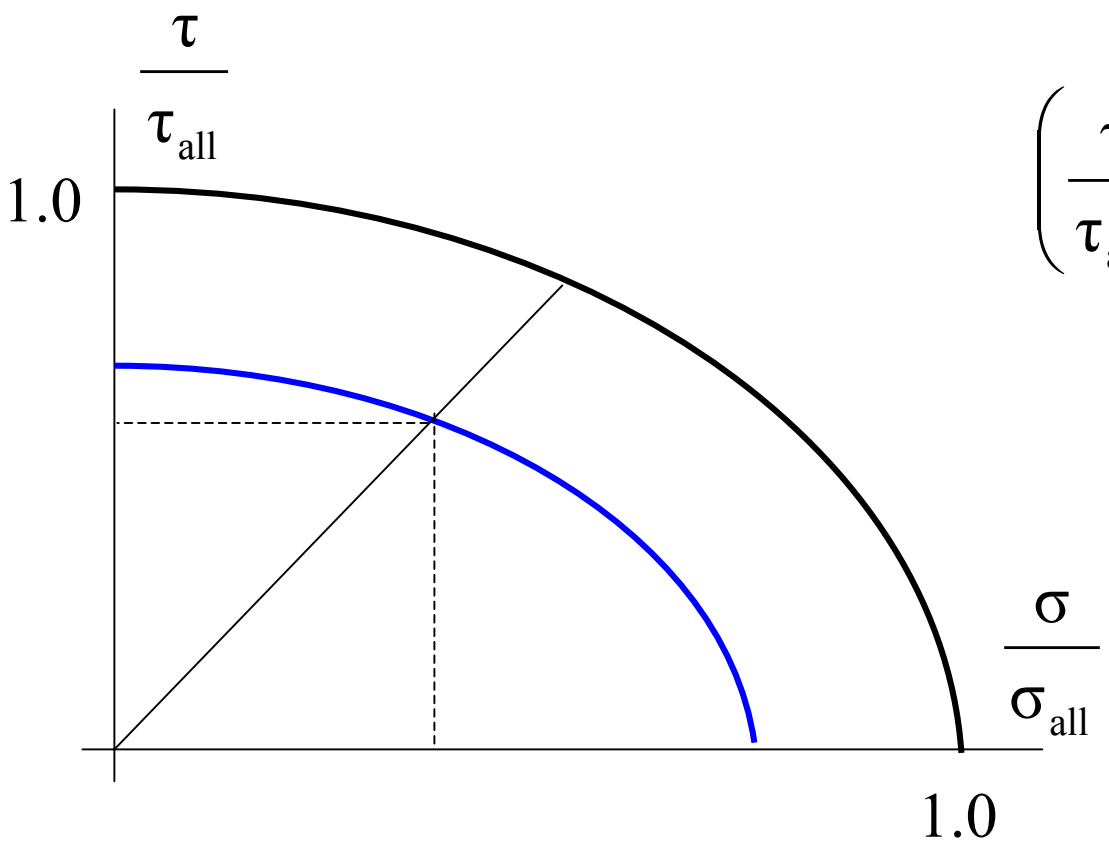
Connections With Significant Preload

The total design force in the fastener is the sum of that from the external load and the fastener's preload.

$$f_i = f_{i,ext} + f_{i,pre}$$

This design approach is conservative if no separation occurs.

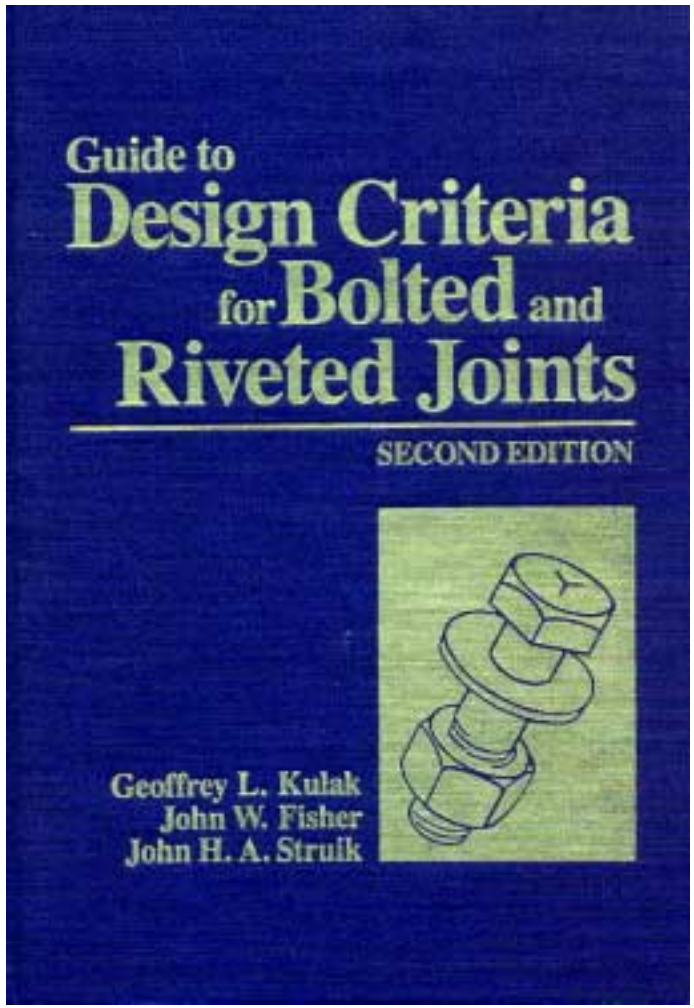
Combined Shear and Tension Interaction Curve



$$\left(\frac{\tau}{\tau_{all}}\right)^2 + \left(\frac{\sigma}{\sigma_{all}}\right)^2 \leq \frac{1}{N_{fs}}$$

Note that just like fatigue interaction curves, there are other interaction curves in use.

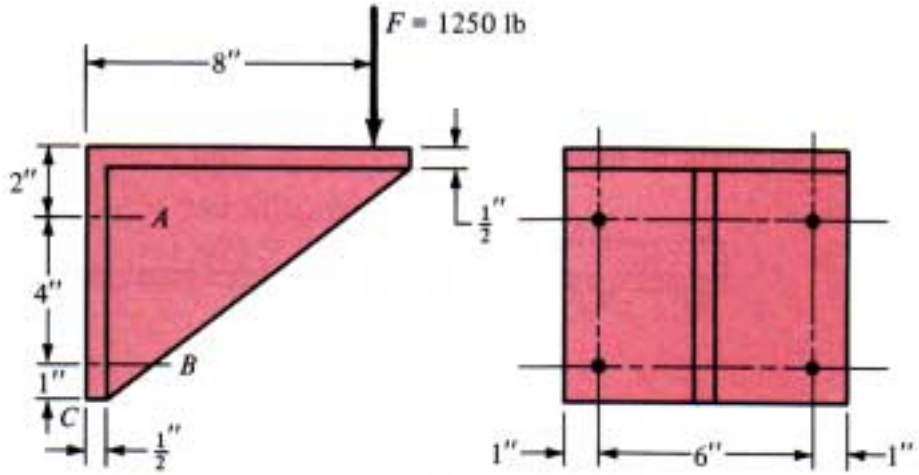
Authoritative Source of Information



The most extensive research on bolted connections has been done by the Civil Engineering community. The best source for information contained in standards may be found in the **Guide to Design Criteria for Bolted and Riveted Joints**.

www.boltcouncil.org/guide1.htm

Assignment



The bracket is to be bolted to a vertical face by means of four 3/8-16UNC-2A SAE Grade 5 bolts. The bolts are preloaded to 90 percent of the proof load. The joint constant, C, is equal to 0.173. Compute the maximum tension stress in the bolts and identify which bolt(s) in which it will occur. Compute the factor of safety for the most severely load fastener taking into account combined tension and shear.