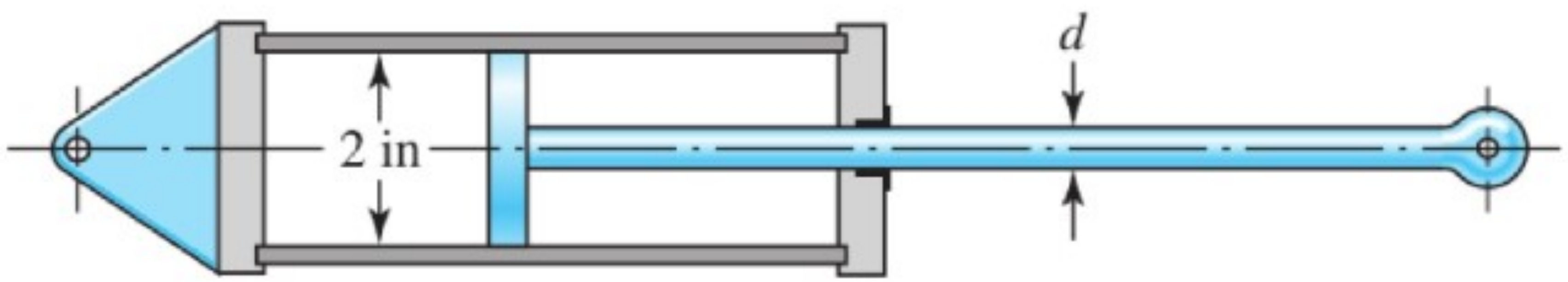
4–131 The hydraulic cylinder shown in the figure has a 2-in bore and is to operate at a pressure of 1500 psi. With the clevis mount shown, the piston rod should be sized as a column with both ends rounded for any plane of buckling. The rod is to be made of forged AISI 1030 steel without further heat treatment.

$S_y = 37.5$ kpsi

$E = 30$ Mpsi

Problem 4–131



(*a*) Use a design factor $n_d = 2.5$ and select a preferred size for the rod diameter if the column length is 50 in.

(*b*) Repeat part (*a*) but for a column length of 16 in.

(*c*) What factor of safety actually results for each of the cases above?

$$(1500\ psi)\left(\frac{\pi 2^2}{4}\right) = 4712\ lb$$

$$(4712\ lb)(2.5) = 11781\ lb = P_{cr}$$

$$P_{cr} = \frac{C\pi^2 EI}{l^2}$$

$$11781 = \frac{\pi^2\, 30\times10^6\, I}{50^2}$$

$$\frac{(11781)(50^2)}{\pi^2\, 30\times10^6} = \frac{\pi D^4}{64}$$

$$\frac{(11781)(50^2)(64)}{\pi^3\, 30\times10^6} = D^4$$

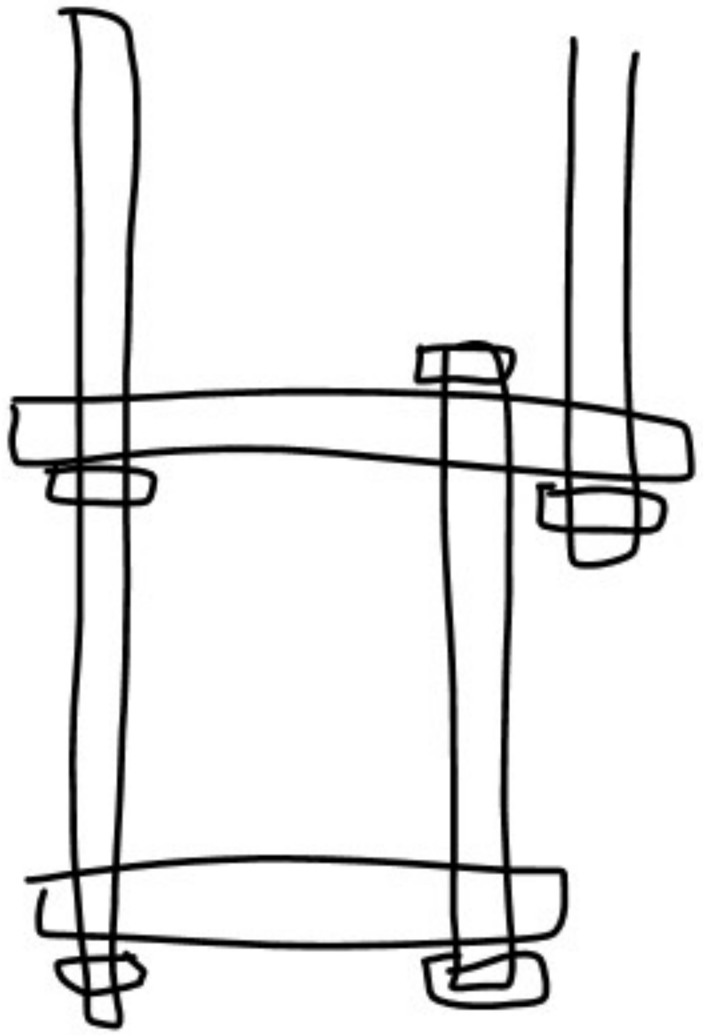
$D = 1.193$ in

$D = 1.25$ in

$$\frac{(11781)(16^2)(64)}{\pi^3\, 3\times10^7} = D^4$$

$D = 0.675$ in

$\frac{11}{16} = 0.6875$ in $= D$



$$\frac{P_{cr}\,(l^2)(64)}{\pi^3\, 30\times10^6} = D^4$$

$$\frac{D^4\,\pi^3\,30\times10^6}{64\,l^2} = P_{cr}$$

$$\frac{1.25^4\,\pi^3\,30\times10^6}{64(50^2)} = 14194 \text{ lb}$$

$$\frac{14194}{4712} = \boxed{3.01}$$

$$\frac{0.6875^4\,\pi^3\,30\times10^6}{64(16)^2} = 12684 \text{ lb}$$

$$\frac{12684}{4712} = \boxed{2.69}$$

Failure Theories

Ductile (yield)

- MSS Max shear stress
- DE Distortion Energy
- DCM Ductile Coulomb-Mohr

Brittle (fracture)

- MNS Max normal stress
- BCM Brittle Coulomb-Mohr
- MM Modified-Mohr

MSS $\sigma_1 \geq \sigma_2 \geq \sigma_3$ S_y yield strength

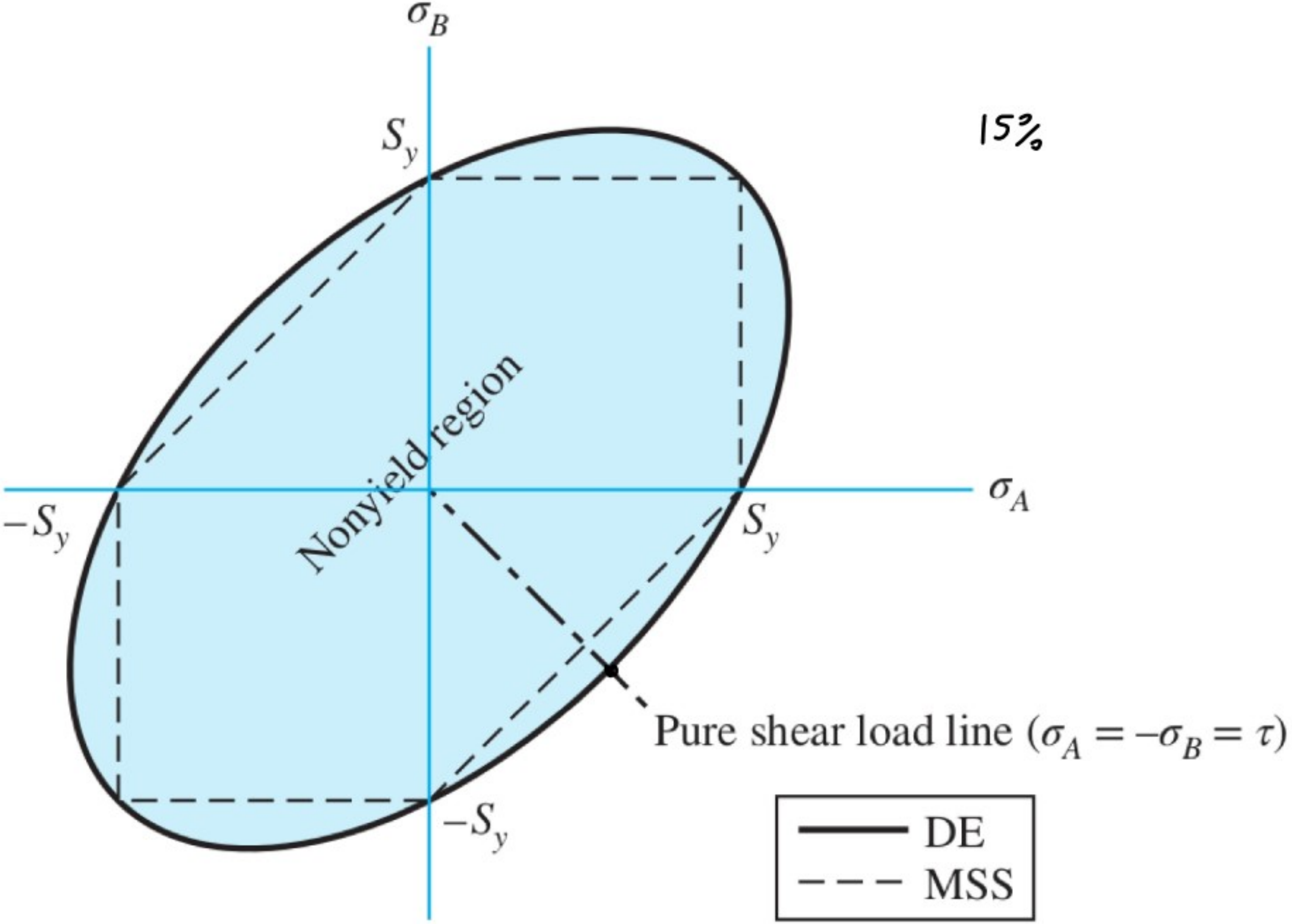
$$\tau_{max} = \frac{\sigma_1 - \sigma_3}{2} \geq \frac{S_y}{2} \qquad \sigma_1 - \sigma_3 \geq S_y$$

DE

$$\sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}} \geq S_y$$

Von Mises Stress

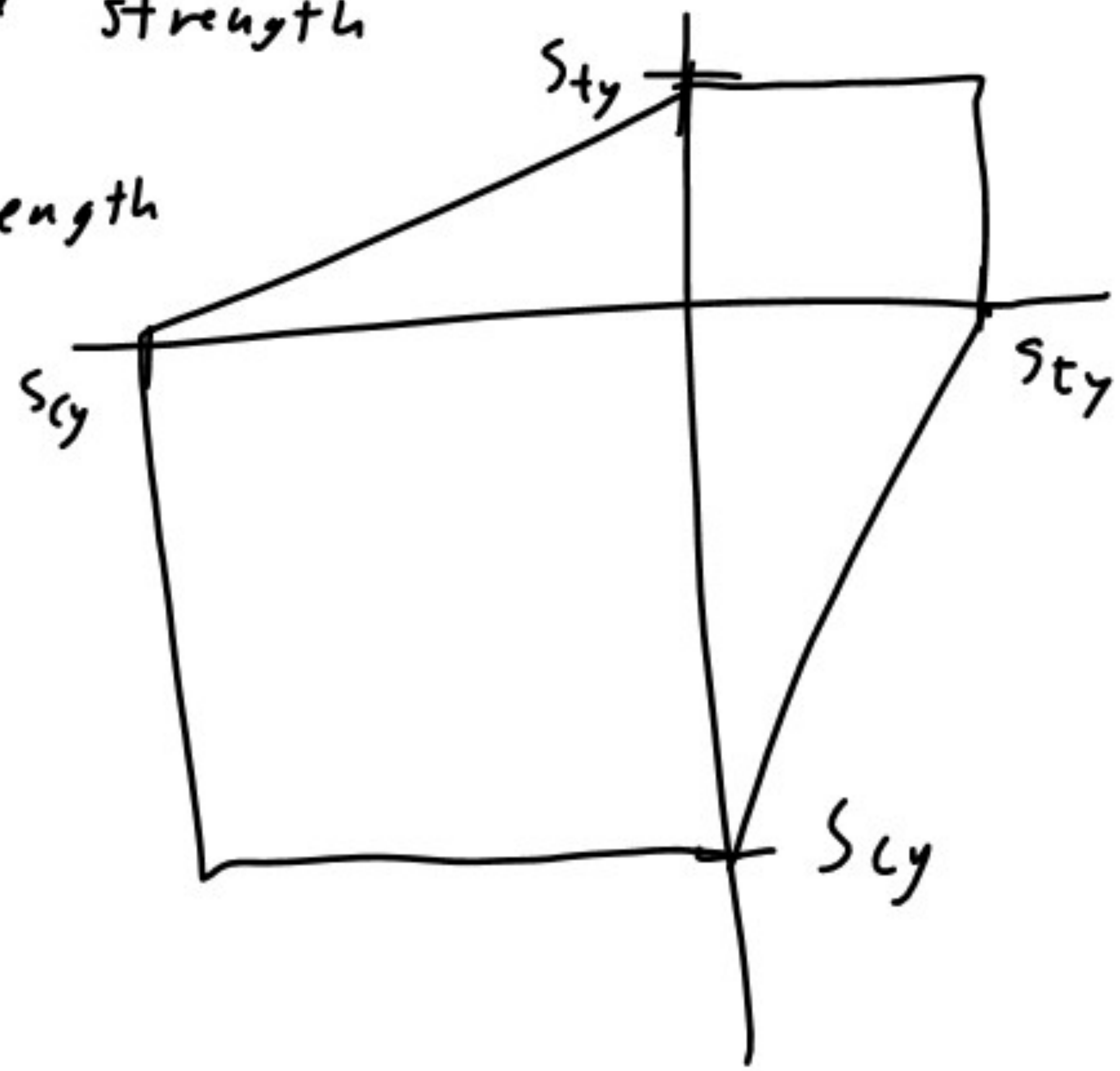
$\sigma' \geq S_y$


σ_B
S_y
15%
Nonyield region
σ_A
$-S_y$
S_y
Pure shear load line ($\sigma_A = -\sigma_B = \tau$)
$-S_y$
DE
MSS

• DCM

S_{cy} compressive yield strength

S_{ty} tensile yield strength



MNS

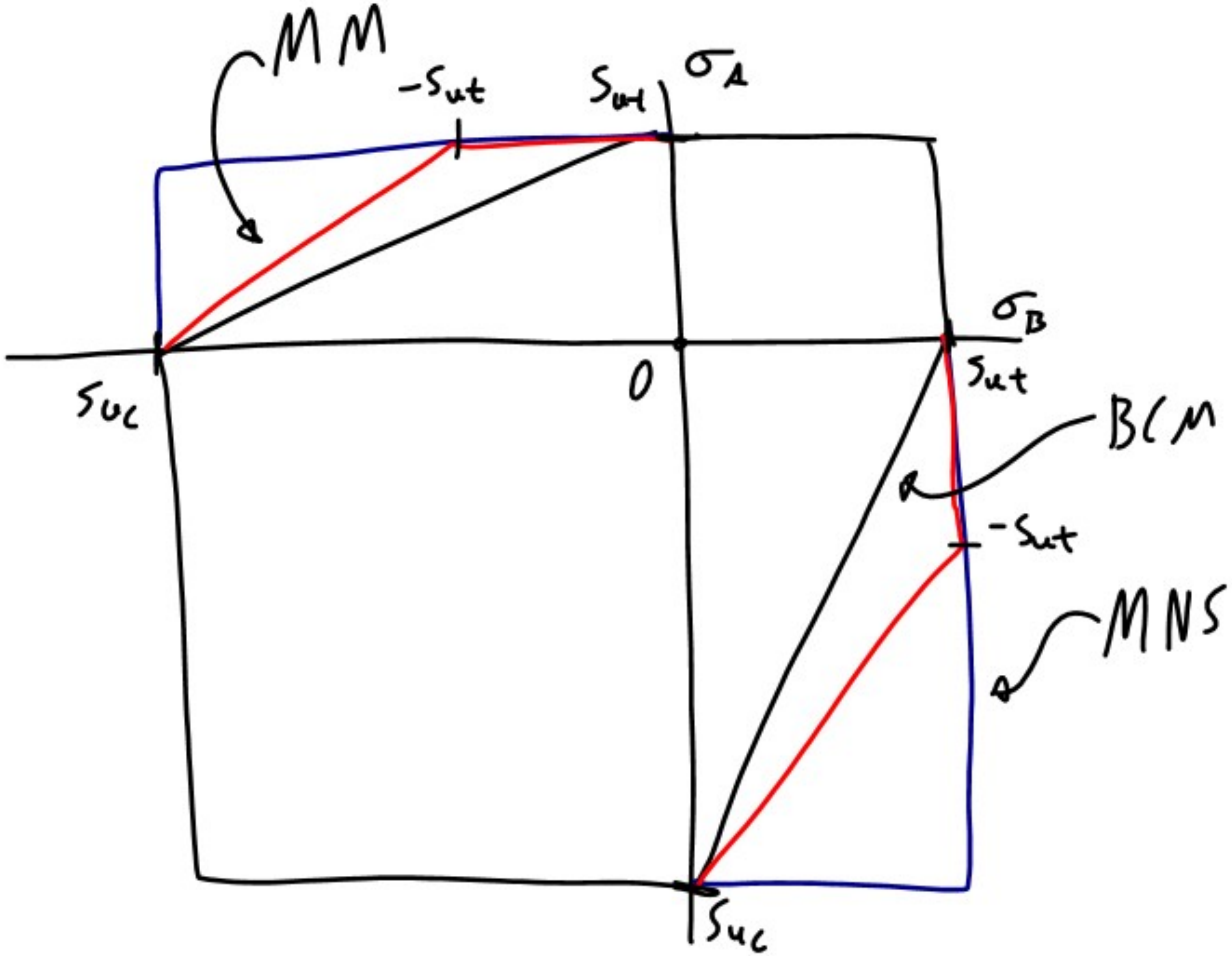
$\sigma_1 \geq S_{ut}$ $\sigma_3 \leq -S_{uc}$

BCM

$\sigma_A = \frac{S_{ut}}{n}$ $\sigma_A \geq \sigma_B \geq 0$ n factor of safety

$\frac{\sigma_A}{S_{ut}} - \frac{\sigma_B}{S_{uc}} = \frac{1}{n}$ $\sigma_A \geq 0 \geq \sigma_B$

$\sigma_B = -\frac{S_{uc}}{n}$ $0 \geq \sigma_A \geq \sigma_B$


MM
-Sut
Sut
σA
σB
Suc
0
Sut
BCM
-Sut
MNS
Suc

- Something Fun (https://www.tiktok.com/@engineeringverse.io/video/7192195590426725678)