UNIVERSIDAD MAYOR DE SAN SIMÓN

FACULTAD DE CIENCIAS Y TECNOLOGÍA

PRACTICA No. 3

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Carrera:
Ingeniería Electromecánica.

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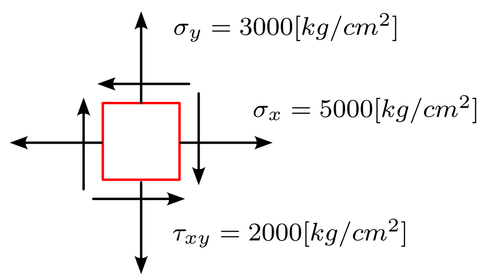
Fecha de entrega: 11 de Octubre del 2022.

PROBLEMA 1:

a) Trazar el circulo de *Mohr*.

b) Hallar: σ_{max}, σ_{min}, α y β.

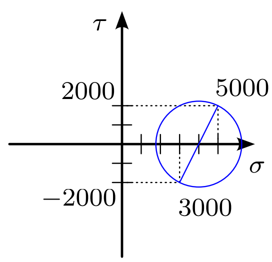
c) Las secciones principales.



Solución:

a) Circulo de *Mohr*:

$$\sigma_x = 5000[\text{kg/cm}^2]$$
$$\sigma_y = 3000[\text{kg/cm}^2]$$
$$\tau_{xy} = 2000[\text{kg/cm}^2]$$



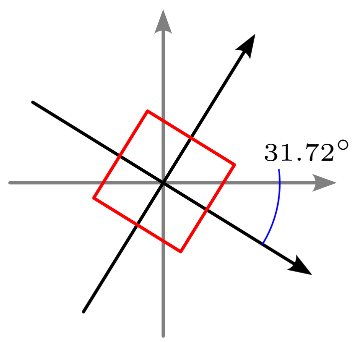
b) σ_{max}, σ_{min}, α y β.

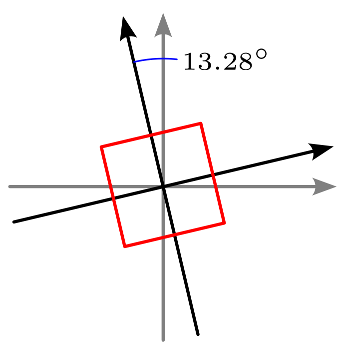
$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{8000}{2} = 4000[\text{kg/cm}^2]$$
$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{2000}{2} = 1000[\text{kg/cm}^2]$$
$$b = \tau_{xy} = 2000[\text{kg/cm}^2]$$
$$R = \sqrt{a^2 + b^2} = \sqrt{1000^2 + 2000^2} = 2236.07$$
$$\sigma_{\text{max}} = \sigma_0 + R = 6236.08[\text{kg/cm}^2]$$
$$\sigma_{\text{min}} = \sigma_0 - R = 1763.93[\text{kg/cm}^2]$$
$$\tau_{\text{max}} = R = 2236.07[\text{kg/cm}^2]$$

$$\tan 2\alpha = \frac{b}{a} = \frac{2000}{1000} = 1000$$
$$\alpha = \frac{\tan^{-1}(1000)}{2} = 31.72^\circ$$
$$2\alpha + 2\beta = 90^\circ$$
$$\beta = \frac{90 - 2\alpha}{2} = 13.28^\circ$$

$$\boxed{\begin{aligned} &\sigma_{\mathsf{max}} = 6236.08[\mathsf{kg/cm}^2] \\ &\sigma_{\mathsf{min}} = 1763.93[\mathsf{kg/cm}^2] \\ &\alpha = 31.72^\circ \\ &\beta = 13.28^\circ \end{aligned}}$$

c)



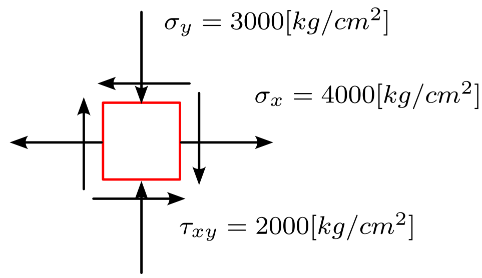


PROBLEMA 2:

a) Trazar el circulo de *Mohr*.

b) Hallar: σ_{max}, σ_{min}, α y β.

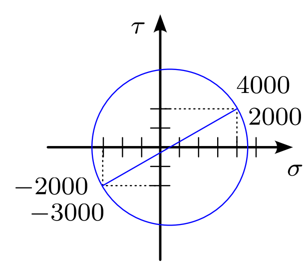
c) Las secciones principales.



Solución:

a) Circulo de *Mohr*:

$$\sigma_x = 4000[\mathsf{kg/cm^2}]$$
$$\sigma_y = -3000[\mathsf{kg/cm^2}]$$
$$\tau_{xy} = 2000[\mathsf{kg/cm^2}]$$



b) σ_{max}, σ_{min}, α y β.

$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{4000 - 3000}{2} = 500[\mathsf{kg/cm^2}]$$
$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{4000 - (-3000)}{2} = 3500[\mathsf{kg/cm^2}]$$
$$b = \tau_{xy} = 2000[\mathsf{kg/cm^2}]$$
$$R = \sqrt{a^2 + b^2} = \sqrt{3500^2 + 2000^2} = 4031.13$$
$$\sigma_{\mathsf{max}} = \sigma_0 + R = 4531.13[\mathsf{kg/cm^2}]$$
$$\sigma_{\mathsf{min}} = \sigma_0 - R = -3531.13[\mathsf{kg/cm^2}]$$
$$\tau_{\mathsf{max}} = R = 4031.13[\mathsf{kg/cm^2}]$$

$$\tan 2\alpha = \frac{b}{a} = \frac{2000}{3500} = \frac{4}{7}$$

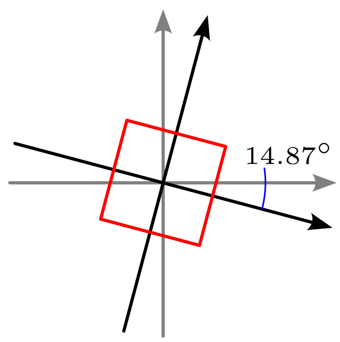
$$\alpha = \frac{\tan^{-1}(0.5714)}{2} = 14.87^\circ$$

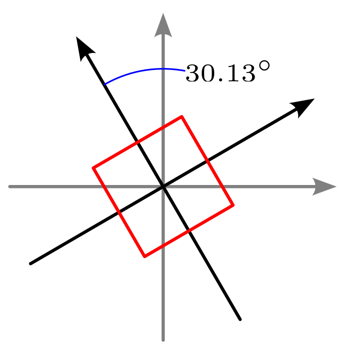
$$2\alpha + 2\beta = 90^\circ$$

$$\beta = \frac{90 - 2\alpha}{2} = 30.13^\circ$$

$$\boxed{\begin{array}{l} \sigma_{\text{max}} = 4531.13[\text{kg/cm}^2] \\ \sigma_{\text{min}} = -3531.13[\text{kg/cm}^2] \\ \alpha = 14.87^\circ \\ \beta = 30.13^\circ \end{array}}$$

c)



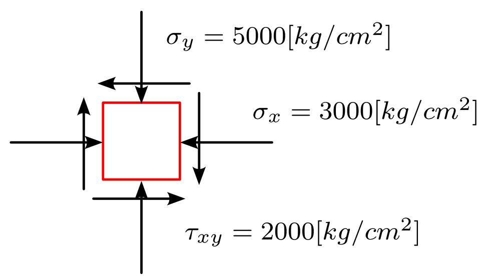


PROBLEMA 3:

a) Trazar el circulo de *Mohr*.

b) Hallar: σ_{max}, σ_{min}, α y β.

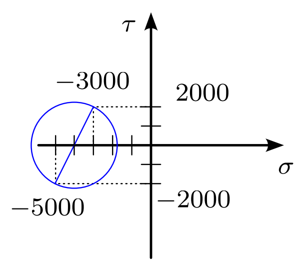
c) Las secciones principales.



Solución:

a) Circulo de *Mohr*:

$$\sigma_x = -3000[\text{kg/cm}^2]$$
$$\sigma_y = -5000[\text{kg/cm}^2]$$
$$\tau_{xy} = 2000[\text{kg/cm}^2]$$



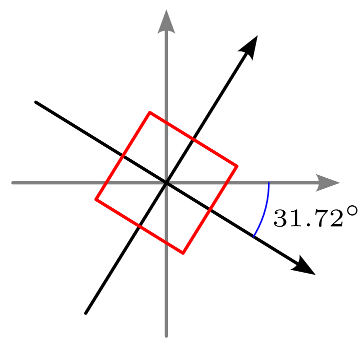
b) σ_{max}, σ_{min}, α y β.

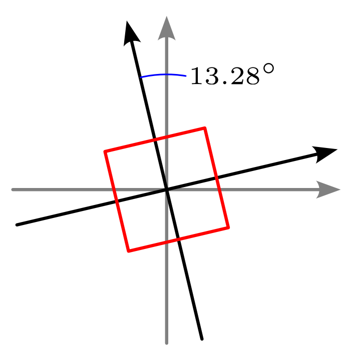
$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{-3000 - 5000}{2} = -4000[\text{kg/cm}^2]$$
$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{-3000 - (-5000)}{2} = 1000[\text{kg/cm}^2]$$
$$b = \tau_{xy} = 2000[\text{kg/cm}^2]$$
$$R = \sqrt{a^2 + b^2} = \sqrt{1000^2 + 2000^2} = 2236.07$$
$$\sigma_{\text{max}} = \sigma_0 + R = -1763.93[\text{kg/cm}^2]$$
$$\sigma_{\text{min}} = \sigma_0 - R = -6236.07[\text{kg/cm}^2]$$
$$\tau_{\text{max}} = R = 2236.07[\text{kg/cm}^2]$$

$$\tan 2\alpha = \frac{b}{a} = \frac{2000}{1000} = 2$$
$$\alpha = \frac{\tan^{-1}(2)}{2} = 31.72°$$
$$2\alpha + 2\beta = 90°$$
$$\beta = \frac{90 - 2\alpha}{2} = 13.28°$$

$$\boxed{\begin{array}{l} \sigma_{\text{max}} = -1763.93[\text{kg/cm}^2] \\ \sigma_{\text{min}} = -6236.07[\text{kg/cm}^2] \\ \alpha = 31.72° \\ \beta = 13.28° \end{array}}$$

c)



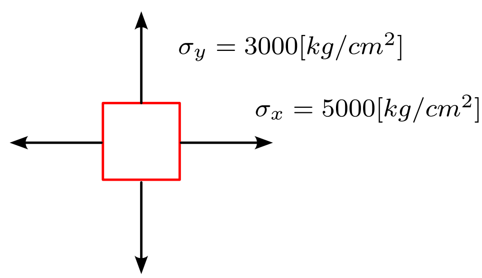


PROBLEMA 4:

a) Trazar el circulo de *Mohr*.

b) Hallar: σ_{max}, σ_{min}, α y β.

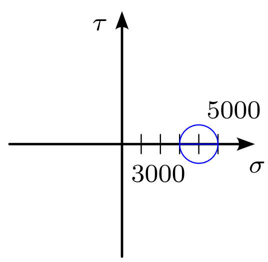
c) Las secciones principales.



Solución:

a) Circulo de *Mohr*:

$$\sigma_x = 5000[\text{kg/cm}^2]$$
$$\sigma_y = 3000[\text{kg/cm}^2]$$
$$\tau_{xy} = 0[\text{kg/cm}^2]$$



b) σ_{max}, σ_{min}, α y β.

$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{5000 + 3000}{2} = 4000[\text{kg/cm}^2]$$
$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{5000 - 3000}{2} = 1000[\text{kg/cm}^2]$$
$$b = \tau_{xy} = 0[\text{kg/cm}^2]$$
$$R = \sqrt{a^2 + b^2} = \sqrt{1000^2 + 0^2} = 1000$$
$$\sigma_{\text{max}} = \sigma_0 + R = 5000[\text{kg/cm}^2]$$
$$\sigma_{\text{min}} = \sigma_0 - R = 3000[\text{kg/cm}^2]$$
$$\tau_{\text{max}} = R = 1000[\text{kg/cm}^2]$$

$$\tan 2\alpha = \frac{b}{a} = \frac{0}{1000} = 0$$

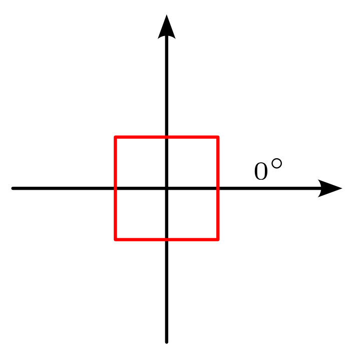
$$\alpha = \frac{\tan^{-1}(0)}{2} = 0°$$

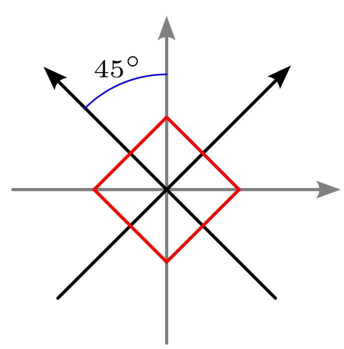
$$2\alpha + 2\beta = 90°$$

$$\beta = \frac{90 - 2\alpha}{2} = 45°$$

$$\boxed{\begin{array}{l} \sigma_{\mathsf{max}} = 5000[\mathsf{kg/cm^2}] \\ \sigma_{\mathsf{min}} = 3000[\mathsf{kg/cm^2}] \\ \alpha = 0° \\ \beta = 45° \end{array}}$$

c)



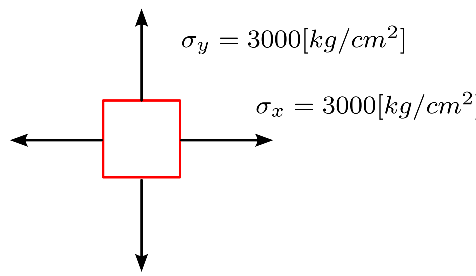


PROBLEMA 5:

a) Trazar el circulo de *Mohr*.

b) Hallar: σ_{max}, σ_{min}, α y β.

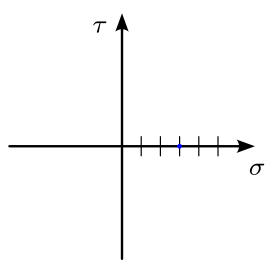
c) Las secciones principales.



Solución:

a) Circulo de *Mohr*:

$$\sigma_x = 3000[\mathsf{kg/cm}^2]$$
$$\sigma_y = 3000[\mathsf{kg/cm}^2]$$



b) σ_{max}, σ_{min}, α y β.

$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{3000 + 3000}{2} = 3000[\mathsf{kg/cm}^2]$$
$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{3000 - 3000}{2} = 0[\mathsf{kg/cm}^2]$$
$$b = \tau_{xy} = 0[\mathsf{kg/cm}^2]$$
$$R = \sqrt{a^2 + b^2} = \sqrt{0^2 + 0^2} = 0$$
$$\sigma_{\mathsf{max}} = \sigma_0 + R = 3000[\mathsf{kg/cm}^2]$$
$$\sigma_{\mathsf{min}} = \sigma_0 - R = 3000[\mathsf{kg/cm}^2]$$
$$\tau_{\mathsf{max}} = R = 0[\mathsf{kg/cm}^2]$$
$$\alpha = \text{indeterminado}$$

$$\beta = \text{indeterminado}$$

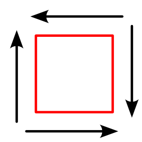
$$\boxed{\begin{array}{l} \sigma_{\text{max}} = 3000[\text{kg/cm}^2] \\ \sigma_{\text{min}} = 3000[\text{kg/cm}^2] \\ \alpha = \text{indeterminado} \\ \beta = \text{indeterminado} \end{array}}$$

PROBLEMA 6:

a) Trazar el circulo de *Mohr*.

b) Hallar: σ_{max}, σ_{min}, α y β.

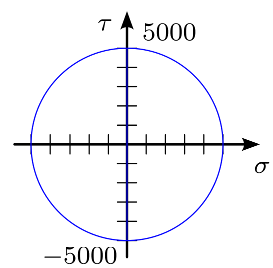
c) Las secciones principales.



Solución:

a) Circulo de *Mohr*:

$$\sigma_x = 0[\text{kg/cm}^2]$$
$$\sigma_y = 0[\text{kg/cm}^2]$$
$$\tau_{xy} = 5000[\text{kg/cm}^2]$$



b) σ_{max}, σ_{min}, α y β.

$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{0+0}{2} = 0[\text{kg/cm}^2]$$
$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{0-0}{2} = 0[\text{kg/cm}^2]$$
$$b = \tau_{xy} = 5000[\text{kg/cm}^2]$$
$$R = \sqrt{a^2 + b^2} = \sqrt{0^2 + 5000^2} = 5000$$
$$\sigma_{\text{max}} = \sigma_0 + R = 5000[\text{kg/cm}^2]$$
$$\sigma_{\text{min}} = \sigma_0 - R = -5000[\text{kg/cm}^2]$$
$$\tau_{\text{max}} = R = 5000[\text{kg/cm}^2]$$

$$\text{sen}\,2\alpha = \frac{b}{R} = \frac{5000}{5000} = 1$$

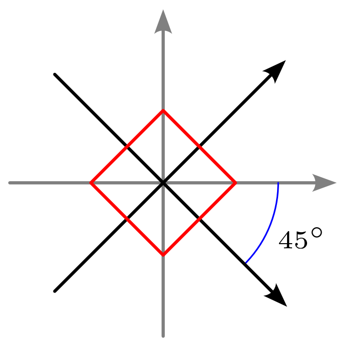
$$\alpha = \frac{\text{sen}^{-1}(1)}{2} = 45^\circ$$

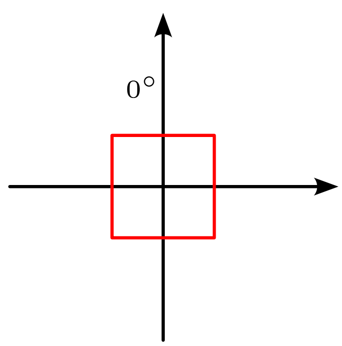
$$2\alpha + 2\beta = 90^\circ$$

$$\beta = \frac{90 - 2\alpha}{2} = 0^\circ$$

$$\boxed{\begin{array}{l} \sigma_{\text{max}} = 5000[\text{kg/cm}^2] \\ \sigma_{\text{min}} = -5000[\text{kg/cm}^2] \\ \alpha = 45^\circ \\ \beta = 0^\circ \end{array}}$$

c)

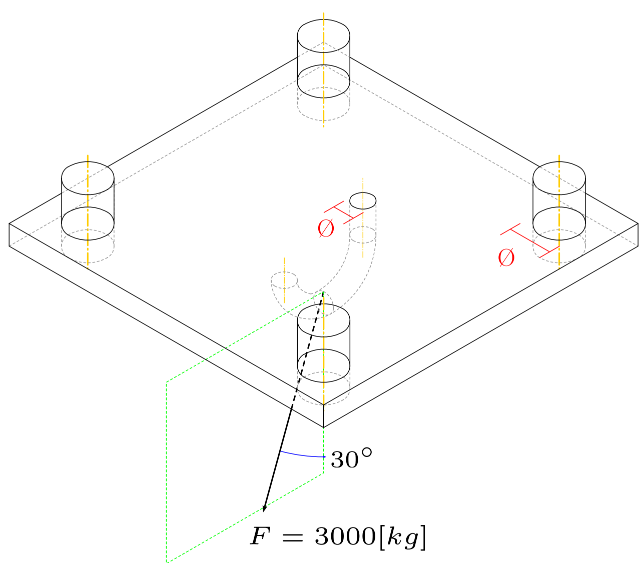




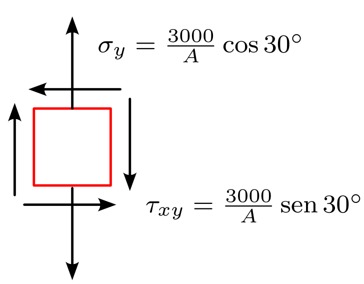
PROBLEMA 7:

a) Hallar el diámetro del gancho para una SAE1020 con $n = 2$.

b) Hallar el diámetro de los pernos para una SAE1010 con $n = 2$.



Solución:

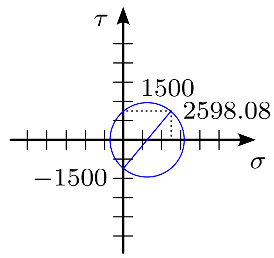


Circulo de *Mohr*:

$$\sigma_x = 0[\text{kg/cm}^2]$$

$$\sigma_y = \frac{3000}{A}\cos 30° = \frac{1500\sqrt{3}}{A}[\text{kg/cm}^2]$$

$$\tau_{xy} = \frac{3000}{A}\,\text{sen}\,30° = \frac{1500}{A}[\text{kg/cm}^2]$$



σ_{max}, σ_{min}, α y β.

$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{0 + \frac{1500\sqrt{3}}{A}}{2} = \frac{750\sqrt{3}}{A}[\text{kg/cm}^2]$$

$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{0 - \frac{1500\sqrt{3}}{A}}{2} = -\frac{750\sqrt{3}}{A}[\text{kg/cm}^2]$$

$$b = \tau_{xy} = \frac{1500}{A}[\text{kg/cm}^2]$$

$$R = \sqrt{a^2 + b^2} = \sqrt{\left(-\frac{750\sqrt{3}}{A}\right)^2 + \left(\frac{1500}{A}\right)^2} = \frac{\sqrt{3937500}}{A}$$

$$\sigma_{\text{max}} = \sigma_0 + R = \frac{3283.35}{A}[\text{kg/cm}^2]$$

$$\sigma_{\text{min}} = \sigma_0 - R = -\frac{685.28}{A}[\text{kg/cm}^2]$$

$$\tau_{\text{max}} = R = \frac{1984.31}{A}[\text{kg/cm}^2]$$

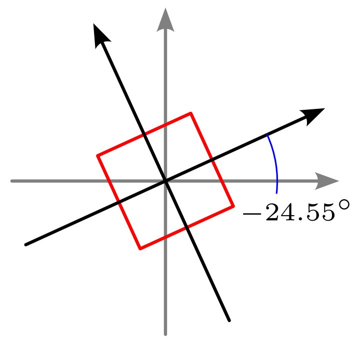
$$\tan 2\alpha = \frac{b}{a} = \frac{1500}{-750\sqrt{3}} = -\frac{2}{\sqrt{3}}$$

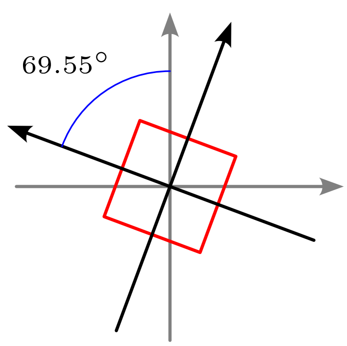
$$\alpha = \frac{\tan^{-1}(-1.1547)}{2} = -24.55°$$

$$2\alpha + 2\beta = 90°$$

$$\beta = \frac{90 - 2\alpha}{2} = 69.55°$$

$$\boxed{\begin{array}{l} \sigma_{\text{max}} = \dfrac{3283.35}{A}[\text{kg/cm}^2] \\[2ex] \sigma_{\text{min}} = -\dfrac{685.28}{A}[\text{kg/cm}^2] \\[2ex] \alpha = -24.55° \\ \beta = 69.55° \end{array}}$$





a) Diámetro del gancho ($\sigma_f = 2500[kg/cm^2]$):

$$\sigma_{\text{max}} \leq \bar{\sigma}$$
$$\frac{3283.35}{A} \leq \frac{\sigma_f}{n}$$
$$\frac{3283.35}{\frac{\pi}{4}Ø^2} \leq \frac{\sigma_f}{2}$$
$$\sqrt{\frac{(4)(2)(3283.35)}{\pi(2500)}} \leq Ø$$
$$1.8288[cm] \leq Ø$$

$$\boxed{\begin{array}{l} Ø \geq 18.29[mm] \\ Ø = \frac{3''}{4} \end{array}}$$

$$\tau_{\text{max}} \leq \bar{\tau}$$
$$\frac{1984.31}{A} \leq \frac{0.5\sigma_f}{n}$$
$$\frac{1984.31}{\frac{\pi}{4}Ø^2} \leq \frac{0.5\sigma_f}{2}$$

$$\sqrt{\frac{(4)(2)(1984.31)}{\pi(0.5)(2500)}} \leq \text{Ø}$$
$$2.0106[cm] \leq \text{Ø}$$

$$\boxed{\boxed{\begin{array}{l}\text{Ø} \geq 20.11[mm] \\ \text{Ø} = \dfrac{13}{16}''\end{array}}}$$

b) Diámetro de los pernos ($\sigma_f = 2100[kg/cm^2]$):

$$\sigma_{\text{max}} \leq \bar{\sigma}$$
$$\frac{3283.35}{4A} \leq \frac{\sigma_f}{n}$$
$$\frac{3283.35}{4\frac{\pi}{4}\text{Ø}^2} \leq \frac{\sigma_f}{2}$$
$$\sqrt{\frac{(2)(3283.35)}{\pi(2100)}} \leq \text{Ø}$$
$$0.9977[cm] \leq \text{Ø}$$

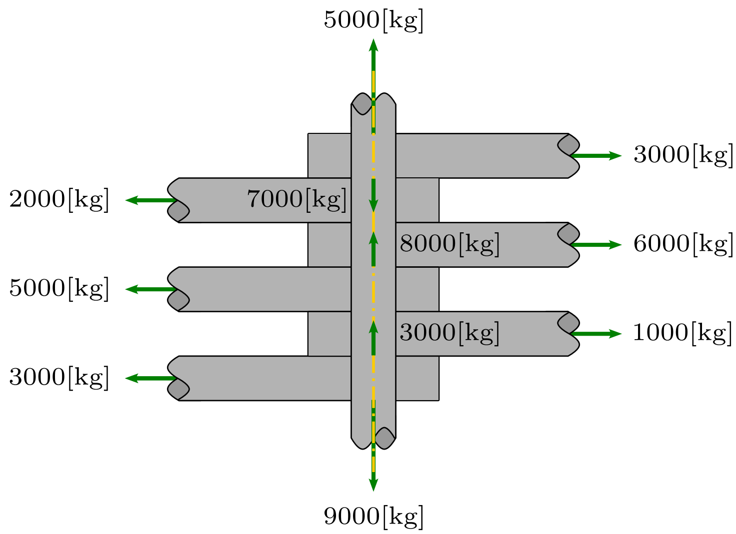
$$\boxed{\begin{array}{l}\text{Ø} \geq 9.98[mm] \\ \text{Ø} = \dfrac{13}{32}''\end{array}}$$

$$\tau_{\text{max}} \leq \bar{\tau}$$
$$\frac{1984.31}{4A} \leq \frac{0.5\sigma_f}{n}$$
$$\frac{1984.31}{4\frac{\pi}{4}\text{Ø}^2} \leq \frac{0.5\sigma_f}{2}$$
$$\sqrt{\frac{(2)(1984.31)}{\pi(0.5)(2100)}} \leq \text{Ø}$$
$$1.0969[cm] \leq \text{Ø}$$

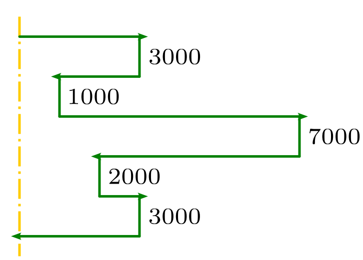
$$\boxed{\boxed{\begin{array}{l}\text{Ø} \geq 10.97[mm] \\ \text{Ø} = \dfrac{7}{16}''\end{array}}}$$

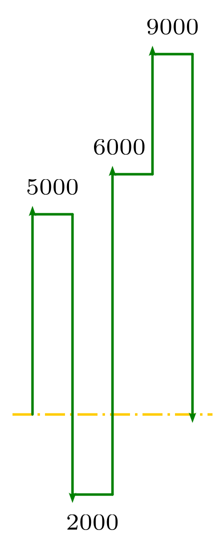
PROBLEMA 8:

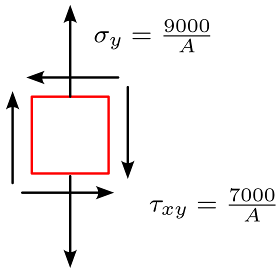
a) Hallar el diámetro del eje para $\sigma_f = 4500[kg/cm^2]$ y $n = 2$.



Solución:

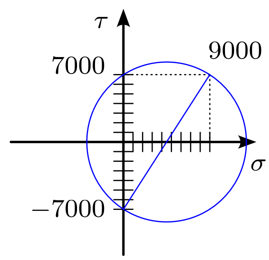






Circulo de *Mohr*:

$$\sigma_x = 0[\text{kg/cm}^2]$$
$$\sigma_y = \frac{9000}{A}[\text{kg/cm}^2]$$
$$\tau_{xy} = \frac{7000}{A}[\text{kg/cm}^2]$$



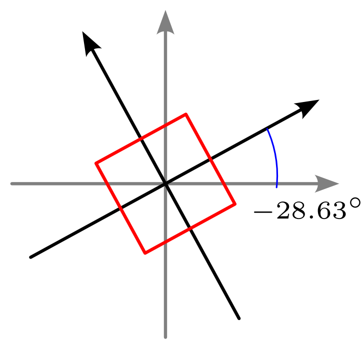
σ_{max}, σ_{min}, α y β.

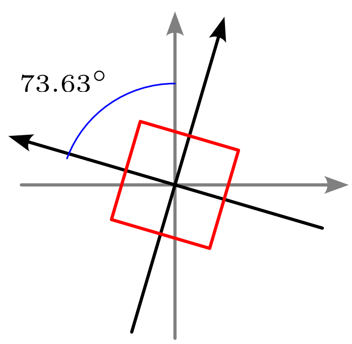
$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{0 + \frac{9000}{A}}{2} = \frac{4500}{A}[\text{kg/cm}^2]$$
$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{0 - \frac{9000}{A}}{2} = -\frac{4500}{A}[\text{kg/cm}^2]$$
$$b = \tau_{xy} = \frac{7000}{A}[\text{kg/cm}^2]$$
$$R = \sqrt{a^2 + b^2} = \sqrt{\left(-\frac{4500}{A}\right)^2 + \left(\frac{7000}{A}\right)^2} = \frac{\sqrt{69250000}}{A}$$
$$\sigma_{\text{max}} = \sigma_0 + R = \frac{12821.66}{A}[\text{kg/cm}^2]$$
$$\sigma_{\text{min}} = \sigma_0 - R = -\frac{3821.66}{A}[\text{kg/cm}^2]$$
$$\tau_{\text{max}} = R = \frac{8321.66}{A}[\text{kg/cm}^2]$$
$$\tan 2\alpha = \frac{b}{a} = \frac{7000}{-4500} = -\frac{14}{9}$$
$$\alpha = \frac{\tan^{-1}(-0.4444)}{2} = -28.63^\circ$$

$$2\alpha + 2\beta = 90°$$

$$\beta = \frac{90 - 2\alpha}{2} = 73.63°$$

$$\boxed{\begin{array}{l} \sigma_{\mathsf{max}} = \dfrac{12821.66}{A}[\mathsf{kg/cm^2}] \\[2ex] \sigma_{\mathsf{min}} = -\dfrac{3821.66}{A}[\mathsf{kg/cm^2}] \\[2ex] \alpha = -28.63° \\ \beta = 73.63° \end{array}}$$





a) Diámetro del eje ($\sigma_f = 4500[kg/cm^2]$):

$$\sigma_{\mathsf{max}} \leq \bar{\sigma}$$

$$\frac{12821.66}{A} \leq \frac{\sigma_f}{n}$$

$$\frac{12821.66}{\frac{\pi}{4}\varnothing^2} \leq \frac{\sigma_f}{2}$$

$$\sqrt{\frac{(4)(2)(12821.66)}{\pi(4500)}} \leq \text{Ø}$$

$$2.6936[cm] \leq \text{Ø}$$

$$\boxed{\begin{array}{l} \text{Ø} \geq 26.94[mm] \\ \text{Ø} = 1\frac{1}{16}'' \end{array}}$$

$$\tau_{\text{max}} \leq \bar{\tau}$$

$$\frac{8321.66}{A} \leq \frac{0.5\sigma_f}{n}$$

$$\frac{8321.66}{\frac{\pi}{4}\text{Ø}^2} \leq \frac{0.5\sigma_f}{2}$$

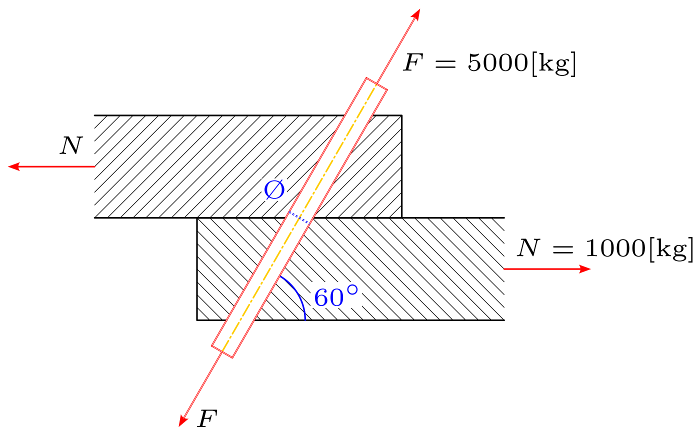
$$\sqrt{\frac{(4)(2)(8321.66)}{\pi(0.5)(4500)}} \leq \text{Ø}$$

$$3.069[cm] \leq \text{Ø}$$

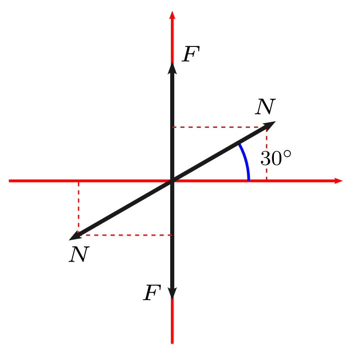
$$\boxed{\boxed{\begin{array}{l} \text{Ø} \geq 30.69[mm] \\ \text{Ø} = 1\frac{13}{64}'' \end{array}}}$$

PROBLEMA 9:

a) Hallar el diámetro del remache para un SAE1045 y $n = 2$.



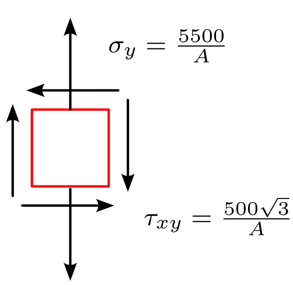
Solución:



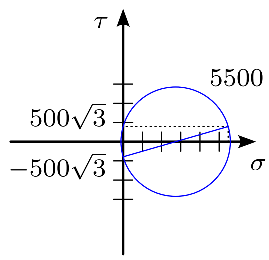
$$\sigma_x = 0[\text{kg/cm}^2]$$

$$\sigma_y = \frac{F + N sen(30°)}{A} = \frac{5000 + 1000\, sen(30°)}{A} = \frac{5500}{A}[\text{kg/cm}^2]$$

$$\tau_{xy} = \frac{N cos(30°)}{A} = \frac{1000\, cos(30°)}{A} = \frac{500\sqrt{3}}{A}[\text{kg/cm}^2]$$



Circulo de *Mohr*:



σ_{max}, σ_{min}, α y β.

$$\sigma_0 = \frac{\sigma_x + \sigma_y}{2} = \frac{0 + \frac{5500}{A}}{2} = \frac{2750}{A}[\mathsf{kg/cm^2}]$$

$$a = \frac{\sigma_x - \sigma_y}{2} = \frac{0 - \frac{5500}{A}}{2} = -\frac{2750}{A}[\mathsf{kg/cm^2}]$$

$$b = \tau_{xy} = \frac{500\sqrt{3}}{A}[\mathsf{kg/cm^2}]$$

$$R = \sqrt{a^2 + b^2} = \sqrt{\left(-\frac{2750}{A}\right)^2 + \left(\frac{500\sqrt{3}}{A}\right)^2} = \frac{\sqrt{8312500}}{A}$$

$$\sigma_{\mathsf{max}} = \sigma_0 + R = \frac{5633.14}{A}[\mathsf{kg/cm^2}]$$

$$\sigma_{\mathsf{min}} = \sigma_0 - R = -\frac{133.14}{A}[\mathsf{kg/cm^2}]$$

$$\tau_{\mathsf{max}} = R = \frac{2883.14}{A}[\mathsf{kg/cm^2}]$$

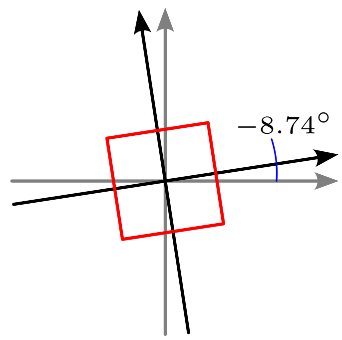
$$\tan 2\alpha = \frac{b}{a} = \frac{500\sqrt{3}}{-2750} = -\frac{2\sqrt{3}}{11}$$

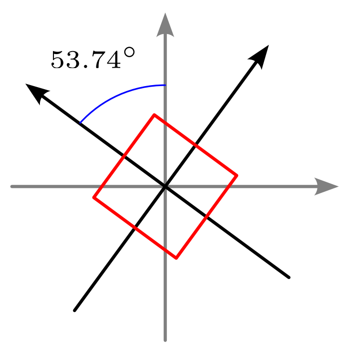
$$\alpha = \frac{\tan^{-1}(-0.3149)}{2} = -8.74^\circ$$

$$2\alpha + 2\beta = 90^\circ$$

$$\beta = \frac{90 - 2\alpha}{2} = 53.74^\circ$$

$$\boxed{\begin{array}{l} \sigma_{\mathsf{max}} = \dfrac{5633.14}{A}[\mathsf{kg/cm^2}] \\[2ex] \sigma_{\mathsf{min}} = -\dfrac{133.14}{A}[\mathsf{kg/cm^2}] \\[2ex] \alpha = -8.74^\circ \\ \beta = 53.74^\circ \end{array}}$$





a) Diámetro del remache ($\sigma_f = 4500[kg/cm^2]$):

$$\sigma_{\text{max}} \leq \bar{\sigma}$$

$$\frac{5633.14}{A} \leq \frac{\sigma_f}{n}$$

$$\frac{5633.14}{\frac{\pi}{4}\text{Ø}^2} \leq \frac{\sigma_f}{2}$$

$$\sqrt{\frac{(4)(2)(5633.14)}{\pi(4500)}} \leq \text{Ø}$$

$$1.7854[cm] \leq \text{Ø}$$

$$\boxed{\begin{array}{l} \text{Ø} \geq 17.84[mm] \\ \text{Ø} = \frac{11}{16}'' \end{array}}$$

$$\tau_{\text{max}} \leq \bar{\tau}$$

$$\frac{2883.14}{A} \leq \frac{0.5\sigma_f}{n}$$

$$\frac{2883.14}{\frac{\pi}{4}\text{Ø}^2} \leq \frac{0.5\sigma_f}{2}$$

$$\sqrt{\frac{(4)(2)(2883.14)}{\pi(0.5)(4500)}} \leq Ø$$

$$1.8064[cm] \leq Ø$$

$$\boxed{\begin{array}{l} Ø \geq 18.06[mm] \\ Ø = \dfrac{23''}{32} \end{array}}$$