Machine Design Course for Communication / Electrical Department

Sheet 2 Solution - Design of Bolts

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Problem 1

Two plates 10 mm in thicknesses and subjected to a tensile load of F = 4000 N are connected by 4 bolts as shown in Figure 1. Compute the diameter of the bolts if the maximum stress in the bolts is 200 MPa

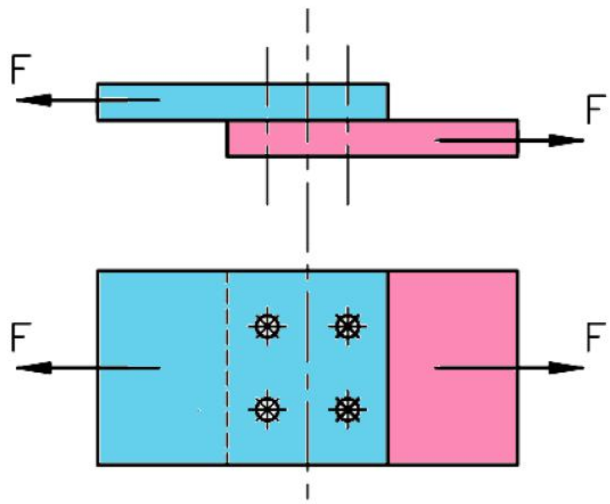


Figure 1.

Givens:

t=10 mm f=4000N N=4 bolts $\tau_{bolts\ max}$=200Mpa

Req: d=?

Solution

$$\tau_{bolts} = \frac{F}{n \times Area} \leq \tau_{bolts,max}$$

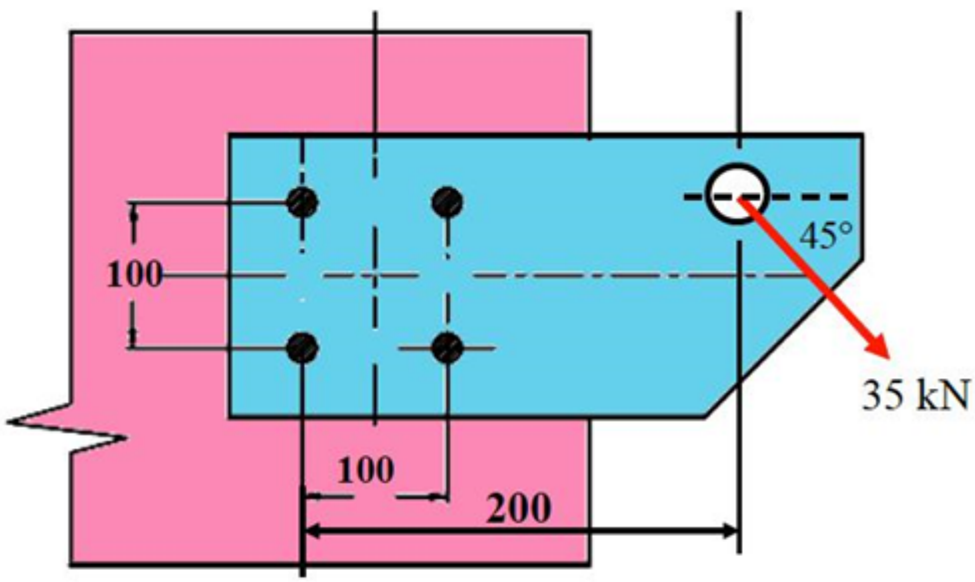
$$\frac{4000}{4 \times \frac{\pi}{4} d_i^2} \leq 200$$

d_i =6.4 mm → d_o=d_i/0.85=7.5 mm

from table the type of bolts will be <u>M8</u>

Problem 2

Four bolts are used to secure the bracket to the wall as shown in Figure 2. All the dimensions are in millimeter. If the bolts are made of the steel having S_y=420 MPa, determine their size of bolts using factor of safety of 2.



Given:

S_y=420Mpa f.o.s = 2 N=4

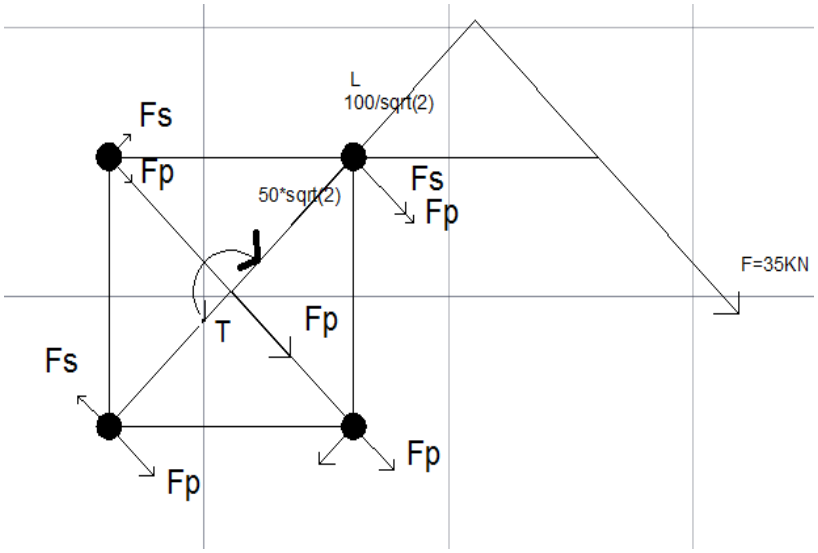
Req:

Size of bolts

Solution

Primary stress:

$$\tau_p = \frac{F}{n\times Area} = \frac{35\times 1000}{4\times Area} = 8.75*10^3/A \quad \rightarrow 1$$



Secondary stress:

T=F*L=F1*r1+F2*r2+F3*r3+F4*r4

F1/r1=F2/r2=F3/r3=F4/r4

As: r1=r2=r3=r4

So: F1=F2=F3=F4

T=F*l=4*Fs*r → Fs=17.5*10^3 N

$\tau_s = \frac{F_s}{Area} = \frac{17.5\times1000}{Area}$ at min ϴ or r_{max}

So the max stress at bolt no. 1 θ =0.0^0

$$\tau_{tot} = \sqrt{\tau_p^2 + \tau_s^2 + 2\times\tau_p\times\tau_s\times\cos\theta}$$

$$\tau_{tot} = \frac{(8.75\times1000+17.5\times1000)}{Area} = \frac{26.25\times1000}{Area}$$

$$\tau_{tot} \le \frac{S_y}{f.o.s}$$

$$\frac{26.25\times1000}{Area} \le 0.577\times\frac{420}{2}$$

$Area$ =250mm^2

d_i=17.8 mm

do=di/0.85=20.9mm

from table we take M24

Problem 3

Three bolts are used to secure the bracket to the wall as shown in Figure 3. All the dimensions are in millimeter. If the bolts are made of the steel having S_y=380 MPa, determine their size of bolts using factor of safety of 2.5.

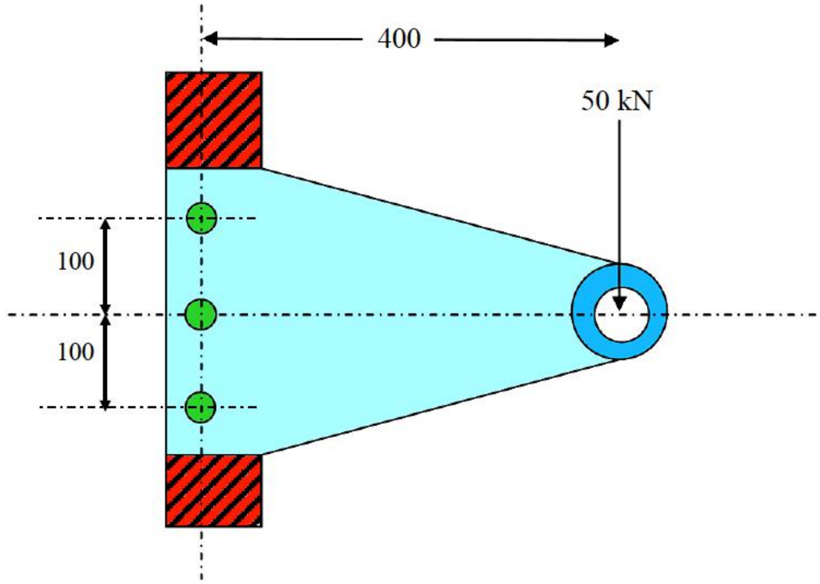


Figure 3.

Givens:

S_y=380 MPa   n=2.5   N=3   F=50 kN

Req:

Size of bolts?

Solution

Primary stress:

$$\tau_p = \frac{F}{n\times Area} = \frac{5000}{3\times Area} = 16.667*10^3/A \quad \rightarrow 1$$

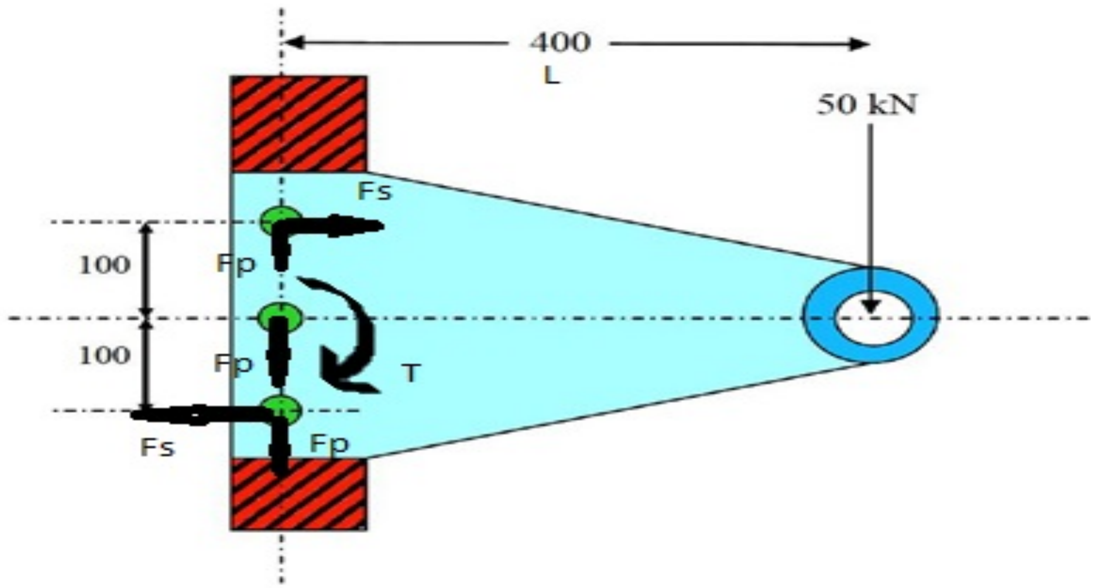


Figure 3.

Secondary stress:

T=F*L=F1*r1+F2*0+F3*r3

F1/r1=F3/r3

As: r1= r3

So: F1= F3

T=F*400=2*F_s*r → Fs=100*10^3N

$\tau_s = \frac{F_s}{Area} = \frac{100\times1000}{Area}$ = →2

Max total stress at min ϴ or r_{max}

So the max stress at bolt no. 1 or 3 ϴ=90^0

$$\tau_{tot} = \sqrt{\tau_p^2 + \tau_s^2 + 2\times\tau_p\times\tau_s\times\cos\theta}$$

$$\tau_{tot} = \frac{\sqrt{(16.667\times10^3)^2+(100\times10^3)^2+2\times16.667\times10^3\times100\times10^3\times\cos 90}}{Area}$$

$$\tau_{tot} = \frac{101.38\times1000}{Area}$$

$$\tau_{tot} \le \frac{S_y}{f.o.s}$$

$$\frac{101.38\times1000}{Area}\leq 0.577\times\frac{380}{2.5}$$

d_i=38.36 mm
do=di/0.85=45.13mm
→from table we take M48

Problem 4

The bracket shown in Figure 4 is secured to a 'C' column by means of three M16 through bolts having S_y=620 MPa, the bracket is subjected to vertical load of 16 kN. Determine the factor of safety for the bolts. Neglect the stresses due to initial tension in bolts. All the dimensions are in millimeter.

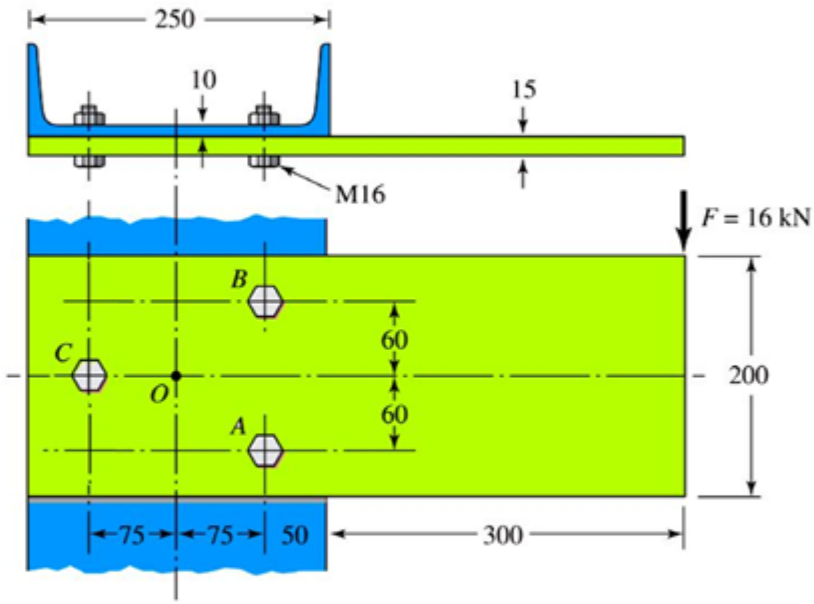


Figure 4.

Givens:

S_y=620 MPa   N=3   F=16 kN   bolt size=M16

Req:

n=??

solution

Primary stress:

$$\tau_p = \frac{F}{n\times Area} = \frac{16000}{3\times\frac{\pi}{4}d^2} = \frac{16000}{3\times\frac{\pi}{4}(0.85\times16)^2} = 145.3\ Mpa \quad \rightarrow 1$$

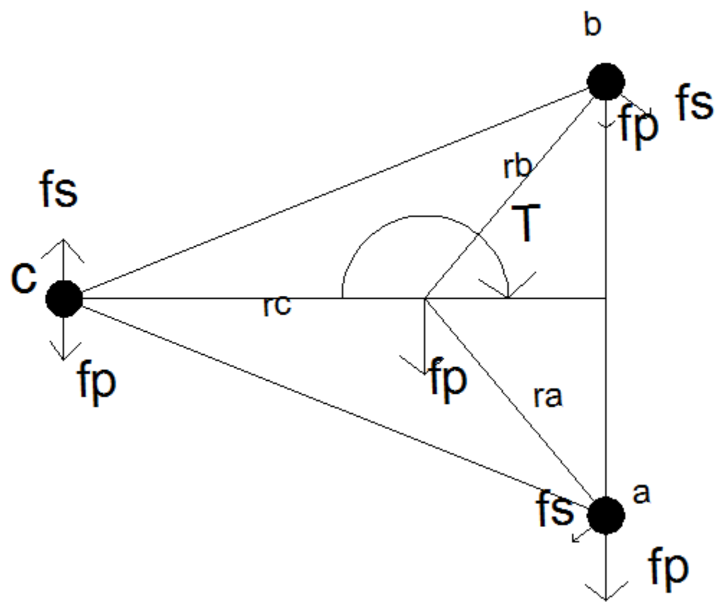
Secondary stress:

T=F*400=Fa*ra+Fb*rb+Fc*rc

Fa/ra=Fb/rb=Fc/rc

As: rc=100mm   ra=rb=sqrt(50^2+60^2)=78.1mm
So: Fa=Fb=22515.3 N   Fc=28829 N

$\tau_{s,a\ or\ b}$ =22515.3/(3*(π*(0.85*16)^2)/4) =155 Mpa



$\tau_{s,c}$=28829/(3*(π*(0.85*16)^2)/4) =198.5 Mpa
Max total stress at Θ_{min} or r_{max}
max r at c ……   min Θ at a or b
Bolt a:
$\cos\theta$ =50/78.1=0.64

$$\tau_{a,tot} = \sqrt{\tau_p^2 + \tau_s^2 + 2\times\tau_p\times\tau_s\times\cos\theta}$$

$$\tau_{a,tot} = \frac{\sqrt{(16.667\times10^3)^2+(100\times10^3)^2+2\times16.667\times10^3\times100\times10^3\times\cos 90}}{Area}$$

$$\tau_{tot} = 181\ Mpa$$

Bolt c:

Θ_c=180^o

$\tau_{c,tot}$ = $\sqrt{\tau_p^2 + \tau_s^2 + 2\times\tau_p\times\tau_s\times\cos\theta}$

$\tau_{c,tot}$=162 Mpa

$$\tau_{max,tot} = 181\ Mpa$$

Design Eqn:

$$\tau_{max,tot} \leq \frac{S_y}{f.o.s}$$

$$181 \leq 0.577\times\frac{620}{f.o.s}$$

→ $f.o.s$ =1.96