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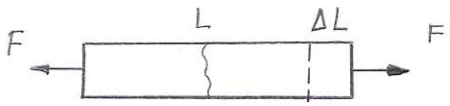
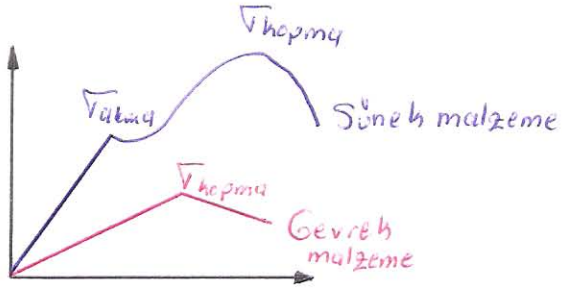
MAKİNE ELEMANLARI 1



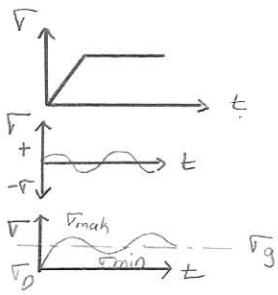
Mukavemet Hesabı

$$\sigma_{mak} \leq \sigma_{em}$$

$$\frac{F}{A}, \frac{mc}{I}$$



	Sünek Malzeme	Gevrek Malzeme
Statik Yük	$\sigma_{em} = \frac{\sigma_{ak}}{S}$	$\sigma_{em} = \frac{\sigma_{ak}}{S} \cdot \frac{1}{K_ç}$
Dinamik Yük (Tam değişken)	$\sigma_{em} = \frac{\sigma_d}{S} \cdot \frac{K_y \cdot K_b}{K_ç} \cdot K_d$	
Statik+Dinamik Yük (Kısmen değişken)	$\sigma_{eş} = \sigma_D + \sigma_g \frac{\sigma_{ak} \cdot K_ç}{\sigma_d \cdot K_y \cdot K_b} \leq \sigma_{em}$	



Dinamik $\sigma_D = \frac{\sigma_{mak} + \sigma_{min}}{2}$

$\sigma_g = \frac{\sigma_{mak} - \sigma_{min}}{2}$

σ_{em} = Emniyetli gerilme
σ_{ak} = Akma gerilmesi
S = Emniyet katsayısı
$K_ç$ = Çentik Faktörü
σ_d = Sürekli mukavemet
K_y = Yüzey faktörü
K_b = Büyüklük faktörü
K_d = Diğer faktörler

S = Emniyet Katsayısı
S = 1,5–2 uygun
S = 2–3 malzeme emn.
S > 4 fazla

$K_ç$ = Çentik Faktörü
$K_ç = 1$ (Çentiksiz)
$K_ç = 1 + q(K_t - 1)$
q = Çentik hassasiyeti
K_t = Teorik fark

σ_D = Sürekli Mukavemet
Malzemenin 10^6'dan fazla yük dağılımına dayandığı gerilme

Çelik $\sigma_D \cong 0,5\sigma_K \iff \sigma_K \leq 1400\ N/mm^2$

$\sigma_D \cong 700 \iff \sigma_K > 1400\ N/mm^2$

demir $\sigma_D \cong 0,7\sigma_K$

demirsiz metal $\sigma_D \cong 0,3\sigma_K$

K_b = Büyüklük Faktörü

$K_b = 1$	$\phi d \leq 10$
$K_b = 0,9$	$d = 20$
$K_b = 0,8$	$d = 30$
$K_b = 0,7$	$d = 50$
$K_b = 0,6$	$d = 200$

K_y = Yüzey faktörü

$K_y = 1$	Polisaj
$K_y = 0,88$	Taşlama
$K_y = 0,84$	Talaşlı işlem / Soğuk şekil } $\sigma_K = 400\ N/mm^2$ olanlar için
$K_y = 0,75$	$\sigma_K = 600\ N/mm^2$
$K_y = 0,71$	$\sigma_K = 800\ N/mm^2$
$K_y = 0,67$	$\sigma_K = 1000\ N/mm^2$
$K_y = 0,65$	$\sigma_K = 1200\ N/mm^2$
$K_y = 0,63$	$\sigma_K = 1600\ N/mm^2$

K_d = Diğer faktörler

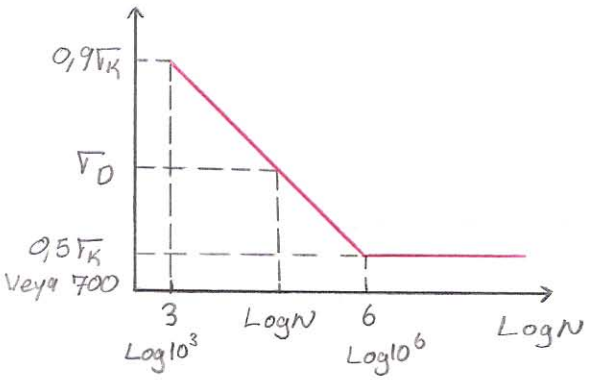
Sıcaklık
$K_t = \frac{450}{380 + t}$ $t > 0°C$

Kaplama
$K_k = 0,65$

Güvenirlik

$K_g = 1$	%50 güvenirlik
$K_g = 0,9$	%90 güvenirlik
$K_g = 0,8$	%99 güvenirlik
$K_g = 0,7$	%99,99 güvenirlik
$K_g = 0,6$	%99,9999 güvenirlik

Logaritmik Ömür Çizgisi



$\sigma_D \approx 0,5\sigma_K \Rightarrow \sigma_K \leq 1400\ N/mm^2$

$\sigma_D \approx 700 \Rightarrow \sigma_K > 1400\ N/mm^2$ (Yay çeliği)

Bileşik Gerilme

① Aynı Cins Gerilmeler Toplanabilir.

Toplam Dik Gerilme = ± Çekme ± Eğilme (− Basma)

$$\sigma_T = \pm \sigma_1 \pm \sigma_2$$
$$F/A \qquad \frac{mc}{I}$$

Toplam Kayma Gerilme = ∓ Kayma ∓ Burulma

$$\tau_T = \pm \tau_1 \pm \tau_2$$
$$\frac{F}{A} \qquad \frac{mc}{I_p}$$

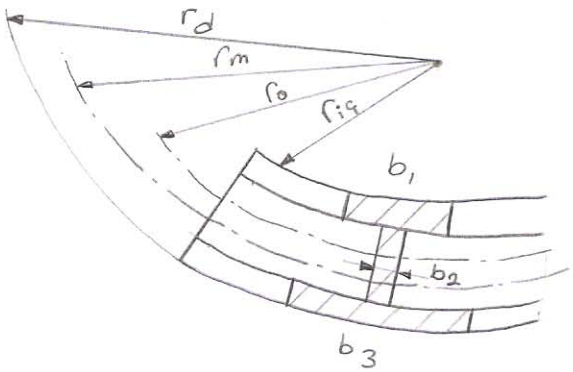
Eşdeğer Statik Gerilme Bileşkesi

$$\sigma_{b_{eş}} = \sqrt{\left(\sigma_o + \sigma_g \frac{\sigma_{ak}.K_ç}{\sigma_o.K_y.K_b}\right)^2 + 4\left(\tau_o + \tau_g \frac{\tau_{ak}.K_ç}{\tau_o.K_y.K_b}\right)^2}$$

② Gerilme Bileşkesi

$$\sigma_b = \sqrt{\sigma^2 + 4\tau^2}$$

Eğri Kirişlerde Eğilme



r_m = Ağırlık merkezine uzaklık

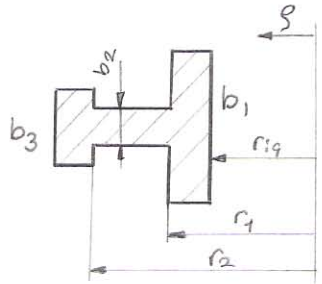
r_o = nötr (tarafsız) eksene uzaklık

Her zaman $r_o < r_m$ olmalıdır.

$$e = r_m - r_o$$

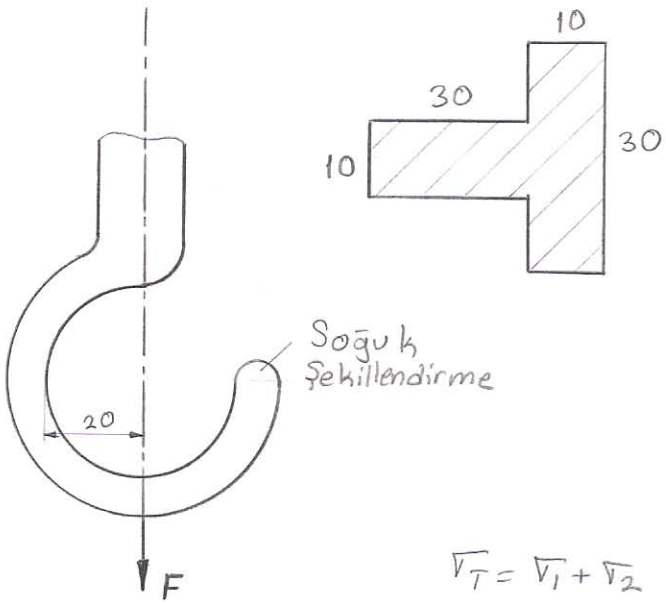
$$\sigma_{iç} = \frac{m(r_o - r_{iç})}{A.e.r_{iç}}$$

$$\sigma_{dış} = \frac{-m(r_{dış} - r_o)}{A.e.r_{dış}}$$



Dikdörtgen şekiller için

$$r_o = \frac{A}{\int \frac{dA}{\varsigma}} = \frac{A}{b_1.\ln\frac{r_1}{r_{iç}} + b_2.\ln\frac{r_2}{r_1} + b_3.\ln\frac{r_3}{r_2}}$$



$\sigma_K = 600\ N/mm^2$

$\sigma_{ak} = 450\ N/mm^2$

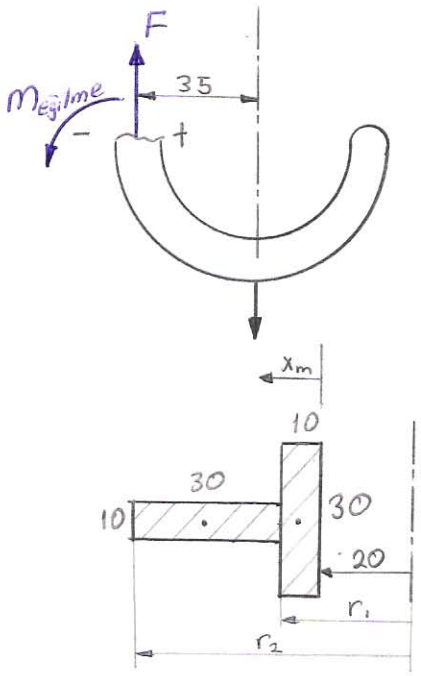
$S = 1,5$

a) Statik durumda F=?

b) Yükün 0 ile F arasında 300000 defa titreşmesi durumunda F=?

$\sigma_T = \sigma_1 + \sigma_2$

$\sigma_{iç} = \frac{F}{A} + \frac{m(r_o - r_{iç})}{A.e.r_{iç}}$



$r_o = \frac{A}{b_1.\ln\frac{r_1}{r_{iç}} + b_2.\ln\frac{r_2}{r_1}} = \frac{(30.10)+(10.30)}{30.\ln\frac{30}{20} + 10.\ln\frac{60}{30}}$

$r_o = 31,42$

$x_m = \frac{\Sigma x A}{A} = \frac{25(10.30)+5(10.30)}{600} = 15$

$r_m = 20 + 15 = 35$

$e = r_m - r_o = 35 - 31,42 = 3,58$

$\sigma_{iç} = \frac{F}{600} + \frac{(F.35)(31,42-20)}{600.3,58.20}$ Momenti Ağırlık merkezine göre al.

$\sigma_{iç} = 0,011F$ (mak)

$\underset{(-)}{\sigma_{dış}} = -\frac{F}{A} - \frac{m(r_{dış} - r_o)}{A.e.r_{dış}} = -\frac{F}{600} - \frac{F.35(60-31,42)}{600.3,58.60} = -0,006F$

a) Statik durumda

$\sigma_{em} = \frac{\sigma_{ak}}{S} \Rightarrow 0,011F = \frac{450}{1,5} \Rightarrow F = 27272,72N$

b) Yorulma var

$\sigma_{eş} = \sqrt{\left(\sigma_o + \sigma_g \frac{\sigma_{ak}.K_q}{\sigma_o.K_y.K_b}\right)^2 + 4\left(\tau_o + \tau_g \frac{\tau_{ak}.K_q}{\tau_d.K_y.K_b}\right)^2}$

0

Kesme yok

$\sigma_{mak} = 0,011F$

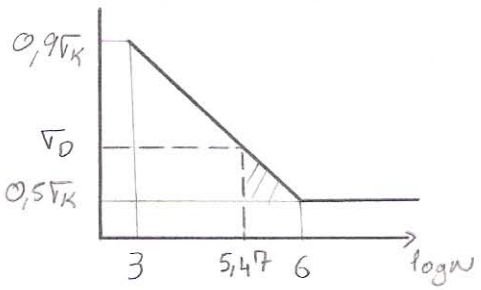
$\sigma_{min} = 0$

$\sigma_o = \frac{\sigma_{mak} + \sigma_{min}}{2} = 0,055F$

$\sigma_g = \frac{\sigma_{mak} - \sigma_{min}}{2} = 0,055F$

$$\tau_{eş} = \tau_o + \tau_g \frac{\tau_{ak} \cdot K_ç}{\tau_d \cdot K_y \cdot K_b}$$

$\log 300000 = 5,47$



$$\frac{\tau_D - 300}{540 - 300} = \frac{6 - 5,47}{5,47 - 3}$$

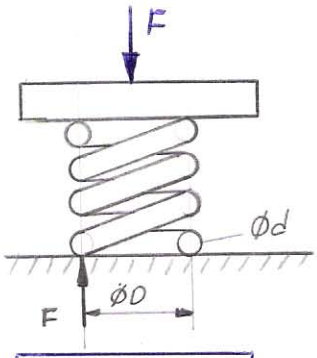
($0,5\tau_K$ ~ 300, $0,9\tau_K$ ~ 540)

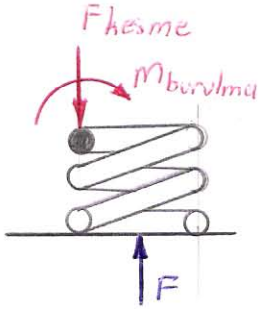
$\tau_D = 353$

$$\tau_{eş} = 0,055F + 0,055F \cdot \frac{480 \cdot 1}{353 \cdot 0,78 \cdot 0,78} = 0,0162F$$

$$0,0162F = \frac{\tau_{ak} \to 480}{S} \qquad F = 18548N$$

YAYLAR (Helisel)





$$\gamma_t = \gamma_1 + \gamma_2$$

$$\gamma_t = \frac{F}{A} + \frac{mc}{I_p}$$

$$\gamma_t = \frac{F}{\frac{\pi d^2}{4}} + \frac{\left(F\frac{D}{2}\right)\cdot\frac{d}{2}}{\frac{\pi \cdot d^4}{32}}$$

$$\gamma_t = \frac{8FD}{\pi d^3}\left(1 + \frac{d}{2D}\right)$$

$$k = \frac{d^4 G}{8D^3 \cdot N_{aktif}}$$

$F = k \cdot x$

$$\gamma_{yay} = K \cdot \frac{8FD}{\pi d_3}$$

N_{aktif} = Sarım sayısı

$N_{aktif} = N_{toplam} - 0,5$ (iki ucu işlemsiz)

1 (iki ucu bükülmüş veya taşlanmış)

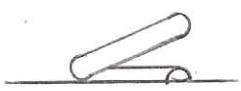
2 (iki ucu hem taşlanmış hem bükülmüş)

$$K_{statik} = 1 + \frac{0,5}{C} \qquad C = \frac{D}{d}$$

$$K_{dinamik} = \frac{4C-1}{4C-4} + \frac{0,615}{C}$$

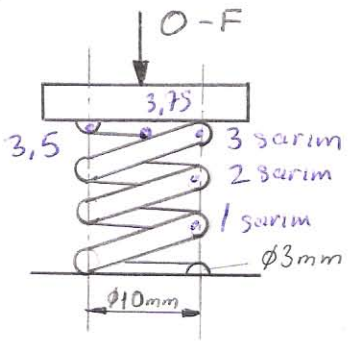
Kullanılacak formül

$G_{çelik} = 85000\ N/mm^2$


Taşlanmış


Bükülmüş


Taşlanmış + Bükülmüş



$\tau_k = 2000\ N/mm^2$

$\tau_{ak} = 1800\ N/mm^2$

$S = 2$

10^8 defa titreşim

(Bir ucu bükülmüş, bir ucu taşlanmış)

$F = ?$

$x_{mak} = ?$

$$\tau_{yay} = K \cdot \frac{8FD}{\pi . d3}$$

$$K = \frac{4c-1}{4c-4} + \frac{0,615}{c} = \frac{4.\frac{10}{3}-1}{4.\frac{10}{3}-4} + \frac{0,615}{\frac{10}{3}} = 1,51$$

$$\tau_{yay} = 1,51\ \frac{8F10}{\pi . 3^3} = 1,42F$$

Yorulma

$$\tau_{b_{eş}} = \sqrt{\left(\tau_o + \tau_g \frac{\tau_{ak} . K_q}{\tau_d . K_y . K_b}\right)^2 + 4\left(\tau_o + \tau_g \frac{\tau_{ak} . K_q}{\tau_d . K_y . K_b}\right)^2}$$

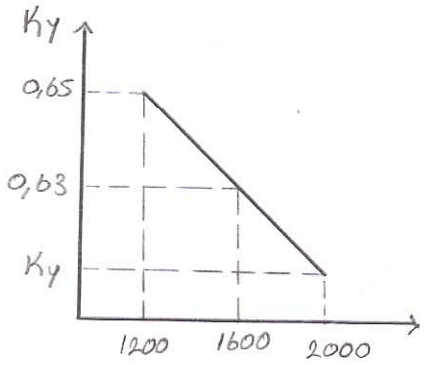
0

$\tau_{mak} = 1,42F$

$\tau_{min} = 0$

$$\tau_o = \frac{\tau_{mak} + \tau_{min}}{2} = 0,71F$$

$$\tau_g = \frac{\tau_{mak} - \tau_{min}}{2} = 0,71F$$



$$\frac{0,65-0,63}{0,65-K_y} = \frac{1600-1200}{2000-1200}$$

$$\frac{0,02}{0,65-K_y} = \frac{400}{800}$$

$$K_y = 0,61$$

$$\tau_{b_{eş}} = \tau_o + \tau_g \frac{\tau_{ak} . K_q}{\tau_d . K_y . K_b} = 0,71 + 0,71\ \frac{\text{Kesme}\ (0,5.1800)\ 1}{(0,5.700)\ 0,61.1}$$

1400'ü aşınca

$\rightarrow \phi d \leq 10 \Rightarrow 1$ al

$$\tau_{b_{eş}} = 7,4F$$

$$\tau_{beş} = \frac{\tau_{ak}}{S} \Rightarrow 7,4F = \frac{1800}{2} \Rightarrow F = 122N$$

$F = k . x$

$$k = \frac{d^4 G}{8^3 N_{aktif}} = \frac{3^4 . 85000}{8.10^3 . 2,75} = 313$$

$N_{aktif} = N_t - 0,5$ taşlanmış $- 0,5$ bükülmüş

$N_{aktif} = 3,75 - 1 = 2,75$

$F = k . x$

$122 = 313 . x$

$x = 0,39mm$

4/ Her 100N için 10mm sapan, maksimum 300N, minimum 100N ile 10^5 defa zorlanan bir ucu işlemsiz, diğer ucu bükülmüş yayın 2 emniyetle ölçülerini bulunuz.

$N_t, d, D = ?$ $(C=4)$

$\sigma_k = 2000\ N/mm^2$

$\sigma_{ak} = 1800\ N/mm^2$

$C = \frac{D}{d}$

$4 = \frac{D}{d}$

$D = 4d$

Çözüm

$\tau_{mak} = K \cdot \frac{8FD}{\pi d^3} \Rightarrow F = 300N$

$K = \frac{4.4-1}{4.4-4} + \frac{0,615}{4} = 1,40$

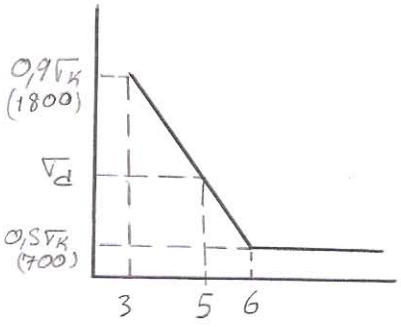
$\tau_{mak} = 1,40\ \frac{8.300.4d}{\pi . d^3} = \frac{4278}{d^2}$

$\tau_{min} = K \cdot \frac{8FD}{\pi d^3} = 1,40\ \frac{8.100.4d}{\pi . d^3} = \frac{1426}{d^2}$

$F = 100N$

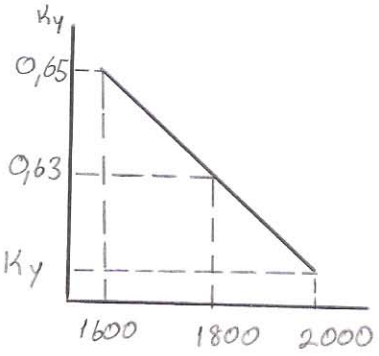
$\tau_d = ?$

$\log 10^5 = 5$



$\frac{\sigma_d - 700}{1800 - 700} = \frac{1}{3}$

$\sigma_d = 1067$



$K_y = 0,61$

$\sigma_b = 2\left(\tau_o + \tau_g\ \frac{\tau_{ak} . K_q}{\tau_d . K_y . K_b}\right) = 2\left(\frac{2852}{d^2} + \frac{1426}{d^2}\ \frac{(0,5.1800).1}{(0,5.1067).0,61.1}\right) = \frac{13591}{d^2}$

$d \leq 10mm$

$\sigma_b = \frac{\sigma_{ak}}{S}$

$\frac{13591}{d^2} = \frac{1800}{2}$

$d = 3,9mm$

$C = \frac{D}{d}$

$4 = \frac{D}{3,9}$

$D = 15,6mm$

$F = k . x$

$100 = k . 10$

$k = 10\ N/mm$

$k = \frac{d^4 G}{8D^3 N_a}$

$10 = \frac{3,9^4 . 85000}{8.(15,6)^3 . N_a}$

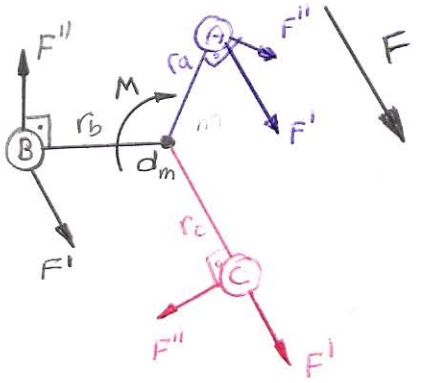
$N_a = 65,6$

$N_a = N_t - 0,25 - 0,5$ (işlemsiz, bükülmüş)

$65,6 = N_t - 0,75$

$N_t = 66,35$

Moment Taşıyan Noktasal Bağlantılar



d_m= Dönme merkezi
(Destek yoksa ağırlık merkezi)

Kuvvet dönme merkezine taşınır.
Moment de dönme merkezine taşınır.

Kuvvet etkisiyle bağlantı kuvveti

$$F' = \frac{F}{n}$$

n= bağlantı sayısı
F' → F ile aynı yönde

Moment etkisiyle bağlantı kuvveti

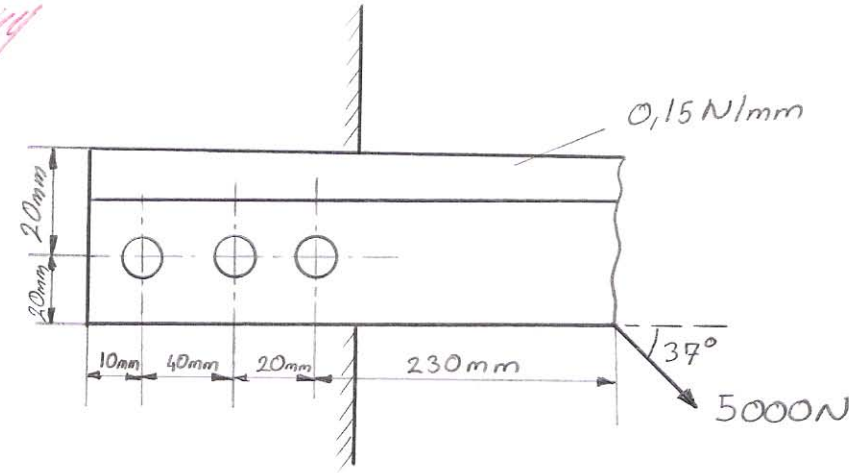
$$F'' = \frac{m.r}{\Sigma r^2}$$

$$\Sigma r^2 = r_A^2 + r_B^2 + r_C^2$$

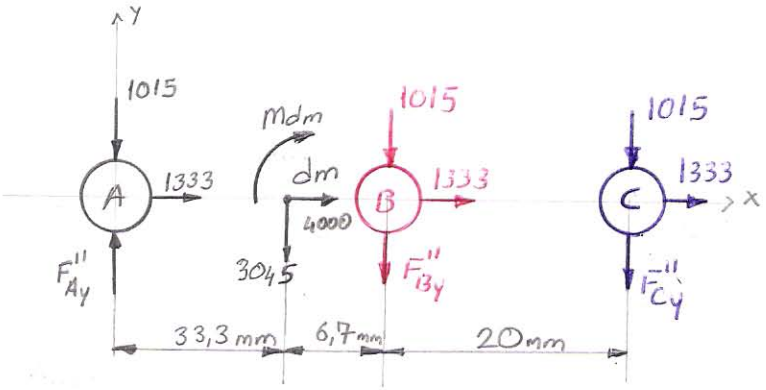
r= Bağlantının merkeze uzaklığı
F'' → m ile aynı yönde

$$F' = \frac{F}{n} \Rightarrow \begin{cases} F'_x = \frac{F_x}{n} \\ F'_y = \frac{F_y}{n} \end{cases}$$

$$F'' = \frac{mr}{\Sigma r^2} \Rightarrow \begin{cases} F''_x = \frac{m r_y}{\Sigma r^2} \\ F''_y = \frac{m r_x}{\Sigma r^2} \end{cases}$$

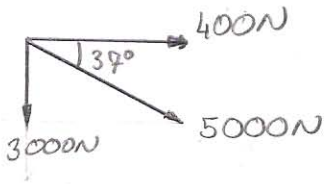


d_p = 10mm
τ_{ak} = 200 N/mm²
S = ?



dm=Sistemin dönme merkezi

$$x_m = \frac{0.\frac{\pi 10^2}{4} + 40.\frac{\pi 10^2}{4} + 60.\frac{\pi.10^2}{4}}{3.\frac{\pi.10^2}{4}} = 33,33\ mm$$



$F_x = 4000N$

$F_y = -3000 - \underbrace{(0,15 \times 300)}_{\text{Sistemin ağırlığı}} = -3045N$ (Sistem ağırlığı)

$M_{dm} = -3000.(300-33,3) + 4000.20 - (0,15.300).\left(\frac{300}{2} - 33,3\right)$

$M_{dm} = -694902\ Nmm$

$F'_x = \frac{4000}{3} = 1333N$ (Bağlantı Sayısı)

$F_y' = \frac{-3045}{3} = -1015N$

$\Sigma r^2 = 33,3^2 + 6,7^2 + (20+6,7)^2 = 1867\ mm^2$

$F''_x = \frac{m r_{\to 0}}{\Sigma r^2} = \frac{694902.0}{1867} = 0$

$F''_{Ay} = \frac{m r_{Ax}}{\Sigma r^2} = \frac{694902.33,3}{1867} = 12390N$

$F''_{By} = \frac{m r_{Bx}}{\Sigma r^2} = \frac{694902.6,7}{1867} = 2490N$

$F''_{Cy} = \frac{m r_{Cx}}{\Sigma r^2} = \frac{694902.26,7}{1867} = 9938N$

Bulunan değerlere göre en çok A perçini zorlanır.

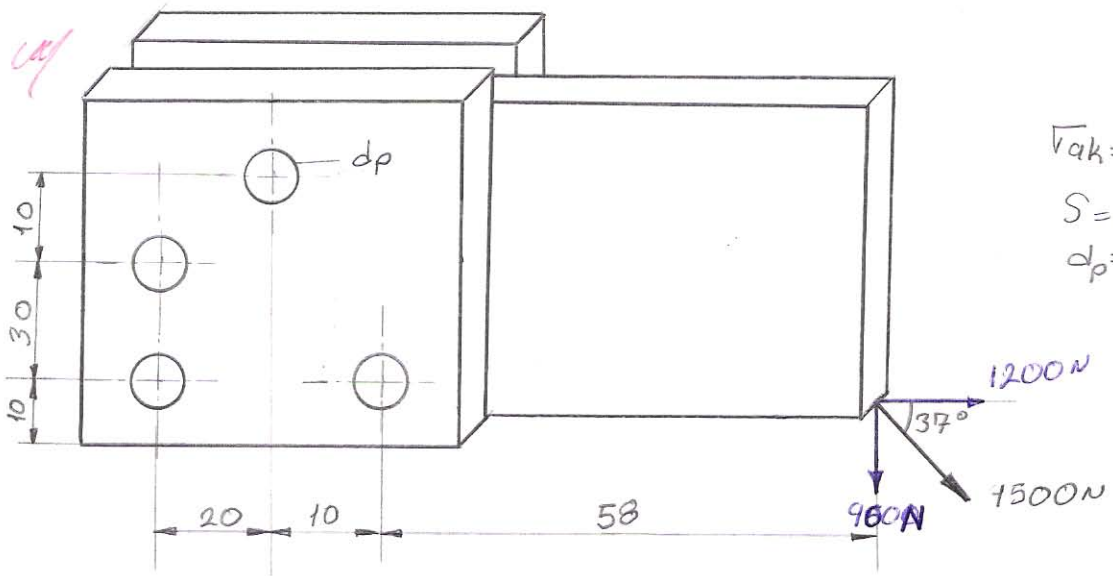
$\Sigma F''_y = 12390 - 1015 = 11375N$

$\Sigma F_x = 1333N$

$F_{mak} = \sqrt{\Sigma F_x^2 + \Sigma F_y^2} = \sqrt{1333^2 + 11375^2} = 11452N$

$\tau \Rightarrow \frac{11452}{\frac{\pi 10^2}{4}} = 0,5.\frac{200}{S}$

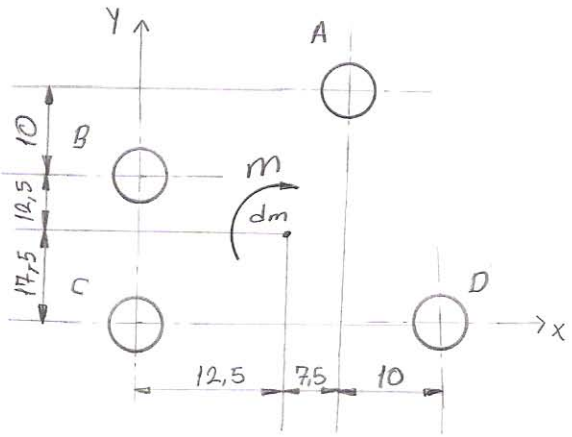
$S = 0,69$ dayanmaz



$\tau_{ak} = 250 N/mm^2$

$S = 2,5$

$d_p = ?$



$$x_m = \frac{20A_p + 30A_p}{4A_p} = 12,5$$

$$y_m = \frac{30A_p + 40A_p}{4A_p} = 17,5$$

$$m = -900 \cdot 7,5 + 1200 \cdot 27,5 = -34000$$

$$F_x' = \frac{F_x}{n} = \frac{1200}{n} = 300N$$

$$F_y' = \frac{F_y}{n} = \frac{900}{4} = 225N$$

$$\Sigma r^2 = 22,5^2 + 7,5^2 + 12,5^2 + 12,5^2 + 17,5^2 + 12,5^2 + 17,5^2 + 17,5^2 = 1950 mm^2$$

$$F_{Ax}'' = \frac{m r_{Ay}}{\Sigma r^2} = \frac{34000 \cdot 22,5}{1950} = 392 N$$

$$F_{Ay}'' = \frac{m r_{Ax}}{\Sigma r^2} = \frac{34000 \cdot 7,5}{1950} = 130N$$

$$F_{mak} = \sqrt{\Sigma F_x^2 + \Sigma F_y^2} = \sqrt{(392+300)^2 + (-225-300)^2} = 727 N$$

A perçini için

$$\tau = \frac{F}{A} \Rightarrow \frac{727}{2 \cdot \frac{\pi \cdot d^2}{4}} = 0,5 \frac{250}{2,5} \qquad d = 10,8 mm$$

Flambaj

$$F_{kr} = F.S = \frac{k.\pi^2.E.I_{min}}{L^2}$$ uzun çubuklar

$$F_{kr} = F.S = \sigma_{ak}.A\left[1 - \frac{\left(\frac{L}{f_3}\right)^2}{4k\pi^2.E}\right]$$ kısa çubuklar (jhonson)

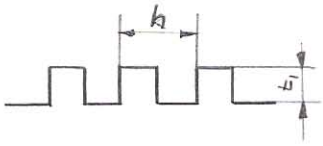
$$r_c = \sqrt{\frac{I}{A}}$$

$$\frac{L}{r_c} \gtrless \sqrt{\frac{2k\pi^2 E}{\sigma_{ak}}}$$ ⇒ Bu kurala uygun ise (Euler) değil ise (jhonson) uygulanır.

$k=1$ iki ucu mafsallı
$k=0,25$ Bir ucu ankastre bir ucu serbest
$k=1,2$ Bir ucu ankastre bir ucu mafsallı
$k=1,4$ iki ucu ankastre

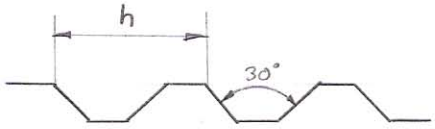
VİDALAR

Kare (Kr)



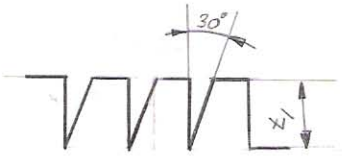
$t = 0,5h$
$t_1 = 0,1d$

Trapez (Tr)



$t_1 = 0,5h$
$\alpha = 30°$

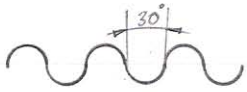
Testere (TS)



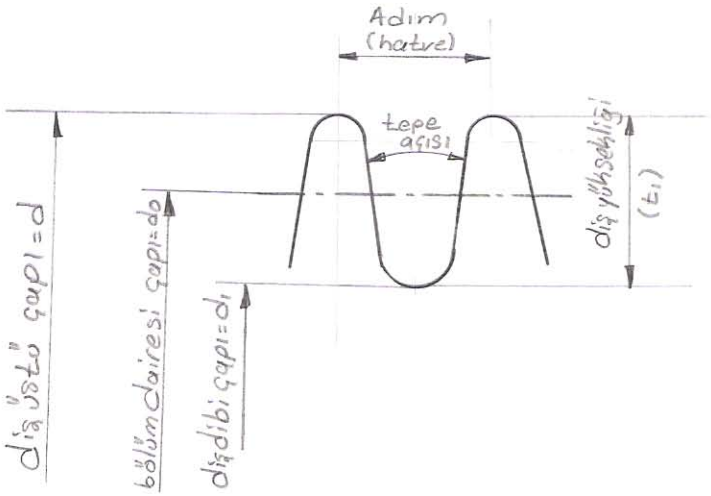
$t_1 = 0,8h$
$\alpha = 0$ $(\alpha = 30°)$

Whitwort ve Boru vidalarda $\alpha = 95°$

Yuvarlak (Yu)

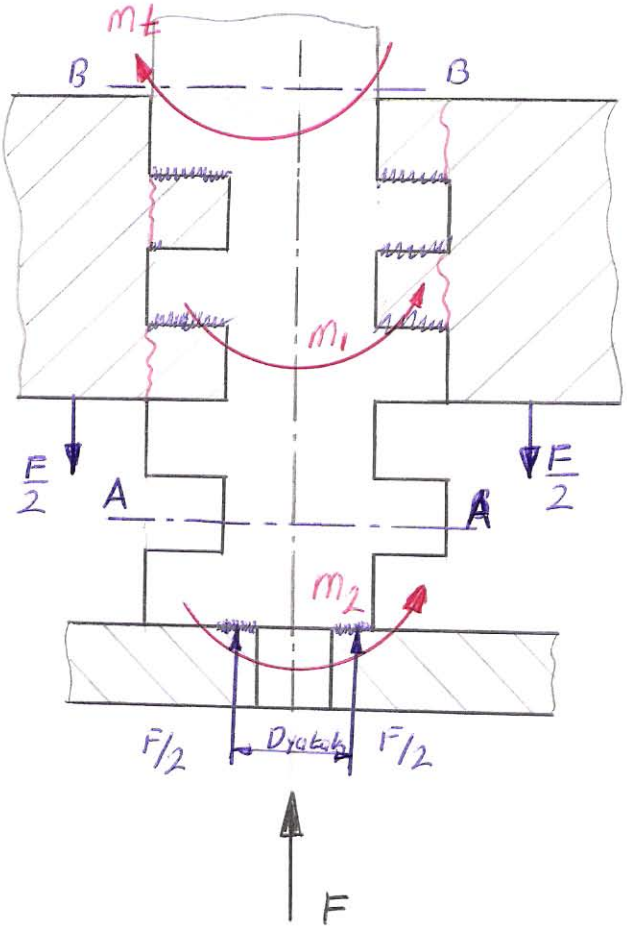


$t_1 = 0,5h$
$\alpha = 30°$



$$d_o = \frac{d + d_1}{2}$$

VİDA MUKAVEMETİ



El ile

$m_t = F_{kol} \cdot L_{kol}$

motor ile

$m_t = \frac{P\ [watt]}{\omega\ [rad/s]}$

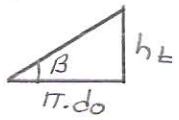
m_1 = Somundaki moment

m_2 = Yataktaki moment

$m_t = m_1 + m_2$

$m_1 = \frac{F.d_o}{2} \tan(\beta + \rho)$

$\tan\beta = \frac{h_t}{\pi . d_o}$



$\tan\rho = \frac{\mu}{\cos(\frac{\alpha}{2})}$

$m_2 = \mu . F . \frac{d_{yatak}}{2}$

$\mu = 0{,}1 \sim 0{,}25$ $\quad d_{yatak} = d_y$

Gövde Gerilmeleri

A-A kesitinde

Basma $\sigma_{AA} = \frac{F}{A} = \frac{F}{\frac{\pi d_g^2}{4}}$

Gerilme çapı $d_g = \frac{d_1 + d_o}{2}$

Burulma $\tau_{AA} = \frac{mc}{I_p} = \frac{16 m_2}{\pi d^3}$

$\sigma_{AA}^b = \sqrt{\sigma_{AA}^2 + 4\tau_{AA}^2}$

B-B kesitinde

Burulma $\tau_{BB} = \frac{16 m_t}{\pi d_y^3}$

Diş gerilmeleri

Yüzey Basıncı $\sigma = \frac{F}{A} = \frac{F}{\frac{\pi}{4}(d^2 - d_1^2)\frac{m}{h}} = \frac{4Fh_t}{\pi(d^2 - d_1^2) M_{aktif}} \leq P_{em}$

$M_{aktif} = m - 2h$

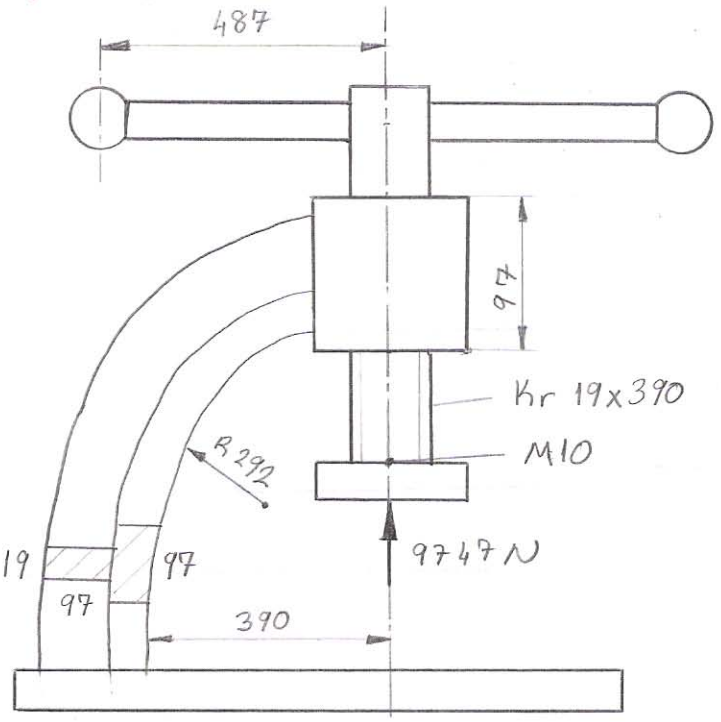
Kesme $\tau = \frac{F}{\pi d_1 . m'}$

$m' = 0{,}5\,m$ (kare)

$m' = m$ (metrik)

$m' = 0{,}675$ (Trapez)

(Soru 3)



Sorunun çözümü

$a = 95$

$\mu = 0,2$

$\sigma_K = 405\ N/mm^2$

$\sigma_{ak} = 284\ N/mm^2$

$F_{kol} = ?$

$S_{AA} = ?$

$S_{BB} = ?$

Flambaj emniyeti $S_{el} = ?$

$\tau = ?$

$F_{kol} = ?$

$d = 19\ mm$

$t_1 = 0,1d = 1,9\ mm$

$h = 3,8\ mm$

$d_1 = 19 - 3,8 = 15,2\ mm$

$d_o = \frac{19+15,2}{2} = 17,1 mm$

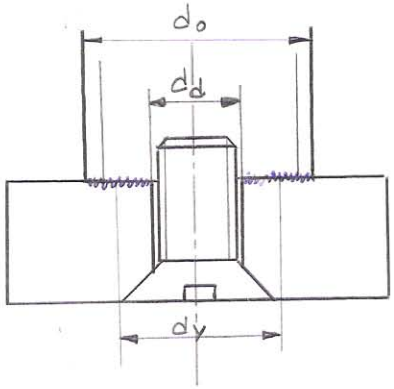
$d_g = \frac{d_1 + d_o}{2} = \frac{15,2+17,1}{2} = 16,15 mm$

$\tan\beta = \frac{h}{\pi . d_o} = \frac{3,8}{\pi . 17,1} \Rightarrow \beta = 4,05^\circ$

$\tan\rho = \frac{\mu}{\cos(\frac{\alpha}{2})} = \frac{0,2}{\cos(\frac{0}{2})} \Rightarrow \rho = 11,3^\circ$

$M_1 = \frac{F . d_o}{2} . \tan(\beta+\rho) = \frac{9747 . 17,1}{2} . \tan(4,05+11,3)$

$M_1 = 22886\ Nmm$



delik çapı $\Rightarrow d_d \cong 1,1 d$ (talaşlı işlem)

$d_y = \frac{d_o + d_d}{2} = \frac{17,1+11}{2} = 14,05 mm$

$M_2 = \mu . F \frac{d_y}{2} = 0,2 . 9747 \frac{14,05}{2}$

$M_2 = 13695\ Nmm$

$M_t = M_1 + M_2$

$M_t = 22886 + 13695$

$M_t = 36581\ Nmm$

$M_t = F_{kol} . L_{kol}$

$36581 = F_{kol} . 487$

$F_{kol} = 75,1 N$

$S_{AA}, S_{BB} = ?$

$$\sigma_{AA} = \frac{F}{A} = \frac{F}{\frac{\pi . d_g^2}{4}} = \frac{9747}{\frac{\pi . 16{,}15^2}{4}} = 47{,}6\ N/mm^2$$

$$\tau_{BB} = \frac{mc}{I_p} = \frac{16 m_2}{\pi d_g^3} = \frac{16.13695}{\pi . 16{,}15^3} = 16{,}6\ N/mm^2$$

$$\sigma_{em} = \frac{\sigma_{ak}}{S} = \sigma_{b_{AA}}$$

$$\sigma_{b_{AA}} = \sqrt{\sigma_{AA}^2 + 4\tau_{AA}^2} = \sqrt{47{,}6^2 + 4.16{,}6^2} = 58\ N/mm^2$$

$$\frac{284}{S} = 58$$

$$S = 4{,}89$$

$$\tau_{BB} = \frac{16 m_t}{\pi d_g^3} = \frac{16.36581}{\pi . 16{,}15^3} = 44{,}2\ N/mm^2$$

$$\tau_{BB} = 0{,}5 . \frac{\sigma_{ak}}{S} \Rightarrow 44{,}2 = 0{,}5 . \frac{284}{S} \Rightarrow S = 3{,}21$$

Flambaj Emniyeti, $S_{fl} = ?$

$$\frac{L}{r_c} \overset{?}{>} \sqrt{\frac{2k\pi^2 E}{\sigma_{ak}}}$$

$L = 390 - 97 = 293$

$r_c = \sqrt{\frac{I}{A}}$

$$\frac{293}{\sqrt{\frac{\frac{\pi 17{,}1^4}{64}}{\frac{\pi 17{,}1^2}{4}}}} = \frac{293}{\frac{17{,}1}{4}} \overset{?}{>} \sqrt{\frac{2.0{,}25.\pi^2.210000}{287}}$$

$\frac{d_g}{4}$

$68{,}5 \overset{?}{>} 60{,}4$

oldoğundan dolayı Euler uygulanır.

$$F_{kr} = F.S = \frac{k\pi^2 . E . I_{min}}{\ell^2}$$

$$9747.S = \frac{0{,}25.\pi^2.210000.\frac{\pi 17{,}1^4}{64}}{293^2} \Rightarrow S_{fl} = 2{,}6 \text{ uygun}$$

$\tau = ?$

$$\tau = \frac{F}{A} = \frac{F}{\frac{\pi}{4}(d^2 - d_1^2)\frac{m}{h}} = \frac{4hF}{\pi(d^2 - d_1^2) M_{alt}} = \frac{4.3{,}8.9747}{\pi(19^2 - 15{,}2^2)(97 - 23{,}8)} = 4{,}06\ N/mm^2$$

Otoblokaj Emniyeti=?

$m \overset{?}{>} \tan\beta . \cos\alpha$ ise otoblokaj var
(Seri kayma olmaz)

$0,2 \overset{?}{>} \tan 4,05 . \cos\alpha$

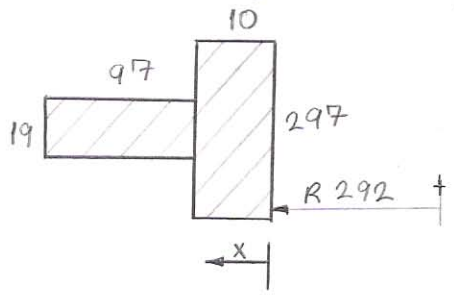
$0,2 \overset{?}{>} 0,0708$ (otoblokaj var, geri kaymaz)

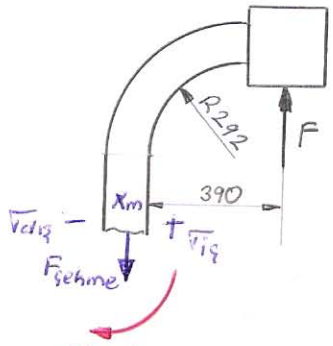
otoblokaj emniyeti $= \frac{\mu}{\tan\beta . \cos\alpha} = \frac{0,2}{0,0708} = 2,82$ (uygun)

güç vidası verimi

$$\eta = \frac{\tan\beta}{\tan(\beta+\rho)} = \frac{\tan 4,05}{\tan(4,05+11,3)} = 0,258 \Rightarrow \%25,8$$

Gövde Emniyeti (Soru 1)





$$\bar{x} = \frac{\Sigma xA}{\Sigma A} = \frac{5.(97.10)+58,5(97.19)}{970+1843} = 40,05\,mm$$

$$r_m = 292 + 40,05 = 332,05\,mm$$

$$r_o = \frac{970+1843}{97.\ln\frac{302}{292}+10.\ln\frac{399}{302}} = 328,48\,mm$$

$$e = r_m - r_o = 332,05 - 328,68 = 3,37\,mm$$

$$\sigma_{iç} = \frac{F}{A} + \frac{m(r_o - r_{iç})}{A.e.r_{iç}} = \frac{9747}{2813} + \frac{(9747.430,05)(328,68-292)}{2813.3,37.292} = 59\ N/mm^2$$

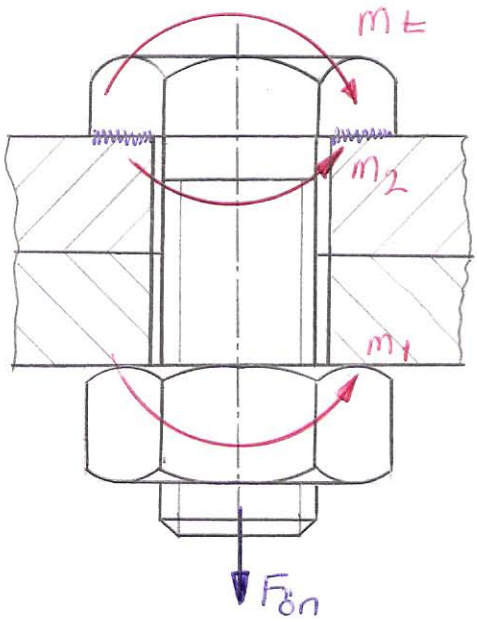
$$\sigma_{dış} = \frac{F}{A} - \frac{m(r_{dış} - r_o)}{A.e.r_{dış}} = \frac{9747}{2813} - \frac{(9747.430,05)(399-328,68)}{2813.3,37.399} = -74,5\ N/mm^2$$

$$\sigma_{dış} = \frac{\sigma_{ak}}{S}$$

$$74,5 = \frac{284}{S}$$

$$S = 3,81 \text{ uygun}$$

BAĞLANTI VİDALARI

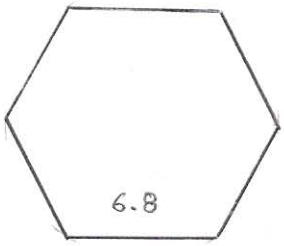


m_t = Anahtar momenti
Torkmetre momenti

$m_t = m_1 + m_2$

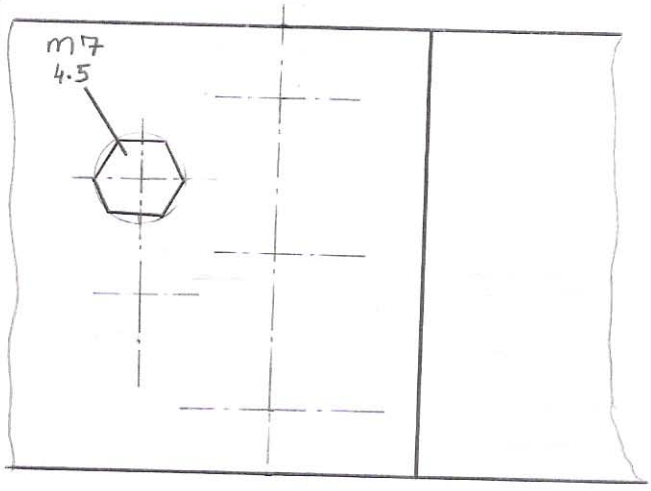
Civata sıkıldığında
$\frac{m_t}{2} = m_1 \cong m_2$
olmalıdır.

$\frac{F.d_o}{2} \cdot \tan(\beta+\varphi)$ yerine bağlantı vidaları için $m_t = 0{,}2 \cdot F_{ön} \cdot d$ kullanılır.
($0{,}15 - 0{,}22$)

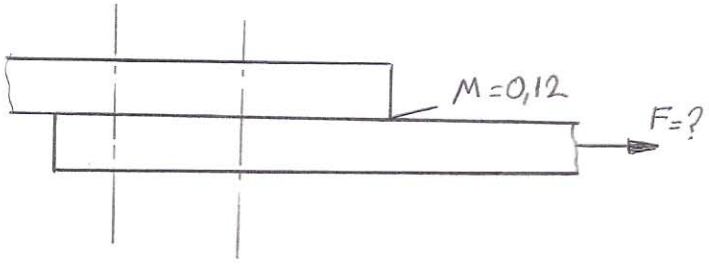


A B
6.8
→ Akma Sınırı
$\sigma_{ak} = 6 \times 8 \times 10$ (A x B x 10) N/mm²
→ Kopma Sınırı
$\sigma_K = 6.100$ (A.100) N/mm²

$d_1 \cong 0{,}8d$
$d_o \cong 0{,}9d$
$d_g \cong 0{,}85d$



F = ?
m_t (Tormetre Momenti) = ?
$\sigma_K = 400\ N/mm^2$
$\sigma_{ak} = 200\ N/mm^2$



d = 7 mm
$d_g = 0{,}85d = 5{,}95$ mm

Çekme $\tau = \frac{F'ön}{\frac{\pi d_g^2}{4}} = \frac{F'ön}{\frac{\pi . 5,95^2}{4}} = 0,035 F'ön$

Burulma $\gamma = \frac{16 m_t}{\pi d_g^3} = \frac{16\left(\frac{0,2 F'ön d}{2}\right)}{\pi d_g^3} = \frac{16(0,1 . F''ön\ 7)}{\pi . 5,95^3} = 0,017 F''ön$

Bileşke $\tau_b = \sqrt{\tau^2 + 4\gamma^2} = \sqrt{(0,035 F''ön)^2 + 4(0,017 F''ön)^2} = 0,05 F''ön$

$0,05 F''ön = \frac{200}{2}$ $\quad F''ön = 2000N$

$N = 5 . 2000 = 10000N$

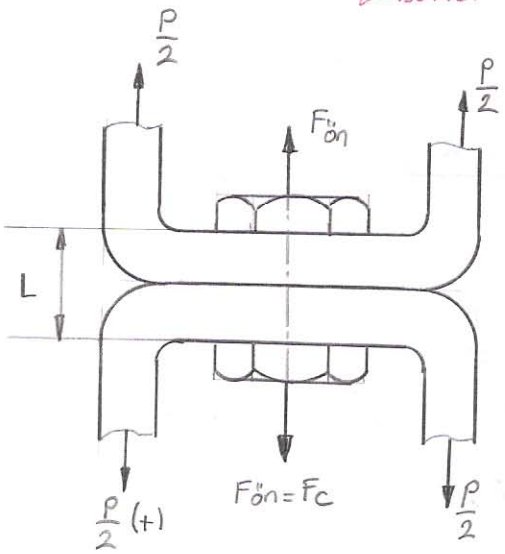
N: Civata Adedi

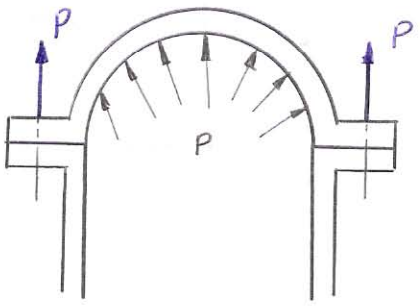
$F_{Sürtünme} = \mu . N$

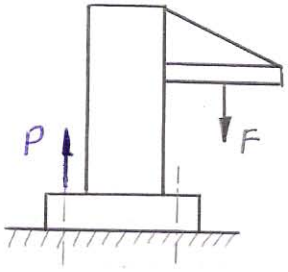
$F_S = 0,12 . 10000 = 1200N$

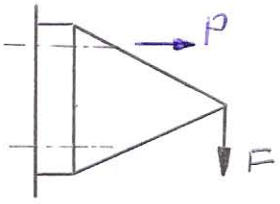
$M_t = 0,2 (F''ön . 5 . 0,9) . d = 5040\ Nmm$

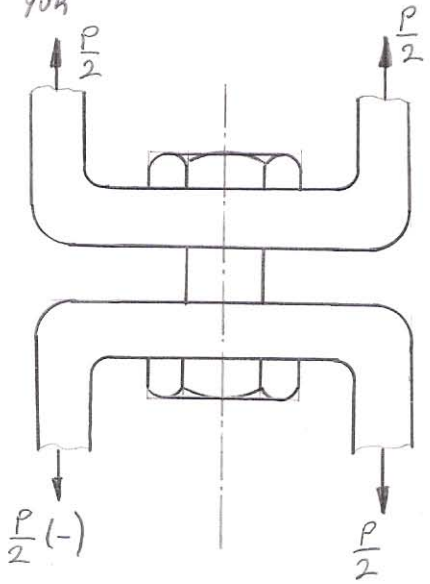
Eksenel Diş Yüklü Civatalar









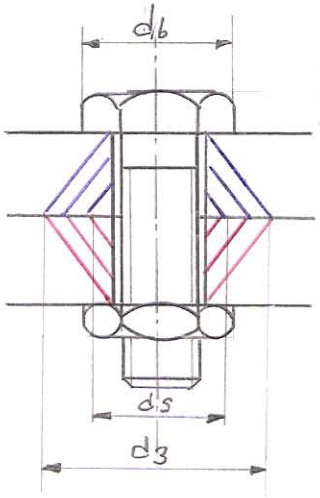


$$F_c = +F'_{ön} + C.P$$
$$F_e = -F''_{ön} + (1-C).P$$

F_c = Cıvata kuvveti

F_e = Elemanları sıkan kuvvet

* F_e (-) olmalıdır yada en az sıfır olmalıdır.



$$C = \frac{k_c}{k_c + k_e} = \frac{1}{1 + \frac{k_e}{k_c}}$$

$$k_e = \frac{A_e E_e}{L} = \frac{\frac{\pi}{4}(d_3^2 - d_d^2) E_e}{L}$$

Cıvatanın bağladığı elemanlar için

$$d_3 = \frac{d_3 + d_b}{2}$$

$$d_3 = d_b + \frac{L}{2} \cdot \tan 30°$$

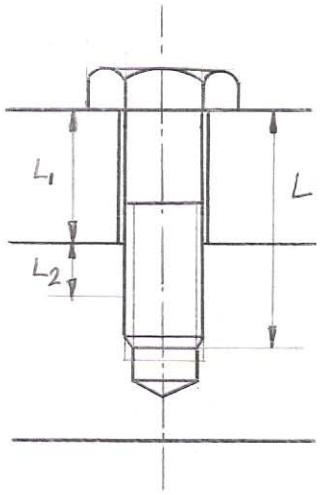
$$d_b = 1{,}5d$$

Yay Sabiti

$k.x = F$

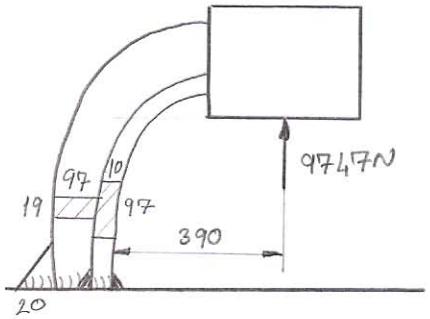
$$k = \frac{AE}{L}$$

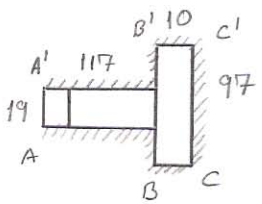
$$k_c = \frac{A_c E_c}{L} = \frac{\frac{\pi d^2}{4} \cdot E_c}{L}$$ Cıvata için



L_2 = Alt parçaya giren diş boyunun yarısı

Sorunun Çözümü (Devamı) (Soru 2)





$t = 10mm$ olduğuna göre kaynak emniyeti nedir?

$S_{tb} = ?$

Kaynak dikişleri:

AB – 2Adet x 117

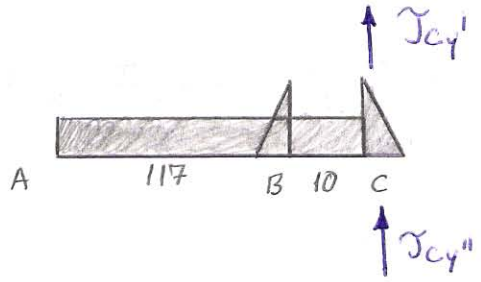
BC – 2Adet x 10

cc' – 1Adet x 97

BB' – 1Adet x (97 – 19)

+

Toplam dikiş uzunluğu = 429mm



Dönme merkezi en sol nokta olan A Noktasıdır.

$$I_{p_{AB}} = I_{op} + Ad^2 = \frac{t.b.l^3}{12} + Ad^2 = \frac{10(117^3)}{12} + (10.117)\left(\frac{117}{2}\right)^2 = 5338710\,mm^4 \times 2\,Adet$$

$$I_{p_{BC}} = \frac{10.10^3}{12} + (10.10)\left(117 + \frac{10}{2}\right)^2 = 1489233\,mm^4 \times 2\,Adet$$

$$I_{p_{CC'}} = \phi + (10.97)(117+10)^2 = 1564130\,mm^4 \times 1\,Adet$$

$$I_{p_{BB'}} = \phi + [(10).(97-19)].(117)^2 = 10677420\,mm^4 \times 1\,Adet$$

$$I_{p_T} = 5338710 \times 2 + 1489233.2 + 1564130.1 + 10677420.1$$

$$I_{p_T} = 39978436\,mm^4$$

$$\tau_{cy}' = \frac{F}{A} = \frac{9747}{429.10} = 2{,}27\ N/mm^2$$

$$\tau_{cy}'' = \frac{M_{rex}}{I_{p_t}} = \frac{\overbrace{[9747(390+10+97+20)]}^{m}.(117+10)}{39978436} = 16\ N/mm^2 \quad \text{(AC arası)}$$

r = hesabı yapılan noktanın dönme merkezine uzaklığı

$$\tau_{cmak} = 2{,}27 + 16 = 18{,}27\ N/mm^2$$

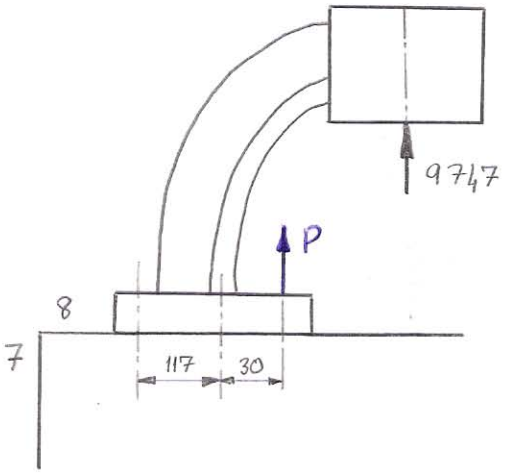
$$\tau_{cmak} = \tau_{em}$$

$$18{,}27 = 0{,}5.0{,}8.\frac{284}{S}$$

kaynak boşluğu

$S = 6{,}6$ pasla

(Soru 4)



Bütün malzemeler Civata dahil

$\sigma_K = 405 N/mm^2$

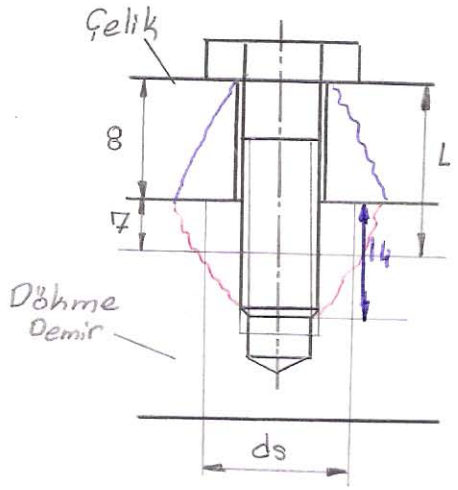
$\sigma_{ak} = 284 N/mm^2$

a) Civata emniyeti $S_c = ?$

b) Torkmetre momenti $m_t = ?$

c) Pres kuvvetinin 2924N ile 9747N arasında 974700 adet değişmesi durumunda civata emniyeti nedir? $K_ç = 1,3$ alınacak.

a)



$$k_c = \frac{A_c . E_c}{L_c} = \frac{\frac{\pi d^2}{4} . E_c}{L_c} = \frac{\frac{\pi . 10^2}{4} . 210000}{15} = 1,10 . 10^6$$

Çelik için

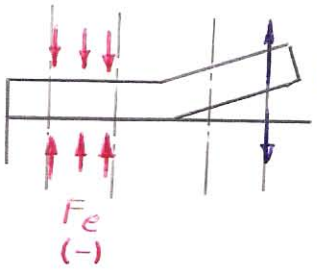
$$k_{eç} = \frac{\frac{\pi}{4}(d_s^2 - d_d^2) . E_ç}{L_ç}$$

$$d_s = \underbrace{d_b}_{1,5d} + \frac{L}{2} . \tan 30° = 1,5 + \frac{15}{2} . \tan 30°$$

$$d_s = 19,33 mm$$

$$d_d = 1,1d = 11 mm$$

$$k_{eç} = \frac{\frac{\pi}{4}(19,33^2 - 11^2) . 210000}{8} = 5,208 . 10^6$$



Dökme Demir için

$$k_{ed} = \frac{\frac{\pi}{4}(19,33^2 - 11^2) . 106000}{7} = 3,004 . 10^6$$

$$d = 10 mm$$

$$d_ç = 0,85d = 8,5 mm$$

$$\frac{1}{k_{et}} = \frac{1}{k_{eç}} + \frac{1}{k_{ed}} = \frac{1}{5,208 . 10^6} + \frac{1}{3,004 . 10^6}$$

$$k_{et} = 1,905 . 10^6$$

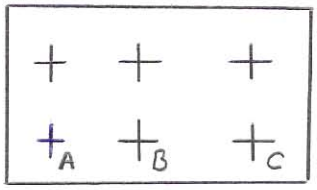
$$C = \frac{1}{1 + \frac{k_{et}}{k_c}} = \frac{1}{1 + \frac{1,905 . 10^6}{1,10 . 10^6}} = 0,366$$

$0 \leqslant F_c = +F''_{ön} + C.P$

$0 \geqslant F_e = -F''_{ön} + (1-C).P$

$F'_{cy} = \frac{F}{n} = \frac{9747}{6} = 1625\,N$

Civata Sayısı



Dönme merkezi

$F''_{cy} = \frac{m r_{cx}}{\Sigma r^2} = \frac{[9747.(370-20+30+117)].(117+30) \rightarrow r_c}{\phi + (117^2).2 + (117+30)^2.2} = 10493\,N$

(r_B: 117^2, r_c: $(117+30)^2$)

$P = F' + F'' = 1625 + 10493 = 12118\,N$

$0 = F_e = -F''_{ön} + (1-C).P$

$0 = -F''_{ön} + (1-0{,}366).12118$

$F''_{ön} \gg 7683\,N$ sabit

$F_c = +F''_{ön} + C.P$

$F_c = 7683 + (0{,}366.12118)$

$F_c = 12118\,N$

$\sigma = \frac{F_c}{\underbrace{A}_{\frac{\pi.d_g^2}{4}}} = \frac{12118}{\pi \frac{8{,}5^2}{4}} = 214\,N/mm^2$ (Maksimum gerilme)

$m_t = 0{,}2.F''_{ön}.d = 0{,}2.7683.10 = 15366\,Nmm$ (Torkmetre momenti)

$m_1 = \frac{m_t}{2} = \frac{15366}{2} = 7683\,Nmm$

$\tau = \frac{16 m_1}{\pi d_g^3} = \frac{16.7683}{\pi.8{,}5^3} = 63{,}7\,N/mm^2$ sabit

$\sigma_b = \sqrt{\sigma^2 + 4\tau^2} = \sqrt{214^2 + 4.63{,}7^2} = 249\,N/mm^2$

$\sigma_b = \sigma_{em} \Rightarrow 249 = \frac{284}{S_{em}} \Rightarrow S_{em} = 1{,}14$ yetersiz

Emniyetli Torkmetre momenti

b) $m_t = 0{,}2(7683.1{,}14.0{,}9).10 = 15795\,Nmm$

(S_{em}, sabit bağlantı)

0,7 = Sık sökülüp takılan
0,9 = Sabit bağlantı

c)

$\sigma_{mak} = 214\ N/mm^2$ (a şıkkında hesaplandı) $\quad P_{mak} = 12118\ N$

$F_{cmin} = 7683 + 0{,}366 \cdot 3635 = 9013\ N$ $\quad P_{min} = 12118 \frac{300e}{1000e} = 3635\ N$

$\sigma_{min} = \frac{9013}{\pi \frac{8{,}5^2}{4}} = 159\ N/mm^2$

$$\sigma_b = \sqrt{\left(\sigma_o + \sigma_g \frac{\sigma_{ak} \cdot K_q}{\sigma_d \cdot K_y \cdot K_b}\right)^2 + 4 \cdot \left(\tau_o + \tau_g \frac{\tau_{ak} \cdot K_q}{\tau_d \cdot K_y \cdot K_b}\right)^2}$$

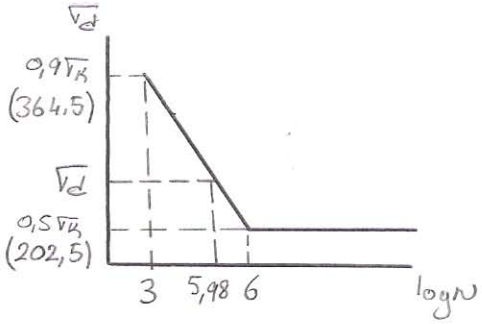
$\sigma_o = \frac{\sigma_{mak} + \sigma_{min}}{2} = \frac{214 + 159}{2} = 186\ N/mm^2$

$\sigma_g = \frac{\sigma_{mak} - \sigma_{min}}{2} = \frac{214 - 159}{2} = 27{,}5\ N/mm^2$

$\tau_o = \frac{\tau_{mak} + \tau_{min}}{2} = \frac{63{,}7 + 63{,}7}{2} = 63{,}7\ N/mm^2$

$\tau_g = \frac{\tau_{mak} - \tau_{min}}{2} = \frac{63{,}7 - 63{,}7}{2} = 0\ N/mm^2$

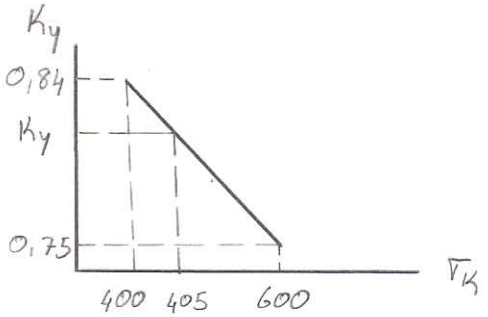
$K_q = 1{,}3$ $\qquad K_b = 1 \Rightarrow d \leq 10\ mm$



$\frac{\sigma_d - 202{,}5}{364{,}5 - 202{,}5} = \frac{6 - 5{,}98}{200}$

$\sigma_d = 204\ N/mm^2$

$\log 974700 = 5{,}98$

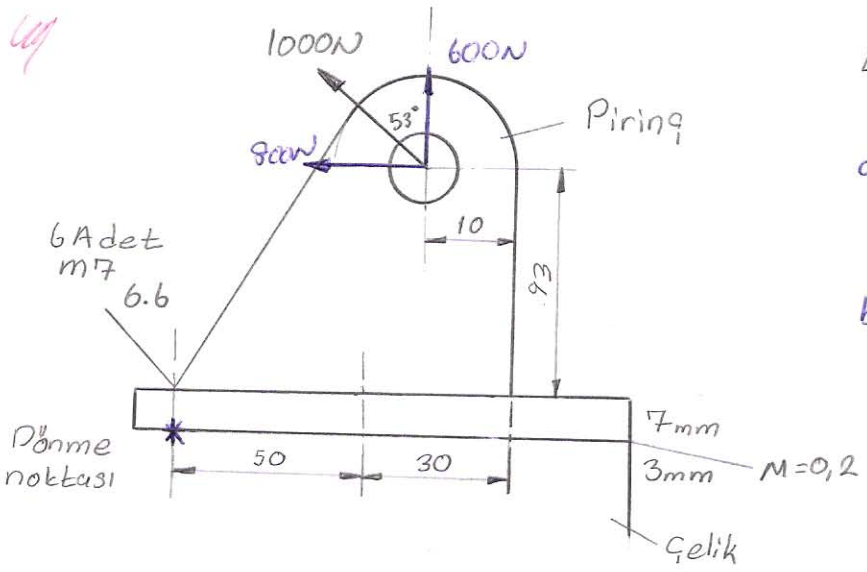


$\frac{K_y - 0{,}75}{0{,}84 - 0{,}75} = \frac{600 - 405}{600 - 400}$

$K_y = 0{,}838$

$$\sigma_b = \sqrt{\left(186 + 27{,}5 \frac{284 \cdot 1{,}3}{204 \cdot 0{,}838 \cdot 1}\right)^2 + 4\left(63{,}7 + 0 \cdot \frac{(284 \cdot 0{,}5) \cdot 1{,}3}{(204 \cdot 0{,}5) \cdot 0{,}838 \cdot 1}\right)^2} = 276\ N/mm^2$$

$\sigma_b = \sigma_{em} \Rightarrow 276 = \frac{284}{S}$ $\qquad S = 1{,}02$ yetersiz



$E_{piring} = 10^5 N/mm^2$

a) Civata Emniyeti $S_c = ?$
Torkmetre momenti $m_t = ?$

b) $F = 200N - 1000N$ arasında 800000 adet titreşirse
$S = ?$

$d = 7 \Rightarrow d_g = 0,85d = 5,95mm$

a)-Civata için

$$k_c = \frac{\frac{\pi d^2}{4} E_c}{L} = \frac{\frac{\pi . 7^2}{4} . 210000}{(7+3)} = 8,08.10^5$$

-Çelik için

$$k_{eç} = \frac{\frac{\pi}{4}(d_s^2 - d_d^2) . E_ç}{L_ç}$$

$$d_s = \underbrace{1,5d}_{d_b} + \frac{L}{2} . \tan 30° = 1,5.7 + \frac{(7+3)}{2} . \tan 30° = 13,4mm$$

$$d_d = 1,1.d = 7,7mm$$

$$k_{eç} = \frac{\frac{\pi}{4}(13,4^2 - 7,7^2) . 210000}{3} = 6,61.10^6$$

- Piring için

$$k_{ep} = \frac{\frac{\pi}{4}(d_s^2 - d_d^2) . E_P}{L_P} = \frac{\frac{\pi}{4}(13,4^2 - 7,7^2) . 10^5}{7} = 1,35.10^6$$

$$\frac{1}{k_{et}} = \frac{1}{k_{eç}} + \frac{1}{k_{ep}} = \frac{1}{6,61.10^6} + \frac{1}{1,35.10^6} \Rightarrow k_{et} = 1,12.10^6$$

$$C = \frac{1}{1 + \frac{k_e}{k_c}} = \frac{1}{1 + \frac{1,12.10^6}{8,08.10^6}} = 0,419$$

$$F_{cy}' = \frac{F_y}{n} = \frac{600}{6} = 100N$$

$$F_{cy}'' = \frac{m r_{cx}}{\Sigma r^2} = \frac{\overbrace{[800(93+7) + 600(50+30-10)]}^{m} . (50+30)}{2.0^2 + 2.50^2 + 2.80^2} = 548N$$

$P = F_y' + F_y'' = 100 + 548 = 648\ N$

$F_s = M.N$

$\frac{800}{b} = 0{,}2.Fe$

↓ Civata Sayısı

$Fe = 667\ N$

O halde $Fe = -F'ön(1-C).P$ olduğundan yukarıda bulunan Fe formülde (-) olarak yazılır.

$Fe = -667 = -F'ön(1-0{,}419).648$

$F'ön = 1044\ N$

$Fc = F''ön + c.P = 1044 + 0{,}419.648 = 1315\ N$

$$\sigma = \frac{Fc}{\frac{\pi d_g^2}{4}} = \frac{1315}{\frac{\pi.5{,}95^2}{4}} = 47{,}3\ N/mm^2$$

$$\tau = \frac{16\left(\frac{0{,}2.F'ön.d}{2}\right)}{\pi d_g^3} = \frac{16\left(\frac{0{,}2.1044.7}{2}\right)}{\pi.5{,}95^3} = 17{,}7\ N/mm^2$$

$$\sigma_b = \sqrt{\sigma^2 + 4\tau^2} = \sqrt{47{,}3^2 + 4.17{,}7^2} = 59\ N/mm^2$$

$\sigma_b = \sigma_{em} \Rightarrow 59 = \frac{360}{S} \rightarrow \sigma_{ak}$

$S = 6{,}09$ fazla

$M_t = 0{,}2F'ön.d = 0{,}2.(1044.\frac{6{,}09}{S}.\underbrace{0{,}9.}_{\text{Sabit bağlantı}}7) = 8011\ Nmm$

b) $\sigma_{mak} = 47{,}3\ N/mm^2$ $\quad P_{mak} = 648\ N$

$P_{min} = 648\ \frac{200}{1000} = 130\ N$

$F_{cmin} = +F'ön + C.P_{min}$

$F_{cmin} = 1044 + 0{,}419.130$

$F_{cmin} = 1098\ N$

$$\sigma_{min} = \frac{F_{cmin}}{\frac{\pi d_g^2}{4}} = \frac{1098}{\frac{\pi\ 5{,}95^2}{4}} = 39{,}5\ N/mm^2$$

$$\sigma_b = \sqrt{\left(\sigma_o + \sigma_g \frac{\sigma_{ak} \cdot K_q}{\sigma_d \cdot K_y \cdot K_b}\right)^2 + 4(\tau_o + \phi)^2}$$

$$\sigma_o = \frac{\sigma_{mak} + \sigma_{min}}{2} = \frac{47,3 + 39,5}{2} = 43,4\ N/mm^2$$

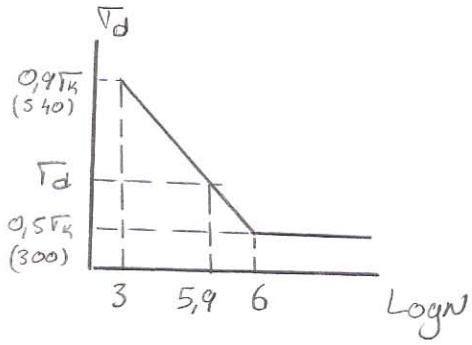
$$\sigma_g = \frac{\sigma_{mak} - \sigma_{min}}{2} = \frac{47,3 - 39,5}{2} = 3,9\ N/mm^2$$

$K_q = 1,3$

$\sigma_{ak} = 360\ N/mm^2$

$K_b = 1 \quad d \leq 10mm$

$K_y = 0,75 \Rightarrow \sigma_k = 600\ N/mm^2$



$$\frac{\sigma_d - 300}{540 - 300} = \frac{6 - 5,9}{6 - 3}$$

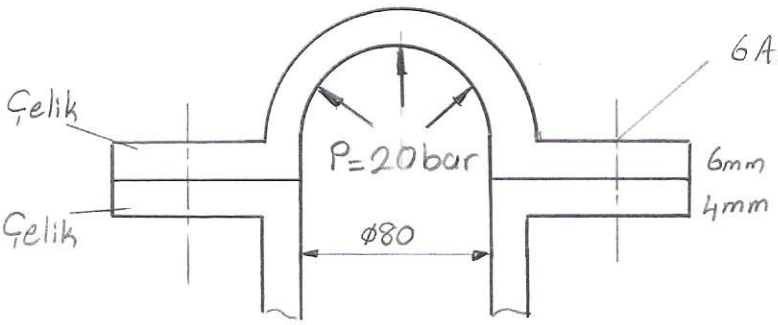
$\sigma_d = 308\ N/mm^2$

$Log 800000 = 5,9$

$$\sigma_b = \sqrt{\left(43,4 + 3,9 \frac{360 \cdot 1,3}{308 \cdot 0,75 \cdot 1}\right)^2 + 4 \cdot (17,7)^2} = 62,32\ N/mm^2$$

$$\sigma_b = \frac{\sigma_{ak}}{S}$$

$62,32 = \frac{360}{S} \qquad S = 5,78$ fazla



Civata Emniyeti $S_c = ?$

Torkmetre Momenti $M_t = ?$

$$P = \frac{20 \cdot 10^5}{1000^2} = 2\ N/mm^2$$

$$P_t = P \cdot A = 2 \cdot \frac{\pi \cdot 80^2}{4} = 10053\ N$$

$$P = \frac{10053}{6} = 1676\ N$$

Civata Adedi

$$C = \frac{1}{1 + \frac{k_e}{k_c}} = \frac{1}{1 + \frac{\frac{\pi}{4}(d_s^2 - d_d^2) E/L}{\frac{\pi}{4} d^2 \cdot E/L}}$$

$$C = \frac{1}{1 + \frac{d_s^2 - d_d^2}{d^2}}$$

$d_d = 1,1d = 11mm$

$d_s = d_b + \underbrace{\frac{L}{2}}_{1,5d} \cdot \tan 30^\circ = 1,5.10 + \frac{6+4}{2} \cdot \tan 30^\circ$

$d_s = 17,9mm$

$$C = \frac{1}{1 + \frac{17,9^2 - 11^2}{10^2}} = 0,334$$

F_e = Elemanları bastıran kuvvet
(Kapağın açılmaması için)

$$F_e = 0 = -F''_{ön} + (1-C)P$$

$$0 = -F''_{ön} + (1-0{,}334).1676$$

$$F''_{ön} = 1116N$$

$$F_c = +F''_{ön} + C.P = 1116 + (0{,}334.1676) = 1676N$$

$$\sigma = \frac{F_c}{A} = \frac{F_c}{\frac{\pi d_g^2}{4}} = \frac{1676}{\pi \frac{10.0{,}85}{4}} = 29{,}5\ N/mm^2$$

$$\tau = \frac{16\ (\frac{0{,}2F''_{ön}.d}{2})}{\pi d_g^3} = \frac{16.\ (\frac{0{,}2.1116.10}{2})}{\pi.(10.0{,}85)^3} = 9{,}25\ N/mm^2$$

$$\sigma_b = \sqrt{\sigma^2 + 4\tau^2} = \sqrt{29{,}5^2 + 4.9{,}25^2} = 34{,}8\ N/mm^2$$

$$\sigma_b = \frac{\sigma_{ak}}{S} \Rightarrow 34{,}8 = \frac{280}{S} \Rightarrow S = 6{,}9 \text{ fazla}$$

$$M_t = 0{,}2.F''_{ön}.d.\ 6{,}9.\ 0{,}9 = 0{,}2.1116.10.6{,}9.0{,}9 = 13843\ Nmm$$

(S ↙, 0,9 ↓ Sabit bağlantı)