YAKIN DOĞU ÜNİVERSİTESİ NEAR EAST UNIVERSITY

Makine Mühendisliği Bölümü Department of Mechanical Engineering

MAK 304 MAKİNE TASARIMI II – ME 304 MACHINE DESIGN II

2015- 2016 Bahar Dönemi - 2015- 2016 Spring Semester

Ara Sınavı - Midterm

Prof. Mehmet Ali Güler Ad, Soyad _____

9 Nisan 2016 (April 9, 2016) Saturday Öğrenci No _____

Verilen Zaman: **2 saat (12:00-02:00)** Time allowed: **2 hours (12:00-02:00)**

Soru No	Maksimum Puan	Puan
1	35	
2	35	
3	35	
4	35	
Toplam	**140**	

ÖNEMLİ UYARI !!!

Yükseköğretim Kurumları Öğrenci Disiplin Yönetmeliği Madde 9-m'ye göre "sınavlarda kopya yapmak veya yaptırmak veya bunlara teşebbüs etmek" fiilinin suçu YÜKSEKÖĞRETİM KURUMUNDAN BİR VEYA İKİ YARIYIL İÇİN UZAKLAŞTIRMA cezasıdır.

Özel Sınav Kuralları:
Sınav süresince cep telefonları kapalı konumda olmak suretiyle sıra üzerine konulmalıdır.

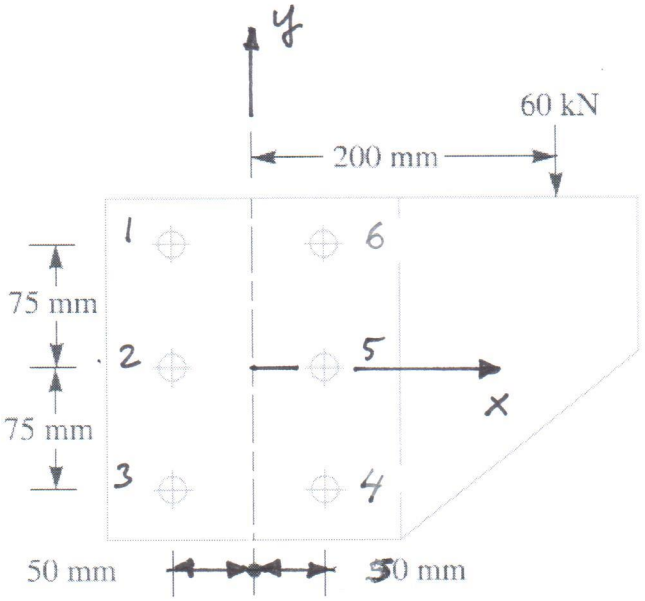
UYARI VE KURALLARI OKUDUM.

Öğrencinin İmzası:
Adı Soyadı :.....

Ön sayfa dahil, bu sınav kağıdında toplam **(10)** sayfa vardır.
There are (10) pages including the cover page

Öğrenci No: .....

Soru 1: (30 puan)



Şekil.1: [Kaynak: Problem 11.5 Sayfa 466 Ugural, Mechanical Design An Integrated Approach]

Şekil 1'de gösterilen braket kolona 6 adet perçin ile bağlanmıştır. Braket 60 kN yük taşımaktadır ve bu yük kolonun merkezinden 200 mm uzaktan uygulanmaktadır. Perçinlerin çapı 18 mm dir. Perçinde müsade edilen maksimum kayma gerilmesi 300 MPa olduğuna göre

a) Perçinlerin merkezini bulunuz
b) Serbest cisim diyagramını çiziniz
c) Her bir perçine etkiyen kesme kuvvetlerini hesaplayınız
d) Kritik perçini bulunuz
e) Kritik perçin için emniyet faktörünü bulunuz.

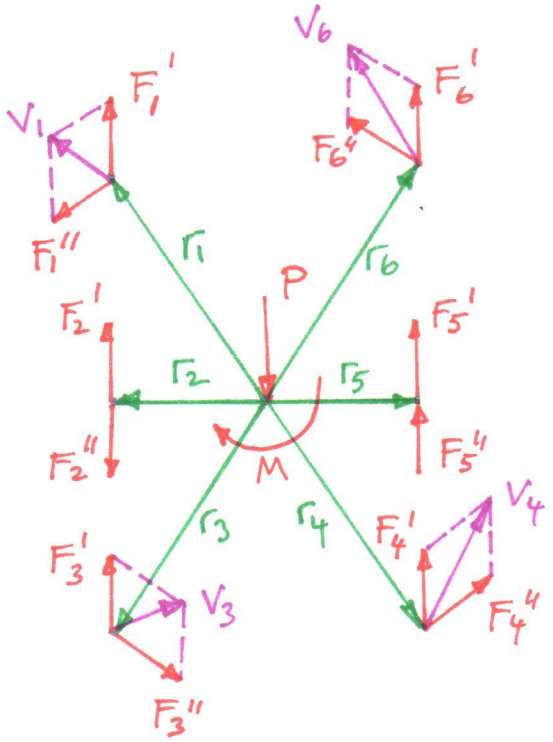
A bracket is riveted to a column by 6 rivets of equal size as shown in Fig. 1. It carries a load of 60 kN at a distance of 200 mm from the centre of the column. Diameter of the rivets are 18 mm. If the maximum shear stress in the rivet is limited to 300 MPa

a) determine the centroid of rivets
b) draw the free body diagram
c) calculate the shear forces acting in each rivet
d) determine the critical rivet
e) find the factor of safety for the critical rivet

$$\bar{x} = \frac{\sum_{i=1}^{6} x_i A_i}{\sum_{i=1}^{6} A_i} = \frac{x_1A_1 + x_2A_2 + x_3A_3 + x_4A_4 + x_5A_5 + x_6A_6}{A_1 + A_2 + A_3 + A_4 + A_5 + A_6}$$

$$= \frac{(-50A) + (-50A) + (-50A) + 50A + 50A + 50A}{6A} = 0$$

$$\bar{y} = \frac{\sum_{i=1}^{6} y_i A_i}{\sum_{i=1}^{6} A_i} = \frac{y_1A_1 + y_2A_2 + y_3A_3 + y_4A_4 + y_5A_5 + y_6A_6}{6A} = 0$$



Öğrenci No: .....

$r_2 = r_5 = 50$ mm

$r_1 = r_3 = r_4 = r_6 = \sqrt{50^2 + 75^2} = 90.14$ mm

$P = 60$ kN $= 60000$ N

$e = 200$ mm

$M = P.e = (60000)(200) = 12 \times 10^6$ N.mm

$$F_1' = F_2' = F_3' = F_4' = F_5' = F_6' = \frac{P}{6} = \frac{60000}{6} = 10000 \text{ N}$$

number of rivets

Since the areas of all the rivets are equal.

$$\frac{\tau_1''}{r_1} = \frac{\tau_2''}{r_2} = \frac{\tau_3''}{r_3} = \frac{\tau_4''}{r_4} = \frac{\tau_5''}{r_5} = \frac{\tau_6''}{r_6}$$

$$\frac{F_1''}{r_1} = \frac{F_2''}{r_2} = \frac{F_3''}{r_3} = \frac{F_4''}{r_4} = \frac{F_5''}{r_5} = \frac{F_6''}{r_6}$$

Since $r_2 = r_5 \Rightarrow F_2'' = F_5''$

$r_1 = r_3 = r_4 = r_6 \Rightarrow F_1'' = F_3'' = F_4'' = F_6''$

$$\frac{F_1''}{90.14} = \frac{F_2''}{50} = \frac{F_3''}{90.14} = \frac{F_4''}{90.14} = \frac{F_5''}{50} = \frac{F_6''}{90.14}$$

$$F_2'' = \frac{50}{90.14} F_1'' = 0.5547 F_1''$$

From Moment equilibrium

$$r_1 F_1'' + r_2 F_2'' + r_3 F_3'' + r_4 F_4'' + r_5 F_5'' + r_6 F_6'' = M$$

$$r_1 F_1'' + r_2 (0.5547) F_1'' + r_3 F_1'' + r_4 F_1'' + r_5 (0.5547) F_1'' + r_6 F_1'' = M$$

$$F_1'' = \frac{M}{r_1 + r_2(0.5547) + r_3 + r_4 + r_5(0.5547) + r_6}$$

$$= \frac{12\times10^6}{(90.14) + (50)(0.5547) + (90.14) + (90.14) + (50)(0.5547) + (90.14)}$$

$$= 28844 \text{ N}$$

$F_2'' = 0.5547\, F_1'' = 16000$ N

$F_3'' = F_1'' = 28844$ N

$F_4'' = F_1'' = 28844$ N

$F_5'' = F_2'' = 16000$ N

$F_6'' = F_1'' = 28844$ N

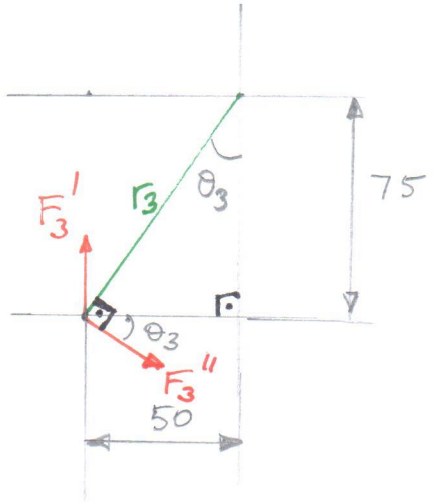
From the free body diagram it is obvious that

$V_2 = F_2'' - F_2' = 16000 - 10000 = 6000$ N $(\downarrow)$

$V_5 = F_5' + F_5'' = 10000 + 16000 = 26000$ N $(\uparrow)$

$V_1 = V_3$

$V_4 = V_6$



<u>For Rivet 3</u>

$\sin\theta_3 = \frac{50}{r_3}$, $\cos\theta_3 = \frac{75}{r_3}$

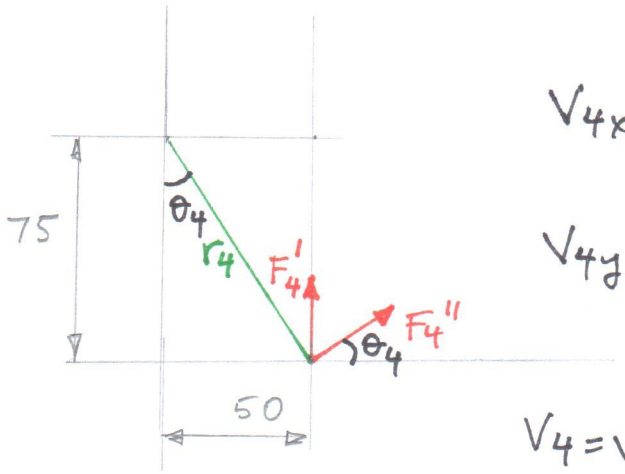
$V_{3x} = F_3'' \cos\theta_3 = F_3'' \cdot \frac{75}{r_3} = 24000$ N $(\rightarrow)$

$V_{3y} = F_3'' \sin\theta_3 - F_3' = 6000$ $(\downarrow)$

$V_3 = \sqrt{V_{3x}^2 + V_{3y}^2} = 24738.6$ N

$V_1 = V_3 = 24738.6$ N

For Rivet 4



$$\sin\theta_4 = \frac{50}{r_4} \quad , \quad \cos\theta_4 = \frac{75}{r_4}$$

$$V_{4x} = F_4'' \cos\theta_4 = F_4'' \cdot \frac{75}{r_4} = 24000 \text{ N } (\rightarrow)$$

$$V_{4y} = F_4'' \sin\theta_4 + F_4' = 26000 \text{ N } (\uparrow)$$

$$V_4 = \sqrt{V_{4x}^2 + V_{4y}^2} = 35383.6 \text{ N}$$

$$V_6 = V_4 = 35383.6 \text{ N}$$

d) The critical rivets are Rivet 4 & 6

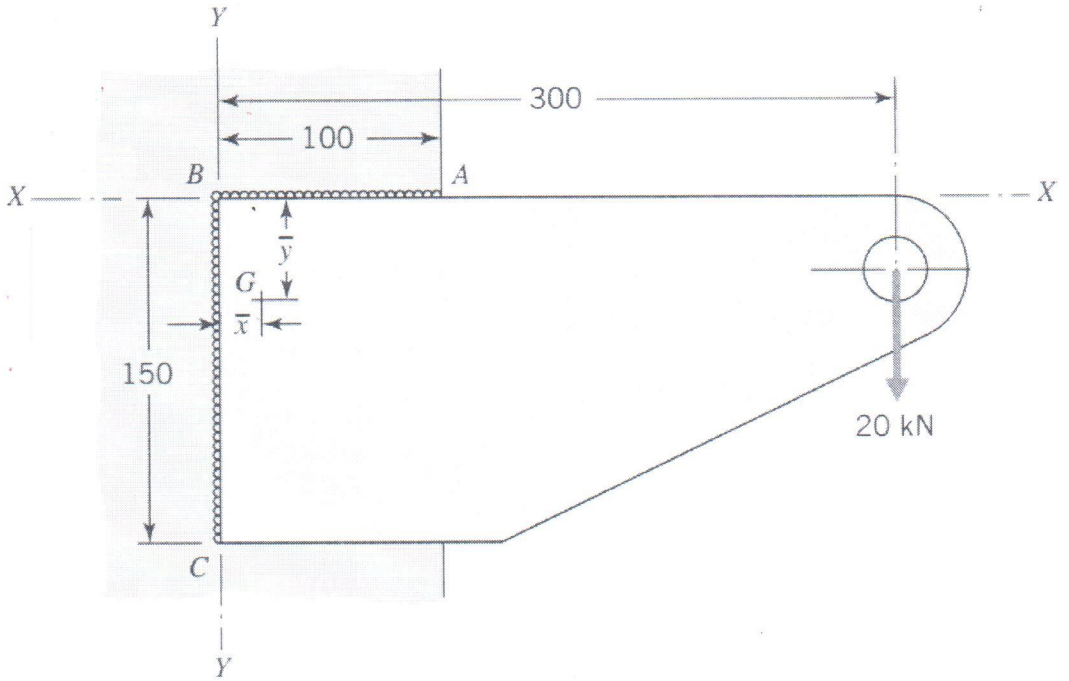
e) Factor of safety

$$n = \frac{\tau_{all}}{\tau_4} = \frac{300}{\dfrac{V_4}{\dfrac{\pi d_4^2}{4}}} = \frac{300}{\dfrac{35383.6}{\dfrac{\pi (18)^2}{4}}} = \frac{300}{139} = 2.16$$

Note: $\tau_4 = \dfrac{V_4}{\dfrac{\pi d_4^2}{4}} = 139 \text{ MPa}$

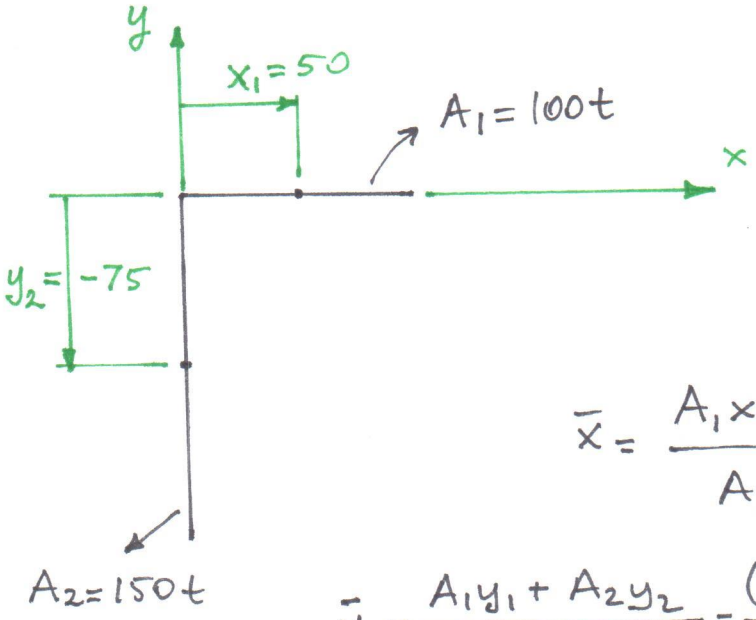
Öğrenci No: .....

Soru 2: (30 puan)



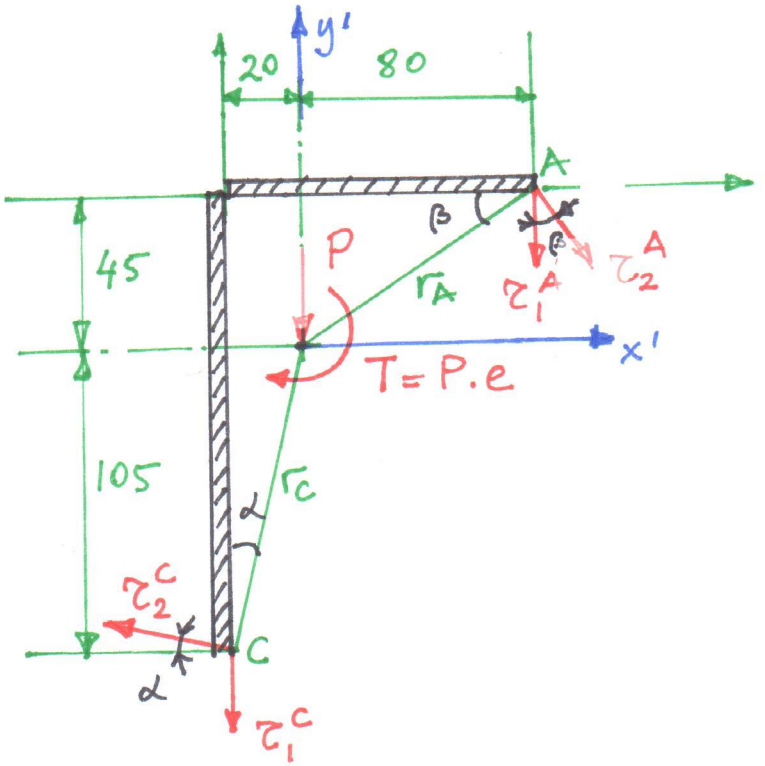
Şekil 2'de gösterilen kaynaklı bağlantıda elektrodun (kaynak malzemesinin) E60 olduğu bilindiğine göre, akmaya karşı emniyet faktörünü 2.5 alarak kaynak dikişi kalınlığını $(h = t / 0.707)$ bulunuz.

Determine the required weld size $(h = t / 0.707)$ *for Fig.2 using E60 welding rod (*$(S_y = 345 \text{ MPa})$ *and a factor of safety of 2.5 based on yielding*



$$\bar{x} = \frac{A_1 x_1 + A_2 x_2}{A_1 + A_2} = \frac{(100t)50 + (150t)0}{100t + 150t} = 20 \text{ mm}$$

$$\bar{y} = \frac{A_1 y_1 + A_2 y_2}{A_1 + A_2} = \frac{(100t)0 + (150t)(-75)}{100t + 150t} = -45 \text{ mm}$$



$P = 20\ kN = 20000\ N$

$e = 300 - 20 = 280\ mm$

$T = P.e = 5.6 \times 10^6\ N.mm$

$r_A = \sqrt{80^2 + 45^2} = 91.79\ mm$

$r_C = \sqrt{20^2 + 105^2} = 106.89\ mm$

<u>Polar moment of inertia</u> (x'-y' axes)

$$J = I_{x'} + I_{y'}$$

$$I_{x'} = \frac{100\,t^3}{12} + (100t)\left(45 + \frac{t}{2}\right)^2$$

neglect neglect

$$+ \frac{t\,150^3}{12} + (150t)\,30^2 = 100t\,(45)^2 + \frac{t\,150^3}{12} + (150t)(30)^2$$

$$I_{x'} = 618750\,t$$

$$I_{y'} = \frac{t\,100^3}{12} + 100t\,(30)^2$$

$$+ \frac{150\,t^3}{12} + 150t\left(20 + \frac{t}{2}\right)^2$$

neglect neglect

$$= \frac{t\,100^3}{12} + 100t\,(30)^2 + 150t\,(20)^2$$

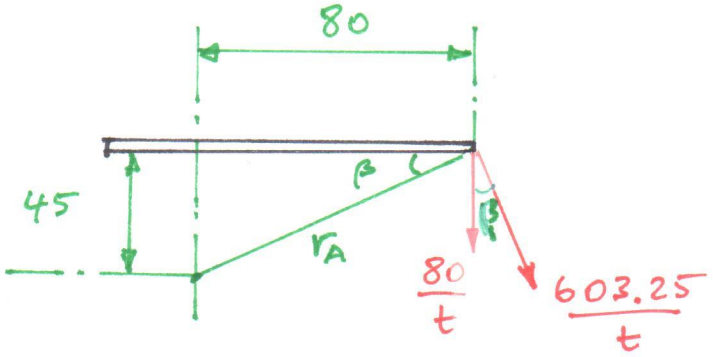
$$I_{y'} = 233333.3\,t$$

$$J = I_{x'} + I_{y'} = 852083.3\,t$$

$$\tau_1^A = \tau_1^C = \frac{P}{A_1 + A_2} = \frac{20000}{100t + 150t} = \frac{20000}{250t} = \frac{80}{t}$$

$$\tau_2^A = \frac{T \cdot r_A}{J} = \frac{(5.6\times10^6)(91.79)}{852083.3t} = \frac{603.25}{t}$$

$$\tau_2^C = \frac{T \cdot r_C}{J} = \frac{(5.6\times10^6)(106.89)}{852083.3t} = \frac{702.5}{t}$$



$$\sin\beta = \frac{45}{r_A} = \frac{45}{91.79}$$

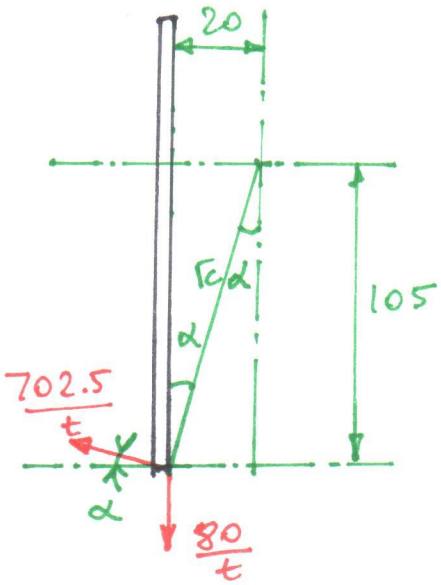
$$\cos\beta = \frac{80}{r_A} = \frac{80}{91.79}$$

$$\tau_x^A = \tau_2^A \cdot \sin\beta = \frac{603.25}{t} \cdot \frac{45}{91.79} = \frac{295.74}{t} \quad (\rightarrow)$$

$$\tau_y^A = \frac{80}{t} + \frac{603.25}{t}\cos\beta = \frac{605.76}{t} \quad (\downarrow)$$

$$\tau^A = \sqrt{(\tau_x^A)^2 + (\tau_y^A)^2} = \sqrt{\left(\frac{295.74}{t}\right)^2 + \left(\frac{605.76}{t}\right)^2}$$

$$\boxed{\tau^A = \frac{674.1}{t}}$$



$$\sin\alpha = \frac{20}{r_C} = \frac{20}{106.89} \; ; \; \cos\alpha = \frac{105}{r_C} = \frac{105}{106.89}$$

$$\tau_x^C = \tau_2^C \cdot \cos\alpha = \frac{702.5}{t} \cdot \frac{105}{106.89} = \frac{690.08}{t} \quad (\leftarrow)$$

$$\tau_y^C = \tau_2^C \cdot \sin\alpha - \frac{80}{t} = \frac{51.44}{t} \quad (\uparrow)$$

$$\boxed{\tau^C = \sqrt{(\tau_x^C)^2 + (\tau_y^C)^2} = \frac{692}{t}}$$

The critical point is point C

$S_y = 345 \text{ MPa}$

$$n = \frac{0.5\, S_y}{\tau} = 2.5$$

$$\frac{(0.5)(345)}{\frac{692}{t}} = 2.5$$

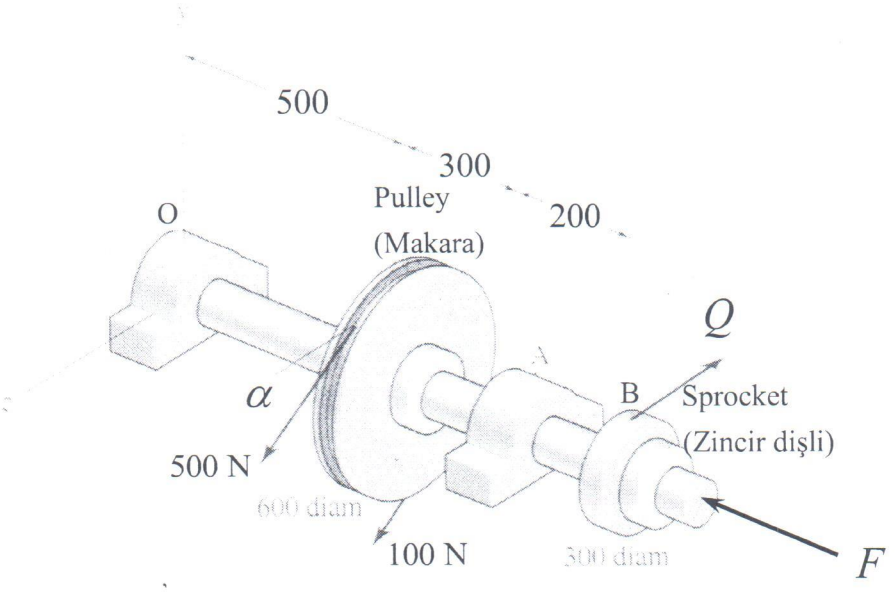
$$t = 10.03 \text{ mm}$$

$$h = \frac{t}{0.707} = \frac{10.03}{0.707}$$

$$h = 14.2 \text{ mm}$$

Öğrenci No: .....

Soru 3: (30 puan)



Şekil. 3

Reference: Prob. 13.25, Fundamentals of Machine Elements, Third Edition, Steven R. Schmid, Bernard J. Hamrock, Bo. O. Jacobson

Şekil.3 te gösterilen mil n rpm hızıyla dönmekte ve 600 mm çapındaki makaradan, 300 mm çapındaki zincir dişliye aktarmaktadır. A yatağı 15 derece temas açısına sahip olan açısal temaslı çift sıralı bilyalı rulman ve O yatağı ise silindrik makaralı (02-series) rulmandır. Aşağıdakileri bulunuz:

a) Serbest cisim diyagramını çiziniz.

b) α açısını tablodaki değer alarak B noktasındaki zincir dişlisine uygulanan Q kuvvetini bulunuz

c) A ve O yataklarına gelen tepki kuvvetlerinin radyal ve eksenel bileşenlerini bulunuz.

d) Her iki rulman yatağındaki eşdeğer yükleri bulunuz.

e) Bu rulman yataklarının nominal ömrünü $L_5 = 5L_{10}$ bulunuz.

f) Hangi rulmanın daha önce hasara uğrayacağını belirleyiniz ve sebebin yazınız.

Varsayım: A noktasında olan rulmanın çapı d_o^A [mm] ve O noktasında olan rulmanın dış çapı d_o^O [mm]. Dış bileziğin döndüğünü ve rulmanların orta şiddetli şoka (medium shock) maruz kaldığını varsayınız. Eksenel yükün yalnız A yatağında taşıdığına dikkat edınız.

Verilenler:

Açı α [°]	**O Rulmanı OD (dış çapı)** d_o^O [mm]	**A Rulmanı OD (dış çapı)** d_o^A [mm]	**Akma Dayanımı** S_y **[Mpa]**	**Çekme Dayanımı** S_{ut} **[Mpa]**	**Eksenel yük** F **[N]**
15	**90**	**52**	**400**	**700**	**200**

Öğrenci No: .....

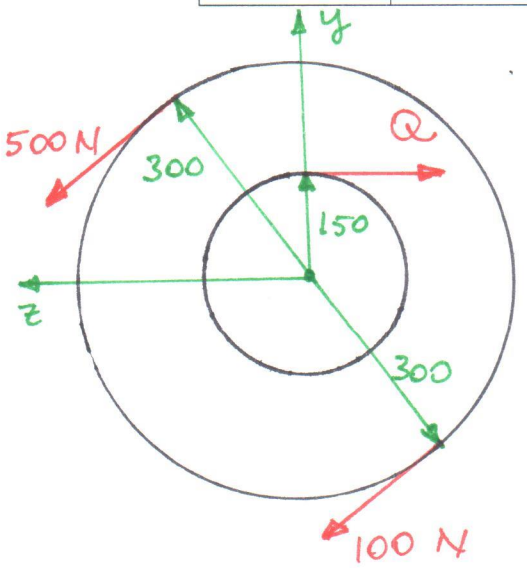
The shaft shown in Fig. 3 rotates at 1100 rpm and transfer power with moderate shock from a 600-mm-diameter pulley to a 300-mm-diameter sprocket. The bearing at point A *is an angular contact double-row ball bearing with a contact angle of 15 degrees and the bearing at point* O *is a cylindrical (roller 02 series) type bearing. Determine the following:*

a) *Draw the free body diagram*
b) *Find the force Q applied to the sprocket at* B by taking the value of the angle α *from the Table*
c) *Find the values of radial and axial reaction force components at bearing* A *and* O.
d) *Find the equivalent load in each bearing at* A *and* O.
e) *Determine the bearings median life* $L_5 = 5L_{10}$ *for 98% reliability.*
f) *Determine which bearing fails first and write the reason.*

Assumption: *The bearing at point A has an outside diameter of* d_o^A [mm] *and the bearing at point O has an outside diameter of* d_o^O [mm]. *Outer ring rotates and the bearings are subjected to moderate shocks. Note that the axial load is only supported by the support at A.*

Given:

Angle α [°]	**Bearing O OD** d_o^O [mm]	**Bearing A OD** d_o^A [mm]	**Yield stress** S_y **[Mpa]**	**Ultimate tensile stress** S_{ut} **[Mpa]**	**Axial load** F **[N]**
10	**90**	**52**	**400**	**700**	**200**

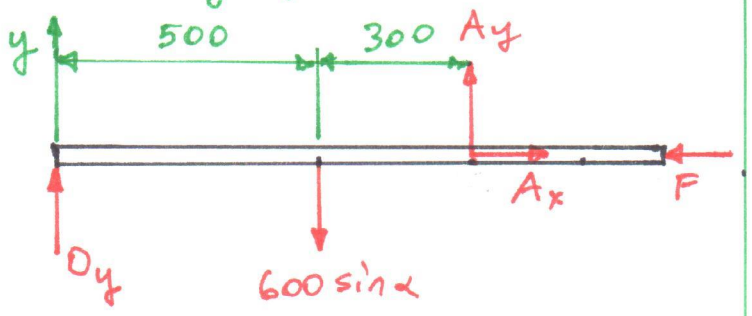


$$\circlearrowleft \Sigma M_x = 0$$

$$(100)(300) - (500)(300) + Q(150) = 0$$

$$Q = 800 \text{ N}$$

x-y plane



$\circlearrowleft + \Sigma M_A = 0$

$O_y \cdot 800 - 600 \sin\alpha (300) = 0$

$O_y = \dfrac{(600) \sin 15 (300)}{800}$

$O_y = 58.2 \text{ N}$

$+\uparrow \Sigma F_y = 0$

$O_y - 600 \sin 15 + A_y = 0$

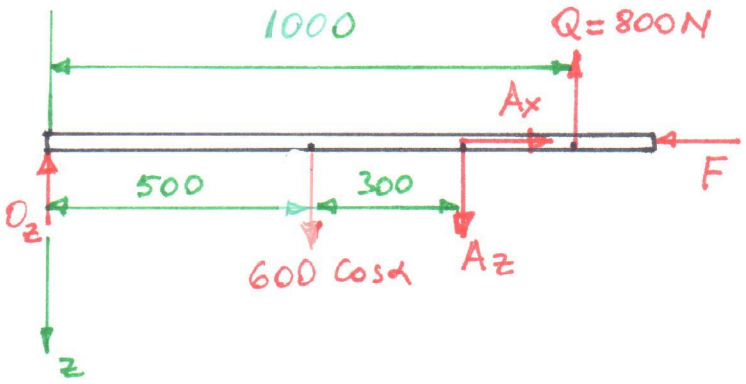
$A_y = 97.1 \text{ N}$

$\xrightarrow{+} \Sigma F_x = 0$

$A_x - F = 0$

$A_x = F = 200 \text{ N}$

x-z plane



$\circlearrowleft + \Sigma M_A = 0$

$O_z \cdot (800) - 600 \cos\alpha (300)$

$- Q (200) = 0$

$O_z = \dfrac{(600) \cos 15 (300) + (800)(200)}{800}$

$O_z = 417.3 \text{ N}$

$+\uparrow \Sigma F_z = 0$

$O_z - 600 \cos\alpha - A_z + Q = 0$

$A_z = 637.7 \text{ N}$

Bearing O : $O_x = 0$, $O_y = 58.2 \text{ N}$, $O_z = 417.3 \text{ N}$

$F_a^O = O_x = 0$

$F_r^O = \sqrt{O_y^2 + O_z^2} = 421.3 \text{ N}$

* Cylindrical (02 series)
* Outer ring rotating $\therefore$ $V = 1.2$
* Moderate shock roller bearing

$K_s = 1.3$ (Table 10.7)

* OD (outside diameter) is 90 mm

$C = 45.7 \text{ kN} = 45\,700 \text{ N}$ (Table 10.4)

$$P^o = K_s\,(X V F_r^o + Y F_a^o) \quad , \quad F_a^o = 0 \;,\; X = 1$$

$$P^o = (1.3)(1)(1.2)(421.3)$$

$$= 657.228 \text{ N}$$

Bearing A

$V = 1.2$, $K_s = 2$ (Table 10.7) , $OD = 52$

$A_x = 200$ N $\Rightarrow$ $F_a^A = 200$ N

$$\left.\begin{array}{l} A_y = 97.1 \text{ N} \\ A_z = 637.7 \text{ N} \end{array}\right\} \quad F_r^A = \sqrt{A_y^2 + A_z^2} = 645.1 \text{ N}$$

Angular contact ball bearing wit $OD = 52$

$C = 14.8$ kN , $C_s = 7.65$ kN (Table 10.3)

$i = 2 \Rightarrow$ double row

$$\frac{i F_a}{C_s} = \frac{(2)(200)}{7650} = 0.052 \;;\; \frac{F_a}{V F_r} = \frac{200}{(1.2)(645.1)} = 0.26$$

From Table 10.6

e	$\frac{i F_a}{C_s}$
0.40	0.029
?	0.052
0.43	0.058

Interpolation

$$\frac{0.058 - 0.029}{0.43 - 0.40} = \frac{0.052 - 0.029}{e - 0.40}$$

$$e = 0.42$$

$$\frac{F_a}{V F_r} = 0.26 < e = 0.42 \Rightarrow X = 1$$

e	Y
0.40	1.57
0.42	?
0.43	1.46

Interpolation

$$\frac{0.43-0.40}{0.42-0.40} = \frac{1.46-1.57}{Y-1.57}$$

$$Y = 1.5$$

$$P^A = K_s(XVF_r^A + YF_a^A)$$

$$= 2\left[(1)(1.2)(645.1) + (1.5)200\right]$$

$$= 2148.24 \text{ N}$$

Bearing O Life

$$L_{10}^{O} = \frac{10^6}{60n}\left(\frac{C}{P}\right)^a$$

$$= \frac{10^6}{60\cdot(1100)}\cdot\left(\frac{45700}{657.228}\right)^{10/3} = 20.9\times10^6 \text{ hours}$$

$$L_5^O = 5L_{10}^O = 104.5\times10^6 \text{ hours}$$

Bearing A Life

$$L_{10}^{A} = \frac{10^6}{60n}\left(\frac{C}{P}\right)^a = \frac{10^6}{(60)(1100)}\left(\frac{14800}{2148.24}\right)^3$$

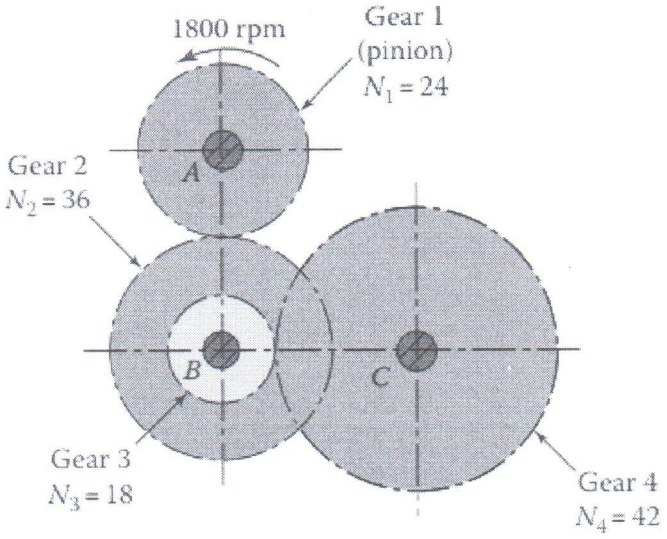
$$L_{10}^A = 4954 \text{ hours}$$

$$L_5^A = 5L_{10}^A = 24770 \text{ hours}$$

Bearing A fails first (sooner than bearing O)

Öğrenci No: .....

Soru 4: (30 puan)



Şekil 4

Şekil 4'te gösterilen dişliler 10 mm'lik module ve 20° basınç açısına ve 15 mm diş kalınlığına sahiptir. 1. dişli 80 kW'lık gücü 1600 dev/dak'da dönerek B miline takıl avare dişli vasıtasıyla 4. Dişliye aktarmaktadır.

a) Her bir dişlinin taksimat dairesi çapını bulunuz.
b) Her bir dişli için serbest cisim diyagramını çiziniz
c) Her bir dişlideki radial ve teğetsel kuvvetleri bulunuz
d) Dişli 1 ve Dişli 4'teki tork değerlerini bulunuz
e) A, B ve C milindeki reaksiyon kuvvetlerini bulunuz.

The gears shown in Fig. 4 have a module of 10 mm, a 20° pressure angle, and a tooth width of 15 mm. Gear 1 transmits 80 kW at 1600 rpm through an idler pair mounted on shaft B to gear 4

a) Determine the diameter of the pitch circle for all gears
b) Draw the free body diagram for each gear
c) Determine the radial and tangential forces on all gears
d) Determine the torque at gear 1 and gear 4
e) Determine the reactions on shaft A, B and C

$$pN = \pi d \quad , \quad pP = \pi \quad , \quad P = \frac{1}{m}$$

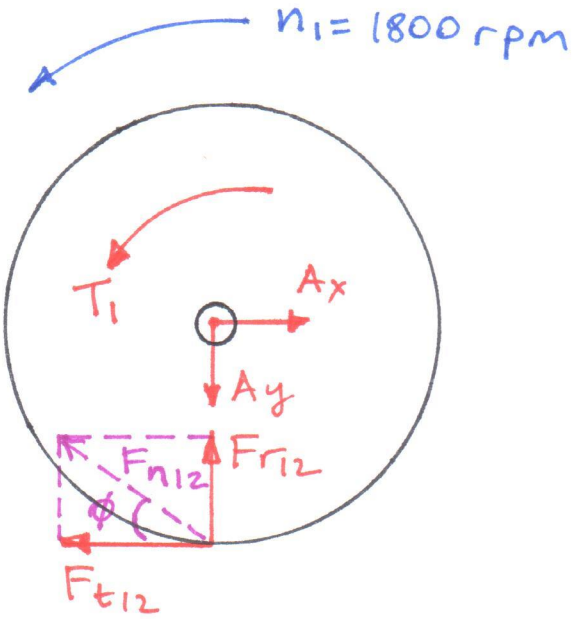
$$\Downarrow$$

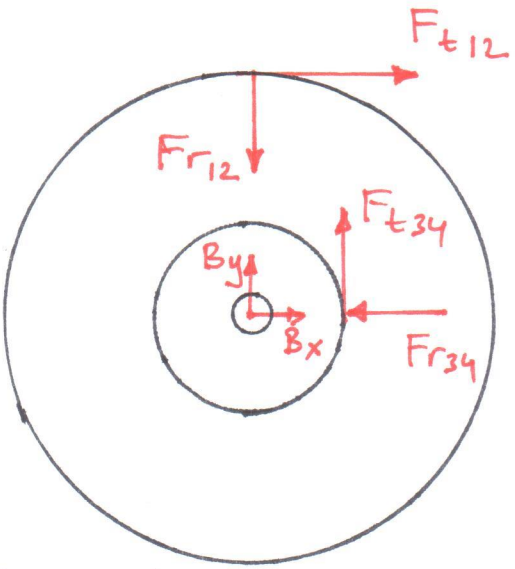
$$p = \frac{\pi}{P} = \pi m$$

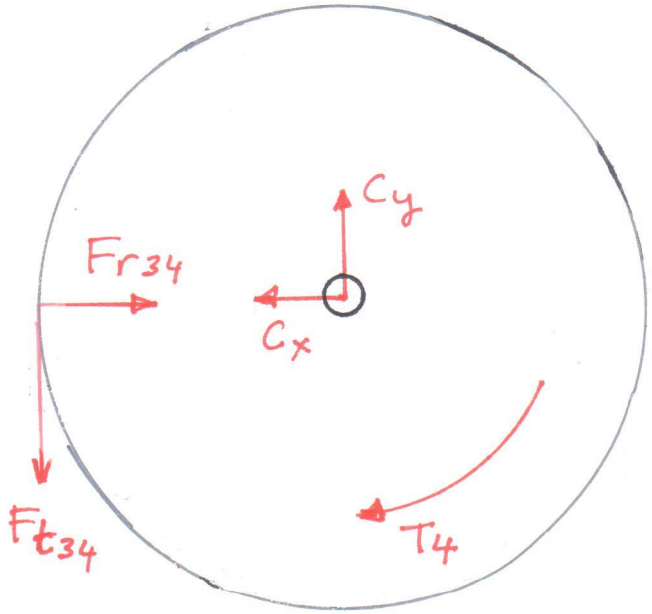
$$\therefore \quad (\cancel{\pi} m) N = \cancel{\pi} d$$

$$d = mN \quad \Rightarrow$$

$$d_1 = mN_1 = (10)24 = 240 \text{ mm}$$
$$d_2 = mN_2 = (10)36 = 360 \text{ mm}$$
$$d_3 = mN_3 = (10)18 = 180 \text{ mm}$$
$$d_4 = mN_4 = (10)42 = 420 \text{ mm}$$







For Gear 1

$$kW = \frac{T_1 \cdot n_1}{9549} \Rightarrow 80 = \frac{T_1 (1800)}{9549} \Rightarrow T_1 = 424.4 \text{ N.m}$$
$$= 424400 \text{ N mm}$$

$$T_1 = F_{t12} \cdot r_1 \Rightarrow F_{t12} = \frac{T_1}{r_1} = \frac{424400}{120} = 3536.7 \text{ N}$$

$$F_{n12} \cos\phi = F_{t12} \Rightarrow F_{n12} = \frac{F_{t12}}{\cos\phi} = \frac{3536.7}{\cos 20} = 3763.7 \text{N}$$

$$F_{n12} \sin\phi = F_{r12} \Rightarrow F_{r12} = (3763.7) \sin 20 = 1287.3 \text{ N}$$

$\xrightarrow{+} \Sigma F_x = 0$: $A_x - F_{t12} = 0 \Rightarrow A_x = F_{t12} = 3536.7 \text{ N}$

$+\uparrow \Sigma F_y = 0$: $F_{r12} - A_y = 0 \Rightarrow A_y = F_{r12} = 1287.3 \text{ N}$

$$R_A = \sqrt{A_x^2 + A_y^2} = 3763.7 \text{ N}$$

For Gear 2 & 3

$\circlearrowleft + \Sigma M_B = 0$: $F_{t12}\, r_2 - F_{t34}\, r_3 = 0$

$$F_{t34} = F_{t12} \cdot \frac{r_2}{r_3} = (3536.7)\frac{180}{90} = 7073.4\,N$$

$$F_{n34} \cos\phi = F_{t34} \Rightarrow F_{n34} = 7527.4\,N$$

$$F_{r34} = F_{n34} \sin\phi \Rightarrow F_{r34} = 2574.5\,N$$

$\xrightarrow{+} \Sigma F_x = 0$: $F_{t12} - F_{r34} + B_x = 0$

$$B_x = F_{r34} - F_{t12} = 2574.5 - 3536.7$$

$$B_x = -962.2\,N$$

$+\uparrow \Sigma F_y = 0$: $F_{t34} - F_{r12} + B_y = 0$

$$B_y = F_{r12} - F_{t34} = 1287.3 - 7073.4$$

$$B_y = -5786.1\,N$$

$$R_B = \sqrt{B_x^2 + B_y^2} = 5865.6\,N$$

For Gear 4

$$T_4 = F_{t34} \cdot r_4 = (7073.4)(210) = 1485414\,N.mm$$
$$= 1485.4\,N.m$$
$$= 1.485\,kN.m$$

$\xrightarrow{+} \Sigma F_x = 0$: $F_{r34} - C_x = 0 \Rightarrow C_x = 2574.5\,N$

$+\uparrow \Sigma F_y = 0$: $C_y - F_{t34} = 0 \Rightarrow C_y = 7073.4\,N$

$$R_C = \sqrt{C_x^2 + C_y^2} = 7527.35\,N$$