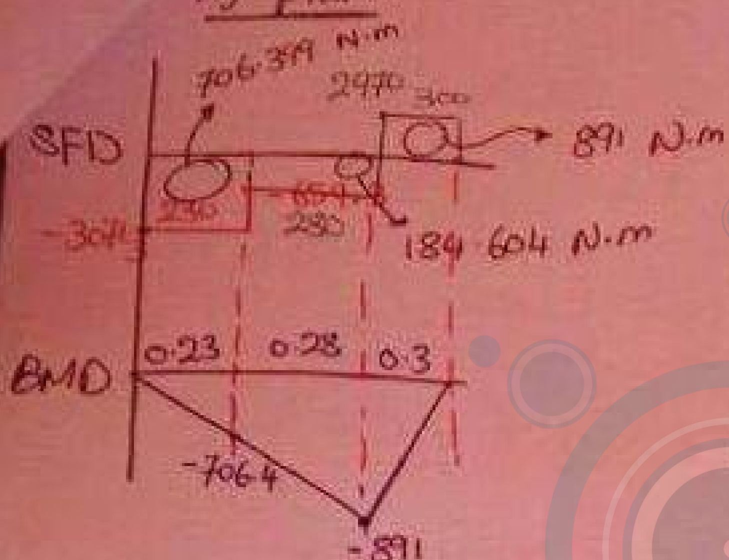
xy-plane



$M_{max} = 891$ N·m

xz-plane

(c) $n_f = 2.5$ $T = (432 - 280)(0.125) = -306$ N·m

$M = 891$ N·m

$T_a = 0$ $M_m = 0$

$T_m = -306$ N·m $M_a = 891$ N·m

$K_a = a S_{ut}^{b}$ $S_{ut} = 690$ MPa

$S_y = 580$ MPa

$= 1.58(690)^{-0.085} = 0.9065$

$K_b = 0.9$ $K_c = 0.54$ $K_d = K_e = K_f = 1$

$S_e' = 0.5(690) = 345$ MPa

⇒ $S_e = 166.07$ MPa ⇒ Assume Sharp fillet Radius $(\frac{r}{d} = 0.02)$

$K_t = 3.0$ (Axial) $K_t = 2.7$ (Bending) $K_{ts} = 2.2$

$$d = \left(\frac{16(2.5)}{\pi} \left\{ \frac{1}{166.07(10)^6} \left[(4)(2.7(891))^2 \right]^{1/2} + \left[3(2.2(306))^2 \right]^{1/2} \frac{1}{690(10)^6} \right\} \right)^{1/3}$$

$$d = \left(\frac{16(2.5)}{\pi} \left\{ 2.897(10)^{-5} + 1.689(10)^{-6} \right\} \right)^{1/3}$$

$d = 73.09$ mm

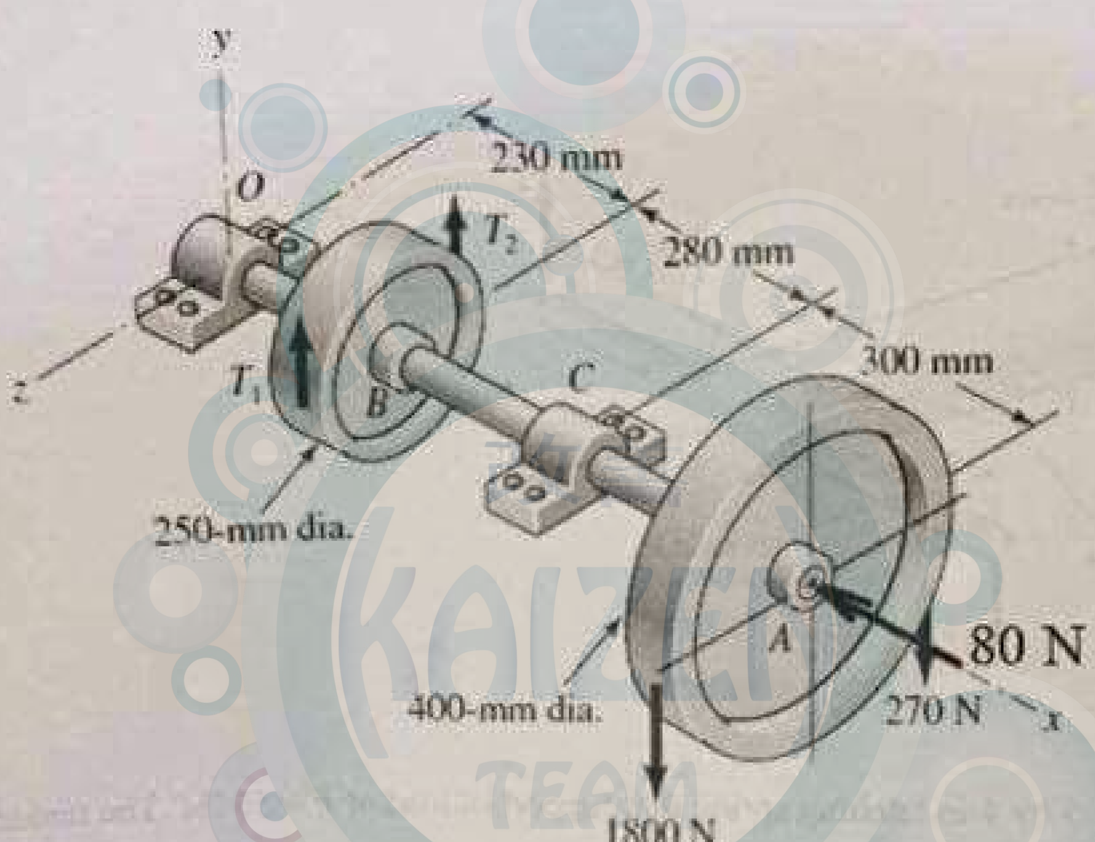
Q3(20P)- A belt-driven jack-shaft is shown in the figure below. The weight of each pulley is 900 N. The shaft is made of AISI 1050 CD (hardened steel) and is driven by a motor at 1200 rpm. All important surfaces have a ground finish. If the shaft is to be designed for an infinite life with a reliability of 99.9% and a safety factor of 1.5. The power is transmitted through the shaft and delivered to the belt on pulley *B*. Assume the belt tension on the loose side at *B* is 15 percent of the tension on the tight side. Determine:

a-Select two bearings for O and C using an application factor of unity and a desired life for each bearing is 9 kh with a 95 percent reliability for the two bearings. (use direct mount)

b-Draw shear-force and bending-moment diagrams for the shaft.

c- Using a factor of safety of 2.5 determine the minimum allowable diameter of the shaft based on a fatigue- failure analysis Modified Goodman. (Make any necessary assumptions).

d-draw the resulting shaft showing all necessary dimensions



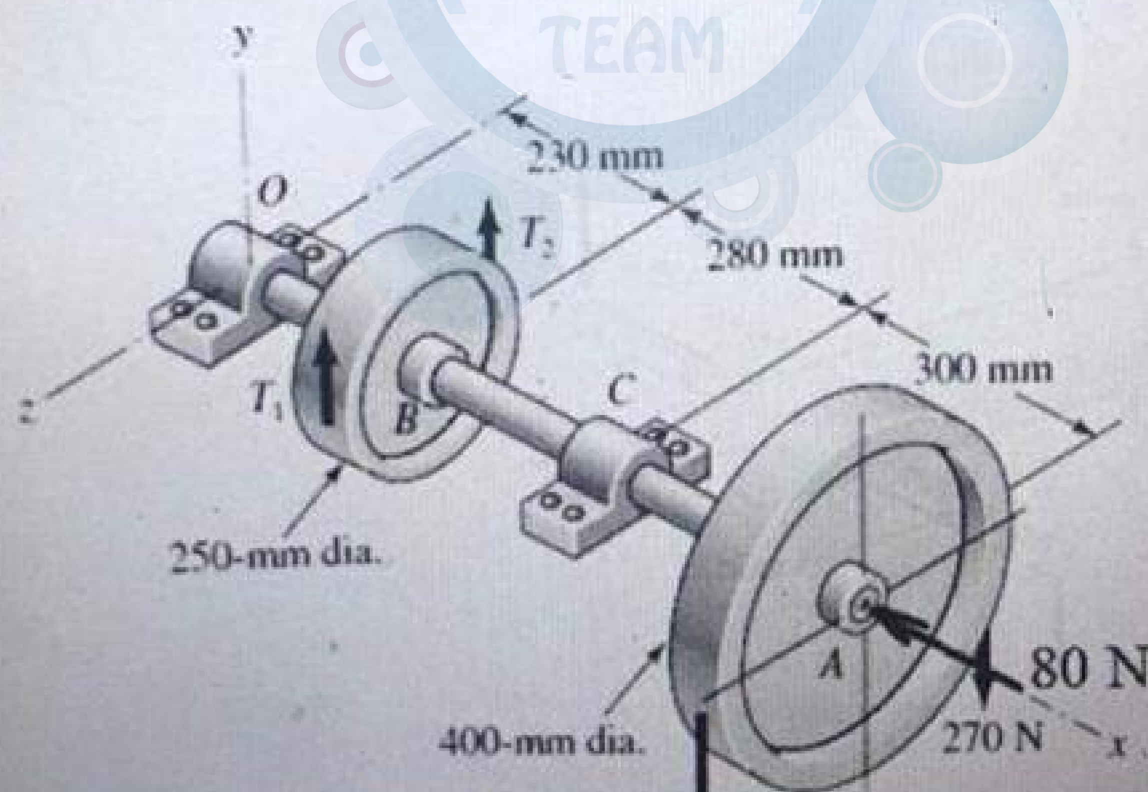
Q3(20P)- A belt-driven jack-shaft is shown in the figure below. The weight of each pulley is 900 N. The shaft is made of AISI 1050 CD (hardened steel) and is driven by a motor at 1200 rpm. All important surfaces have a ground finish. If the shaft is to be designed for an infinite life with a reliability of 99.9% and a safety factor of 1.5. The power is transmitted through the shaft and delivered to the belt on pulley *B*. Assume the belt tension on the loose side at *B* is 15 percent of the tension on the tight side. Determine:

a-Select two bearings for O and C using an application factor of unity and a desired life for each bearing is 9 kh with a 95 percent reliability for the two bearings. (use direct mount)

b-Draw shear-force and bending-moment diagrams for the shaft.

c- Using a factor of safety of 2.5 determine the minimum allowable diameter of the shaft based on a fatigue- failure analysis Modified Goodman. (Make any necessary assumptions).

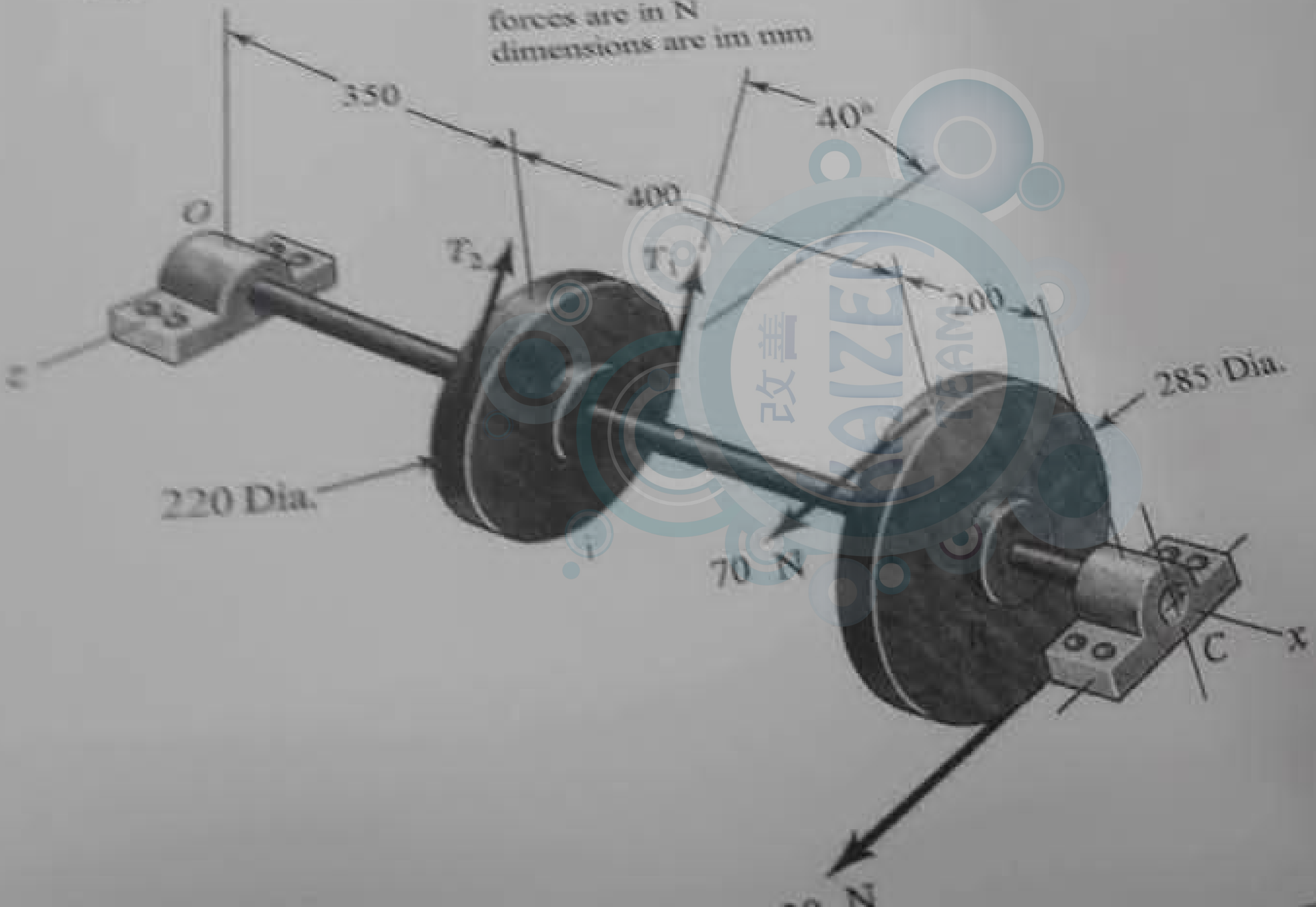
d-draw the resulting shaft showing all necessary dimensions



Q2(16points). The figure shows a shaft mounted in bearings at C and O and having pulleys at A and B. the bearings are to have a life of 90 kh at a combined reliability of 0.99. The countershaft runs at 1600 rev/min. The belt tension on the loose side of pulley A is 10 percent of the tension on the tight side.

a-Select deep-groove bearings for use at C and O using an application factor of 1.2.

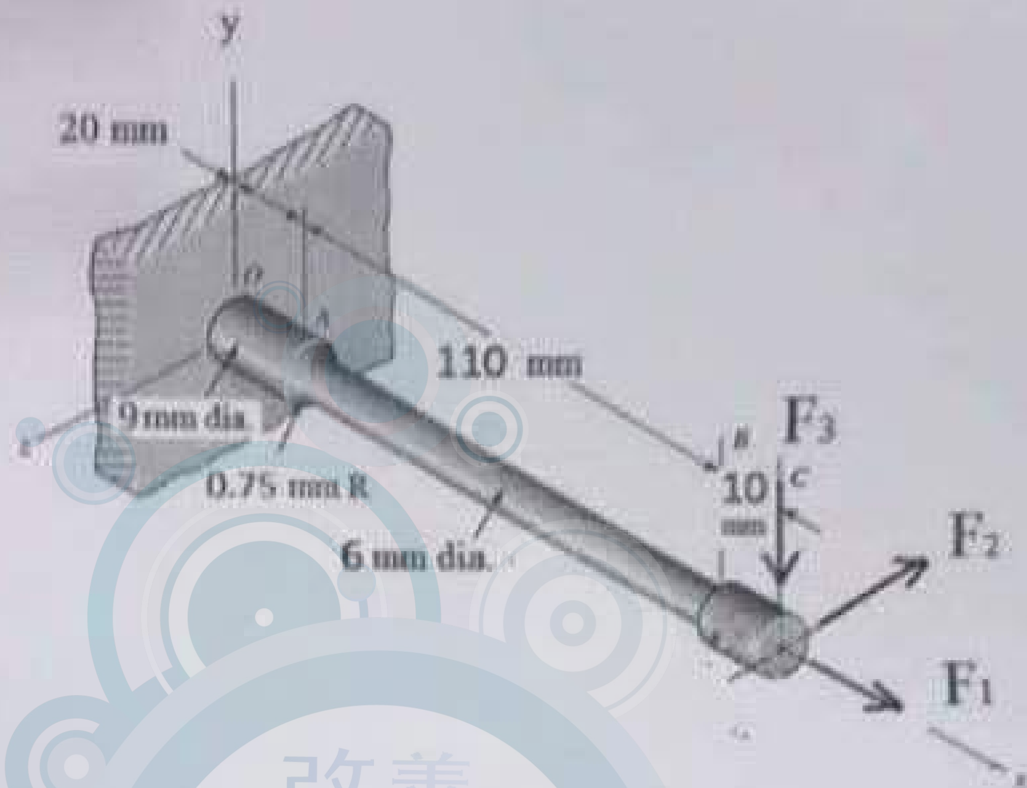
b-If a 100 N axial stress is applied at point C in the -x direction will the same bearings chosen in part a be suitable.



Q1(15P). Q1(15points) The bar in the figure is made of AISI 1006 cold-drawn steel and is loaded by the forces $F1 = 500$ N, $F2 = 3$ kN, and $F3 = 10$ kN

a) For the critical stress element, determine the principal stresses and the maximum shear stress

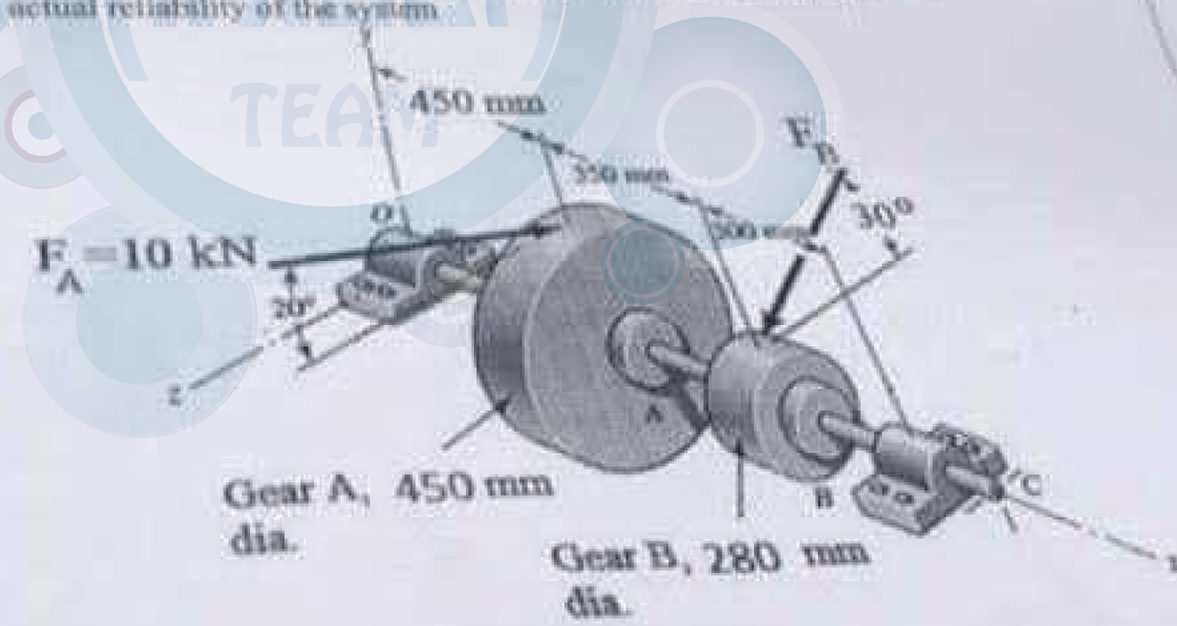
b) Compute the factor of safety, based upon the distortion energy theory, for the critical stress element of the member shown in the figure



Q2(15P)- The shaft shown in the figure is made of AISI 1018 cold-drawn steel and is driven by a motor at 90 rpm. The power is delivered to the shaft on gear A.

a-Select two angular contact ball bearings for O and C using an application factor of unity and a desired life for each bearing is 900h with a 98 percent reliability.

b- what is the actual reliability of the system



(20 p) $5*4$ in $\quad F = 50$ lb $\quad r = \frac{1}{8}$ in

(a)

$$\sigma_i = -\frac{M c_i}{A e r_i} \qquad \sigma_o = \frac{M c_o}{A e r_o}$$

4 in, $\frac{1}{8}$ in

4 in, $\frac{1}{8}$ in, $\frac{1}{8}$ in, O

$r_i = \frac{1}{8}$ in $= 0.125$ in

$r_o = \frac{2}{8}$ in $= 0.25$ in

$r_c = \frac{1}{8} + \frac{1}{16} = 0.1875$ in

$$r_n = \frac{h}{\ln(r_o/r_i)} = \frac{\frac{1}{8}}{\ln(2/8 / \frac{1}{8})} = 0.1803 \text{ in}$$

$e = r_c - r_n = 7.2(10)^{-3}$ in

$c_o = r_o - r_n = 0.0697$ in

$c_i = r_n - r_i = 0.0553$ in

$A = 4(\frac{1}{8}) = 0.5$ in^2

$M = (50)(5) = 250$ lb.in

-1000

$\sigma = \frac{MC}{Ae r}$

$$\sigma_i = -\frac{(250)(0.0553)}{(0.5)(7.2)(10)^{-3}(0.125)} = -4.27 \text{ kpsi}$$

$\sigma_o = 19.36$ kpsi

(b)

$(5 \times 50) = 25$

$M = 250$ lb.in

$r_n = 1.414$ in

$F' = 12.5$ lb $\quad F/4$

$$F'' = \frac{(250)}{4(1.414)} = 44.2 \text{ lb} \qquad \frac{M}{4 r_n}$$

$\alpha = 90 + 45 = 135^\circ$

$$\theta = \cos^{-1}\left(\frac{1}{1.414}\right) = 45^\circ$$

$\alpha = 45^\circ$

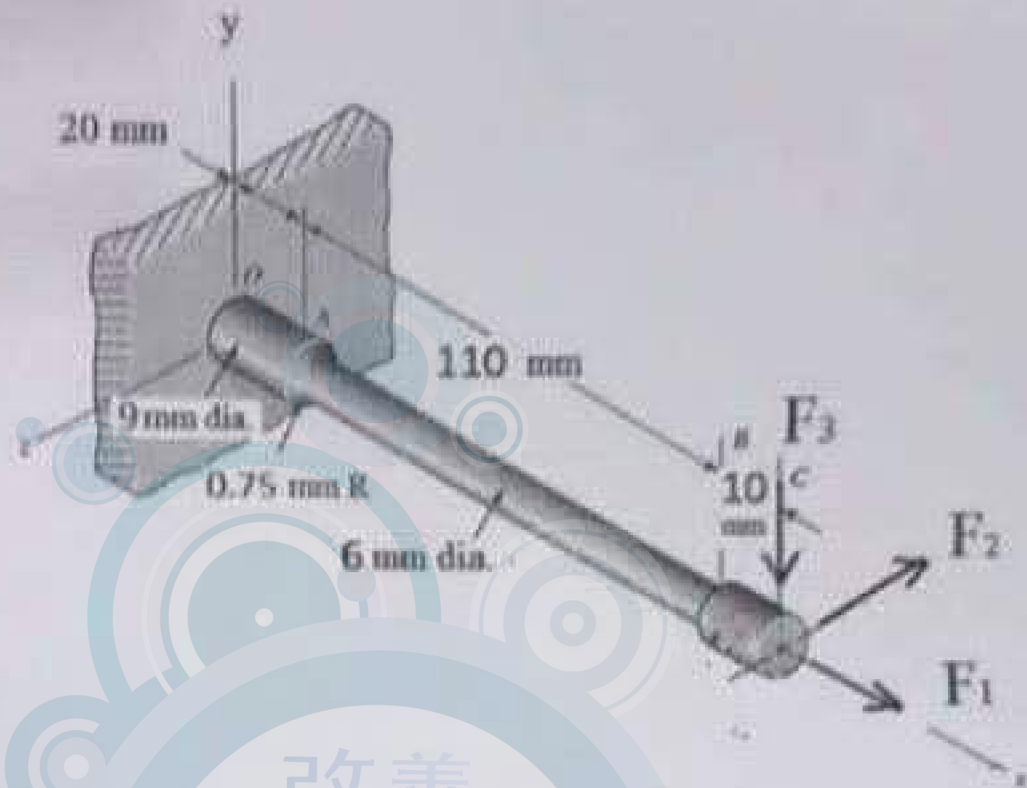
$F_R = 53.77$ lb

$F_R = 36.45$ lb

Q1(15P). Q1(15points) The bar in the figure is made of AISI 1006 cold-drawn steel and is loaded by the forces $F1 = 500$ N, $F2 = 3$ kN, and $F3 = 10$ kN

a) For the critical stress element, determine the principal stresses and the maximum shear stress

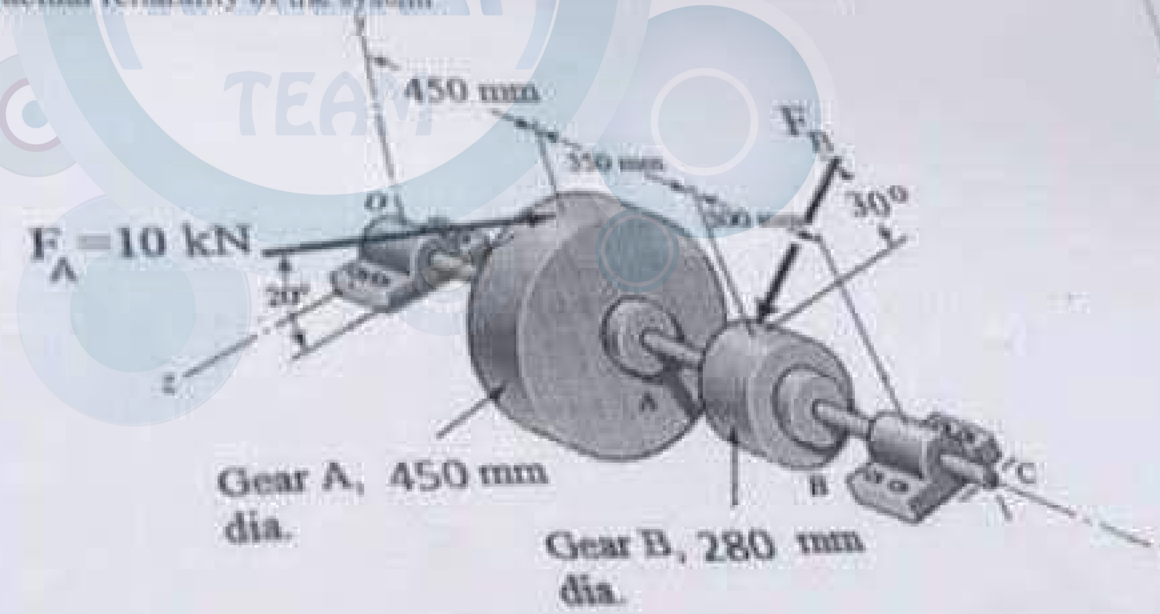
b) Compute the factor of safety, based upon the distortion energy theory, for the critical stress element of the member shown in the figure



Q2(15P)- The shaft shown in the figure is made of AISI 1018 cold-drawn steel and is driven by a motor at 90 rpm. The power is delivered to the shaft on gear A.

a-Select two angular contact ball bearings for O and C using an application factor of unity and a desired life for each bearing is 900h with a 98 percent reliability.

b- what is the actual reliability of the system



Ⓒ Sharp fillet Radius $n = 2.5$

$K_f = K_t = 2.7 \quad K_{fs} = K_{ts} = 2.2 \quad \frac{r}{d} = 0.02 \quad \frac{D}{d} = 1.5$

$K_b = 0.9$

$S_{ut} = 440\ \text{MPa}$

$S_e' = 0.5(440) = 220\ \text{MPa}$

$K_f = K_d = K_e = 1 \quad K_c = 0.59$

$K_a = \left(4.51(440)^{-0.265}\right) = 0.8988 \quad S_{e1} = 104.997\ \text{MPa}$

$$d = \left(\frac{16(2.5)}{\pi}\left\{2.088(10)^{-4} + 2.0351(10)^{-5}\right\}\right)^{1/3} = 142.89\ \text{mm}$$

$K_b = 0.6929 \quad S_{e2} = 80.83\ \text{MPa}$

$r = 0.02(142.89) = 2.86\ \text{mm}$

$q = 0.78 \quad K_f = 2.33$

$q_s = 0.82 \quad K_{fs} = 1.98$

$$d = \left(\frac{16(2.5)}{\pi}\left\{2.341(10)^{-4} + 1.832(10)^{-5}\right\}\right)^{1/3}$$

$= 148.03\ \text{mm} \quad K_b = 0.689$

$S_{e3} = 80.38\ \text{MPa}$

$r = 2.96\ \text{mm} \quad K_f = 2.33$

$K_{fs} = 1.98$

$$d = \left(\frac{16(2.5)}{\pi}\left\{2.354(10)^{-4} + 1.832(10)^{-5}\right\}\right)^{1/3} = 147.82\ \text{mm}$$

$K_b = 0.6892 \quad S_{e4} = 80.4\ \text{MPa}$

Stop

Final Answer

$\Sigma T = 0;$

$$(1800-270)(0.2)+(0.15\,T_1-T_1)(0.125)=0$$

$$\Rightarrow 306=(0.85)(0.125)\,T_1$$

$$\Rightarrow T_1 = 2880\ \text{N}$$

$$T_2 = 432\ \text{N}$$

$\Sigma M_O^y = 0;\quad -R_C^z(0.51)=0 \Rightarrow R_C^z = 0$

$\Sigma M_O^z = 0;\quad (2880+432-900)(0.23)+R_C^y(0.51)-(1800+270+900)(0.81)=0$

$$\Rightarrow R_C^y = 3629.3\ \text{N}$$

$\Sigma F^y = 0;$

$$R_O^y+(2880+432)-900+3629.3-(1800+270+900)=0$$

$$R_O^y = -3071.3\ \text{N}$$

$\Sigma F^z = 0;\quad R_O^z = 0$

$\Rightarrow F_{r(B)} = 3629.3\ \text{N}$

$F_{r(A)} = +3071.3\ \text{N}$

$F_{ae} = 80\ \text{N}$

$F_{i(B)} = 1137.18\ \text{N}$

$$F_{i(A)} = \frac{0.47(+3071.3)}{1.5} = +962.34\ \text{N}$$

$$F_{e(A)} = (0.4)(+3071.3)+1.5(1137.18+80) = \cancel{597.95\ \text{N}} = \cancel{2147.16\ \text{N}}\ 3054.32$$

$$C_{10} = \cancel{1440.1\ \text{N}}\ 6623.95\ \text{N}$$

Select Single Row Timken Tappered Bearing with Bore Diameter 25mm & outside Diameter = 52 mm & Cone = 32205-B & cup = 32205-B

$F_{e(B)} = 3629.3\ \text{N}$

$$C_{10} = (1)(3.6293)\left[\frac{7.2}{0+4.48(1-0.975)^{1/1.5}}\right]^{3/10} \quad 2.4112$$

$$x_D = \frac{(1200)(9{,}000)(60)}{90(10)^6} = 7.2$$

$$\Rightarrow C_{10} = 8.751 = 8751\ \text{N}$$

8751 − 9751

9520 K=1 *

(2)

Final Exam:

Q3): (20 p): weight = 900 N

R = .95 → for two bearing

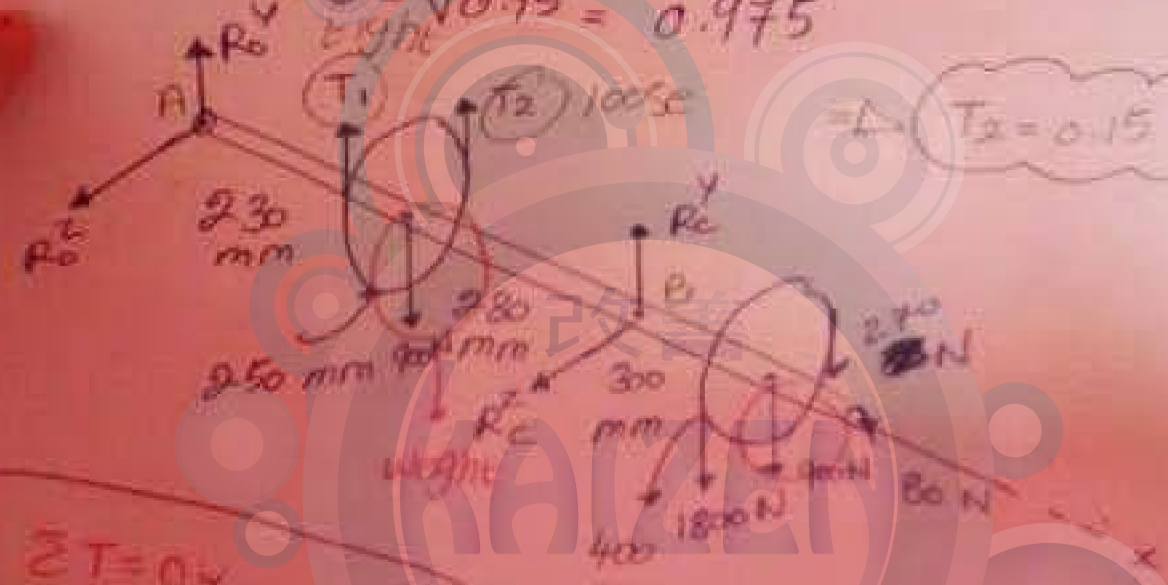
$n_D = 1200$ rpm   AISI 1050 CD Steel   ground

$R = 99.9\%$ Kσn = 1.5

loose side = 15% tight side

@ $l_D = 9{,}000$ hr   af = 1   Direct

$R_D = \sqrt{0.95} = 0.975$



$\Rightarrow T_2 = 0.15\,T_1$

$\Sigma T = 0$;

$(1800-800)(0.2) + (T_2 - T_1)(0.125) = 0$ 270

$200 + (0.15T_1 - T_1)(0.125) = 0$

$200 - 0.85\,T_1(0.125) \Rightarrow T_1 = 1882.35\text{ N}$

$\Rightarrow T_2 = 282.35\text{ N}$

$\Sigma M_O^y = 0$; $-R_C^z(0.51) = 0 \Rightarrow R_C^z = 0$

$\Sigma M_O^z = 0$; $(1882.35 + 282.35 - 900)(0.23) + R_C^y(0.51)$

$- (1800 + 80 + 900)(0.81)$

axial
CH.7
d

completely reversed
Constant] → by default completely reversed

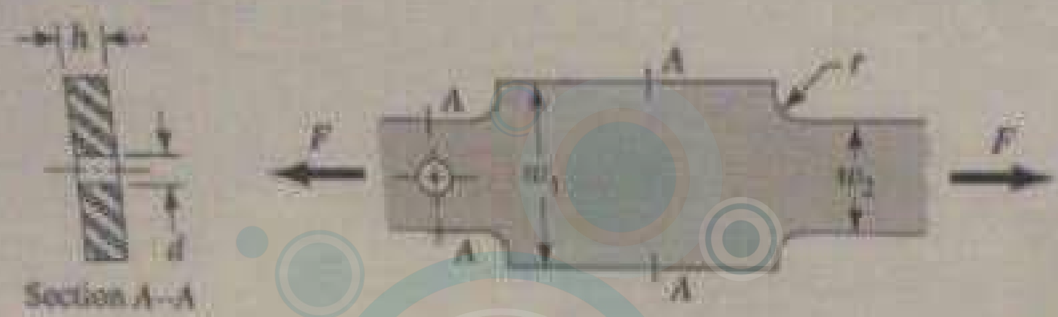
Final Examination

Machine design elements

Q1(15P). The figure shows the free-body diagram of a connecting-link portion having stress concentratio[n] at three sections. The dimensions are $r = 1.5$ mm, $d = 6$ mm, $h = 4$ mm, $w_1 = 20$ mm, and $w_2 = 15$ mm. The force F fluctuate between a tension of 800 N and a compression of 1 kN. The connecting link is made of AISI 1030 CD. Using the modified Goodman failure theory determine:

a-the fatigue factors of safety for the hole and the fillet.

b-number of cycles to failure



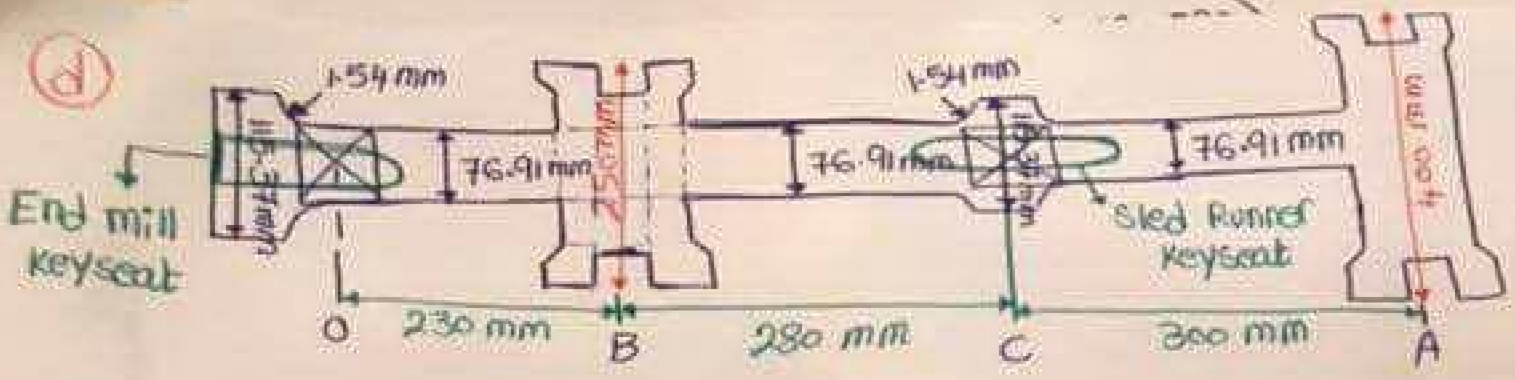
Q2(15P). Shown in the figure is a 20 by 250-mm rectangular steel bar cantilevered to a 250-mm steel channel using five tightly fitted bolts located at A, B, C, D and E. For $F_1 = F_2 = 16$ kN load find

(a) The resultant load on each bolt

(b) The maximum shear stress in each bolt

$N = \left(\frac{\sigma_{rev}/n}{a}\right)$ $a = \frac{(f S_{ut})^2}{S_e} = \frac{((0.81)(520))^2}{190.03} = 1127.1$ MPa

(d)



* Final Exam form ②:

Q_1): AISI 1030 CD steel

$S_{ut} = 520$ MPa

$F \rightarrow -1{,}000\,N \rightarrow 800\,N$

(a)

* Hole:

$\frac{d}{w} = \frac{6}{15} = 0.4$

$K_t = 2.08$ $q = 0.81$

$K_f = 1.87$

$\sigma_{min} = \frac{-1000}{(15-6)(4)(10)^{-6}} = -27.78$ MPa

$\sigma_{max} = \frac{800}{(15-6)(4)(10)^{-6}} = 22.22$ MPa

$\sigma_a = +25$ MPa

$\sigma_m = -2.78$ MPa

$\frac{(1.87)(25)}{190.03} + \frac{(1.87)(2.78)}{520} = \frac{1}{n_f}$

$n_f = 3.91$

* fillet:

$\frac{D}{d} = \frac{20}{15} = 1.33$

$\frac{r}{d} = \frac{1.5}{15} = 0.1$ $q = 0.76$

$K_t = 1.96$

$K_f = 1.73$

$\sigma_{min} = \frac{-1000}{(15)(4)(10)^{-6}} = -16.67$ MPa

$\sigma_{max} = \frac{800}{(15)(4)(10)^{-6}} = 13.33$ MPa

$\sigma_a = 15$ MPa

$\sigma_m = -1.67$ MPa

$S_e = \left(4.51(520)^{-0.265}\right)(1)(0.85)(0.5(520))$

$= 190.03$ MPa

$\frac{(1.73)(15)}{190.03} + \frac{(1.73)(1.67)}{520} = \frac{1}{n_f}$

$n_f = 7.04$

Midterm Exam: Machine design elements

Q1(14points) The shoulder shaft in the figure is made of AISI 1006 cold-drawn steel and is loaded by a bending moment $M = 2$ kN.m. , and a torque $T = 250$ N · m.

a) For the critical stress element, determine the principal stresses and the maximum shear stress

b) Compute the deterministic factors of safety, based upon the distortion energy theory, for critical stress element of the member shown in the figure

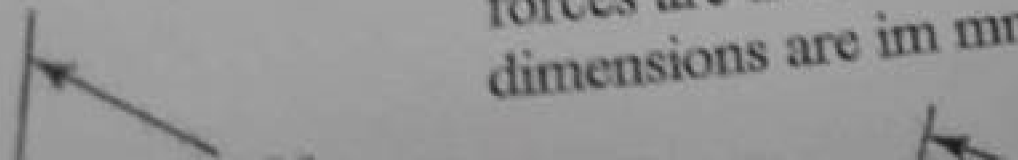
Q2(16points). The figure shows a shaft mounted in bearings at C and O and having pulleys at A and B. the bearings are to have a life of 90 kh at a combined reliability of 0.99. The countershaft runs at 1600 rev/min. The belt tension on the loose side of pulley A is 10 percent of the tension on the tight side.

a-Select deep-groove bearings for use at C and O using an application factor of 1.2.

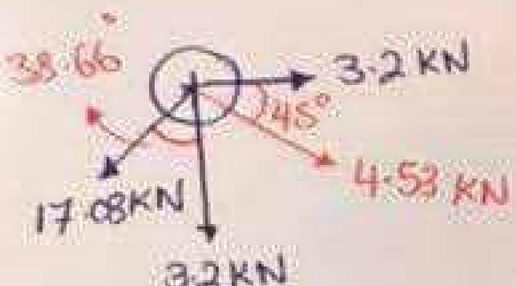
b-If a 100 N axial stress is applied at point C in the -x direction will the same bearings chosen in part a be suitable.

forces are in N

dimensions are im mm



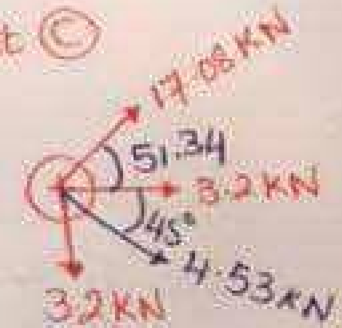
Bolt (A)



$\alpha = 83.66^\circ$

$\boxed{F_{R_A} = 18.15 \text{ KN}}$

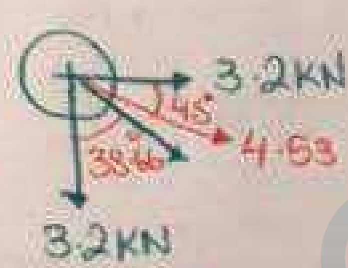
Bolt (C)



$\alpha = 96.34^\circ$

$\boxed{F_{R_C} = 17.18 \text{ KN}}$

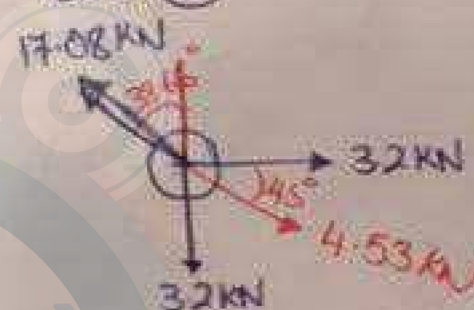
Bolt (B)



$\alpha = 6.34^\circ$

$\boxed{F_{R_B} = 21.59 \text{ KN}}$

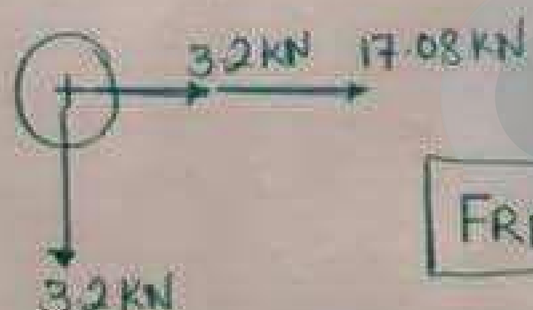
Bolt (D)



$\alpha = 173.66^\circ$

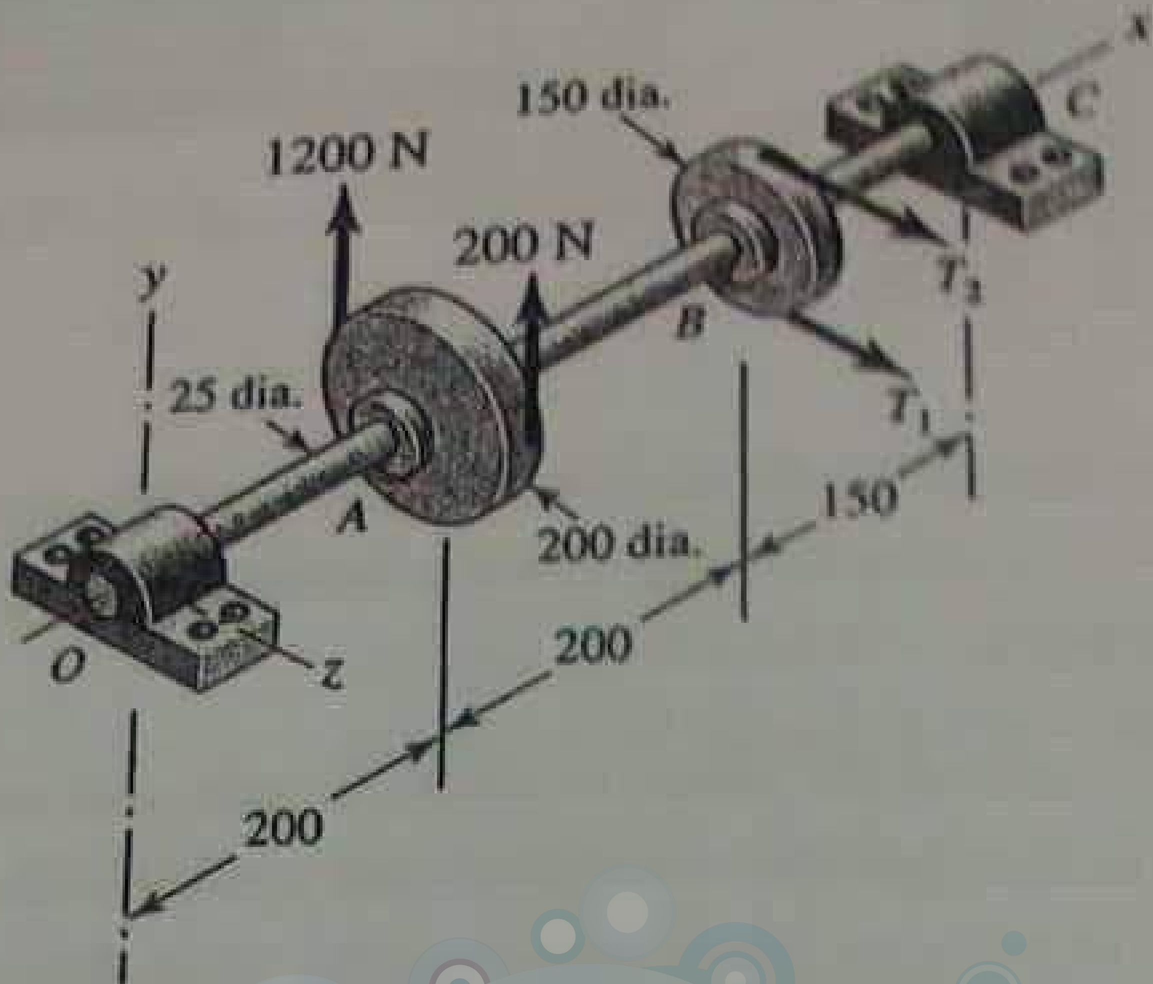
$\boxed{F_{R_D} = 12.59 \text{ KN}}$

Bolt (E)



$\boxed{F_{R_E} = 20.53 \text{ KN}}$

(b) $\tau_{max} = \dfrac{21.59(10)^3}{\frac{\pi}{4}(16)^2(10)^{-6}} = 107.38 \text{ MPa}$



Problem 3–70*

Dimensions in millimeters.

3–72* to 3–73*

$\Sigma T=0$

A gear reduction unit uses the countersha
another gear with the transmitted force F_A
is transmitted through the shaft and delive
the pressure angle shown.

(*a*) Determine the force F_B, assuming the

(*b*) Find the magnitudes of the bearing react

(*c*) Draw shear-force and bending-momen
horizontal plane and another set for th

(*d*) At the point of maximum bending m
shear stress.

(*e*) At the point of maximum bending mor
shear stress.

$$\tau_{max} = \frac{53.77}{\frac{\pi}{4}\left(\frac{5}{16}\right)^2} = 701.1 \text{ psi}$$
$$= 0.7011 \text{ kpsi}$$

$\frac{5}{16}$ in-18 UNC

$$\sigma_{axial} = \frac{50}{\left(4-2\times\frac{5}{16}\right)\left(\frac{1}{8}\right)} = 118.52 \text{ psi}$$
$$= 0.11852 \text{ kpsi}$$

$(w-2d)(t)$

Q1: (10P) AISI 1035 (HR) Steel

$F_{min} = 150$ lb

$F_{max} = 500$ lb

$d = \frac{7}{8}$

$P_{min} = 0$

$P_{max} = 100$ lb

Fixed

$K_t = 2$

$K_{ts} = 1.6$

$r = \frac{1}{8}$ in

$S_{ut} = 72$ kpsi

$S_y = 39.5$ kpsi

Axial

$\sigma_{min} = 0$

$$\sigma_{max} = \frac{100}{\frac{\pi}{4}\left(\frac{7}{8}\right)^2} = 166.3 \text{ psi}$$
$$= 0.1663 \text{ kpsi}$$

$\sigma_a = \sigma_m = 0.08315$ kpsi

$q = \cancel{}\ 0.81$

$K_f = 1.81$

Torsion

$T_{min} = (150)(2) = 300$ lb.in

$T_{max} = (500)(2) = 1000$ lb.in

$$\tau_{min} = \frac{(300)\left(\frac{7}{16}\right)}{\frac{\pi}{2}\left(\frac{7}{16}\right)^4} = 2.281 \text{ kpsi}$$

$\tau_{max} = 7.6$ kpsi

$\tau_m = 4.941$ kpsi

$\tau_a = 2.66$ kpsi

$q_s = \cancel{}\ 0.94$

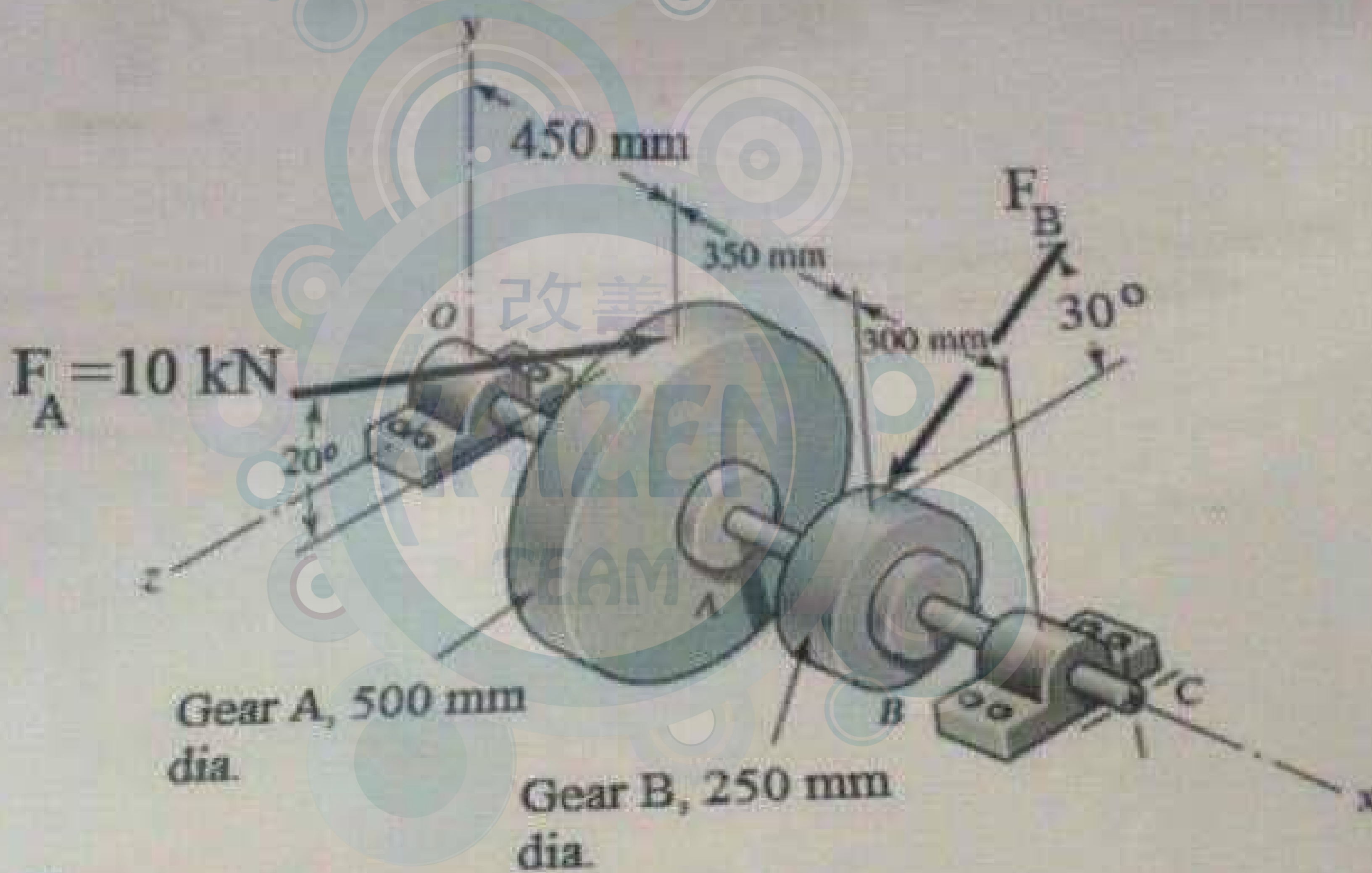
$K_{fs} = \cancel{}\ 1.56$

$$\sigma_a' = \left\{\left[\frac{(1.81)(0.08315)}{0.85}\right]^2 + 3\left[(1.56)(2.66)\right]^2\right\}^{1/2} = 7.19 \text{ kpsi}$$

$$\sigma_m' = \left\{\left[(1.81)(0.08315)\right]^2 + 3\left[(1.56)(4.941)\right]^2\right\}^{1/2} = 13.35 \text{ kpsi}$$

(20P)- The shaft shown in the figure is made of AISI 1018 cold-drawn steel and is driven by a moto
100 rpm. If the shaft is to be designed for an infinite life with a reliability of 99% and a safety factor of
The power is delivered to the shaft on gear A. Determine:

a-Select two bearings for O and C using an application factor of unity and a desired life for each bearing is 1 kh with a 99 percent reliability.
b-Draw shear-force and bending-moment diagrams for the shaft.
c- Using a factor of safety of 2.5 determine the minimum allowable diameter of the shaft based on a fatigue- failure analysis Modified Goodman. (Make any necessary assumptions).



ΣM=0

(b) <u>At the hole:</u>

$$N = \left(\frac{\sigma_{rev}/n}{a}\right)^{1/b} \qquad a = \frac{(f S_{ut})^2}{S_e} = \frac{((0.89)(520))^2}{190.03} = 1127.1 \text{ Mpa}$$

$$b = -\frac{1}{3}\log\left(\frac{0.89 \times 520}{190.03}\right) = -0.1289$$

$$\sigma_{rev} = \frac{\sigma_a}{1 - \frac{\sigma_m}{S_{ut}}} = \frac{25 \times 1.87}{1 - \left(\frac{2.78 \times 1.87}{520}\right)} = 47.22 \text{ Mpa}$$

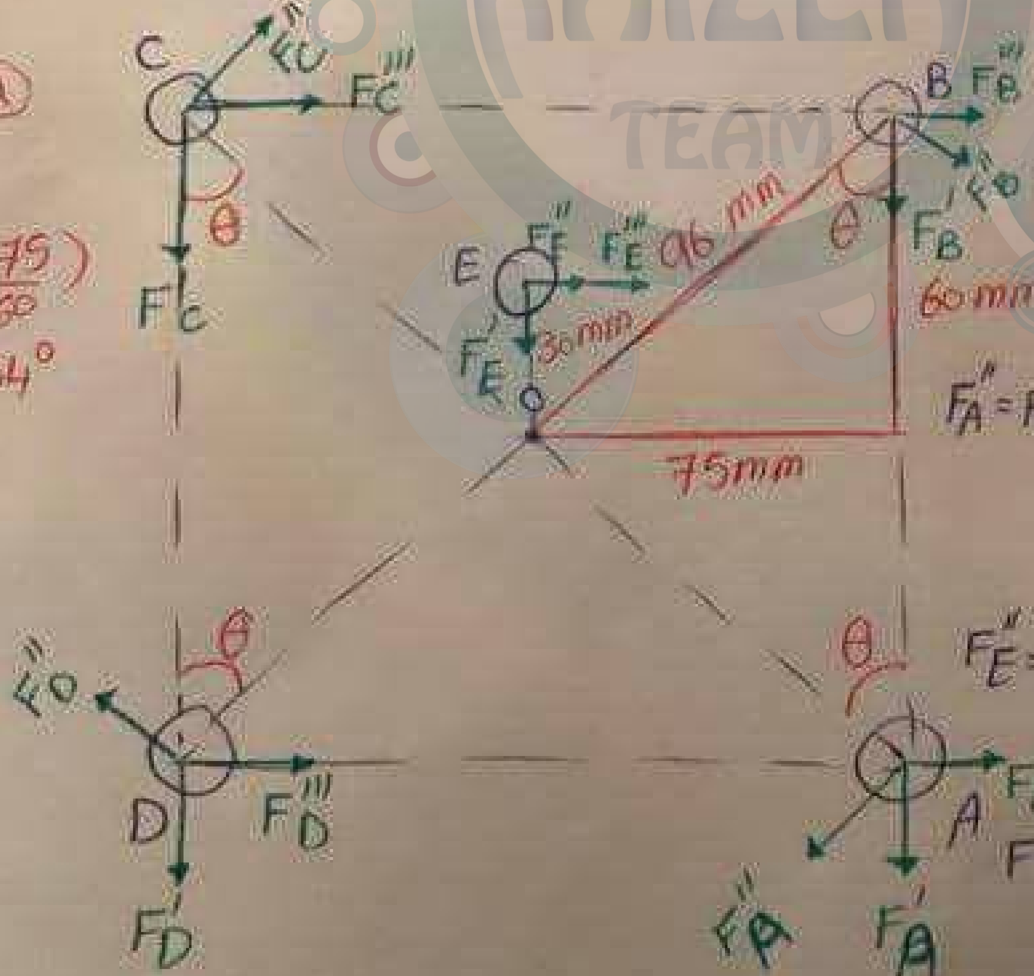
$S_y = 440$ Mpa

$$1.87(25 + 2.78) = \frac{440}{n}$$

$$n = 8.47$$

$$N = \left(\frac{47.22/8.47}{1127.1}\right)^{1/-0.1289} = 772.1(10)^{15} \text{ cycle's}$$

Q2): (a)



$\theta = \tan^{-1}\left(\frac{75}{60}\right) = 51.34°$

$F' = \frac{16}{5} = 3.2$ KN

$M_O = 16(420) = 6720$ N.m

$$F''_A = F''_B = F''_C = F''_D = \frac{(6720)(96)}{4(96)^2 + (30)^2} = 17.08 \text{ KN}$$

$$F''_E = \frac{(6720)(30)}{4(96)^2 + (30)^2} = 5.34 \text{ KN}$$

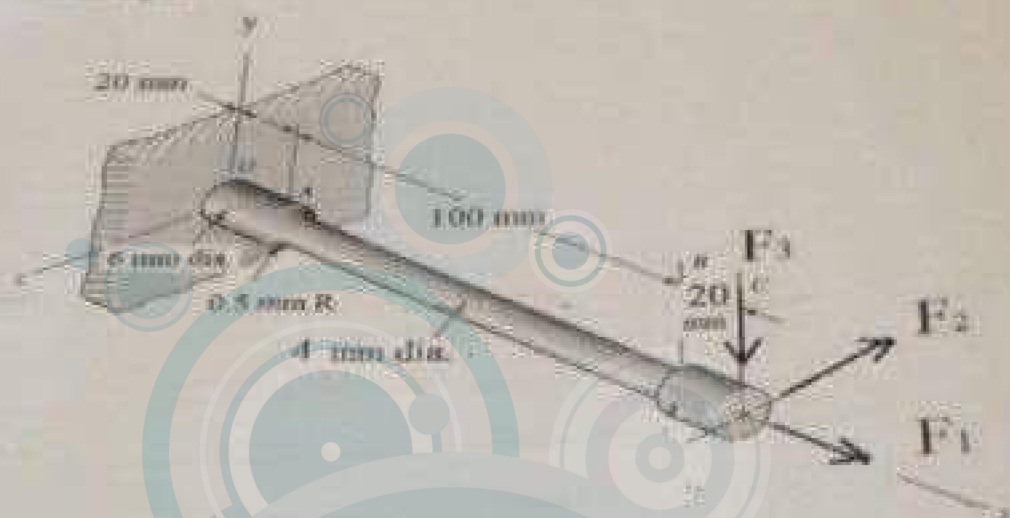
$F''' = \frac{16}{5} = 3.2$ KN

Midterm Exam: Machine design elements

Q1(11points) The bar in the figure is made of AISI 1006 cold-drawn steel and is loaded by the forces $F1 = 1$ kN, $F2 = 4$ kN, and $F3 = 10$ kN

a) For the critical stress element, determine the principal stresses and the maximum shear stress

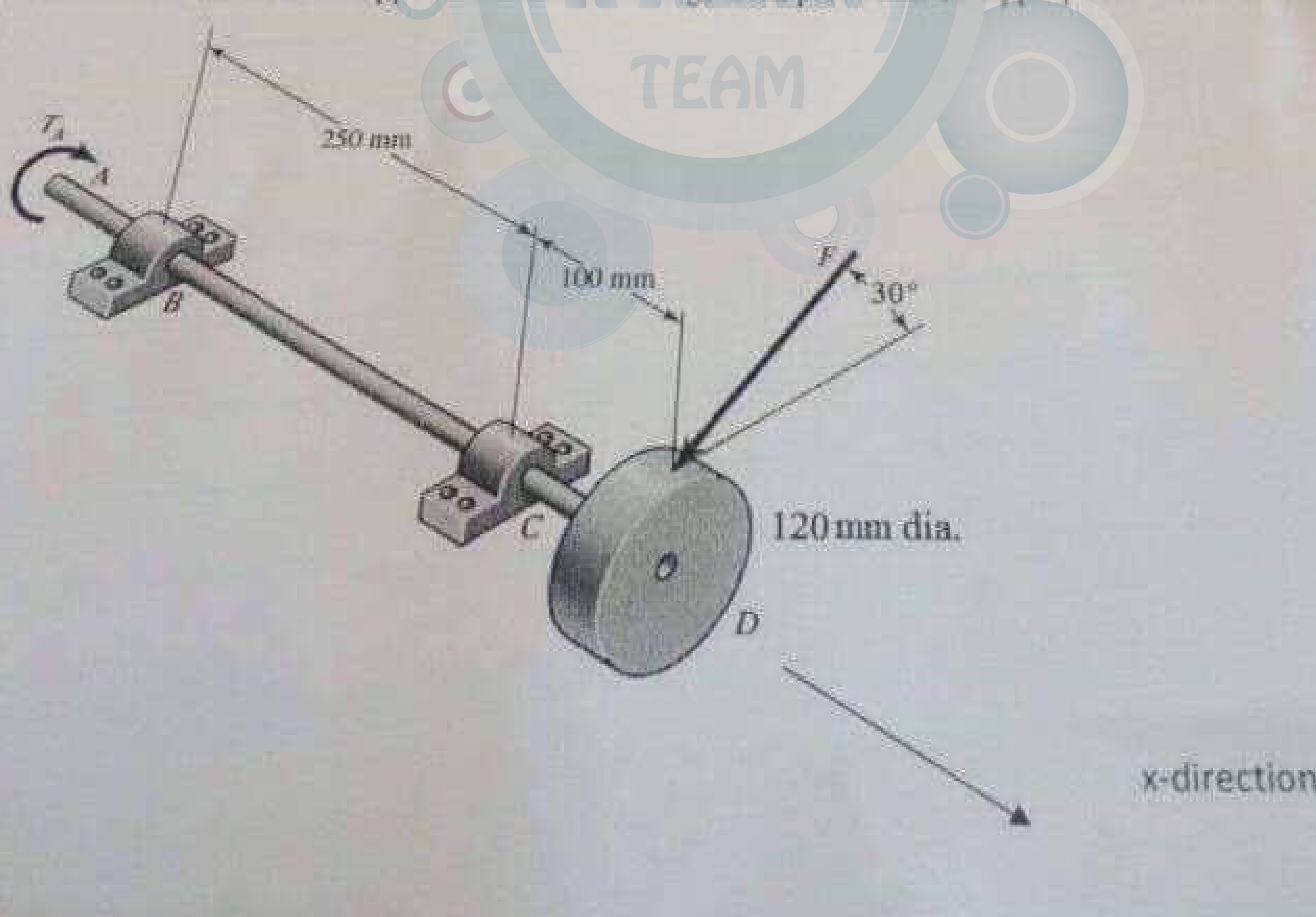
b) compute the factor of safety, based upon the distortion energy theory, for the critical stress element of the member shown in the figure



Q2(14points). *The figure shows a shaft simply supported by bearings at B and C and having a pulley at D. the bearings are to have a life of 5 kh at a combined reliability of 0.99. The shaft transmits a torque to point A of T_A = 180 N·m.*

a- Select deep-groove bearings for use at B and C, using an application factor of unity if the shaft rotates with a speed of 100 rev/min.

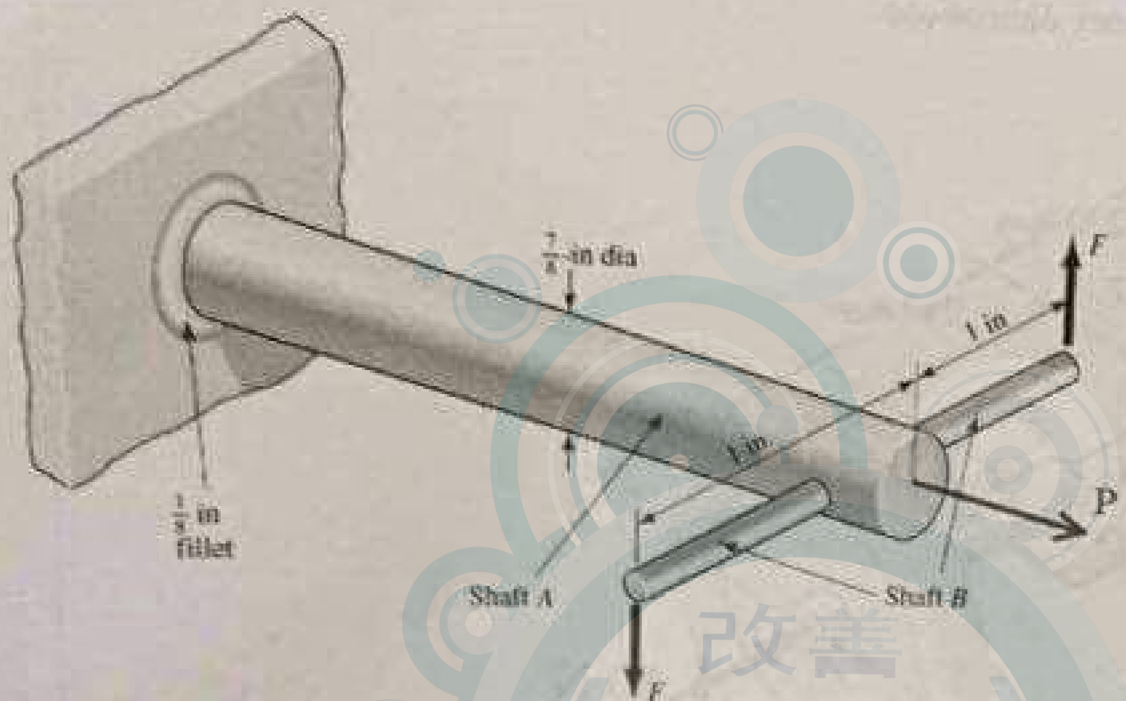
b-If a 70 N thrust load is applied would the bearings from part a still be appropriate and why



Final Examination

Machine design elements

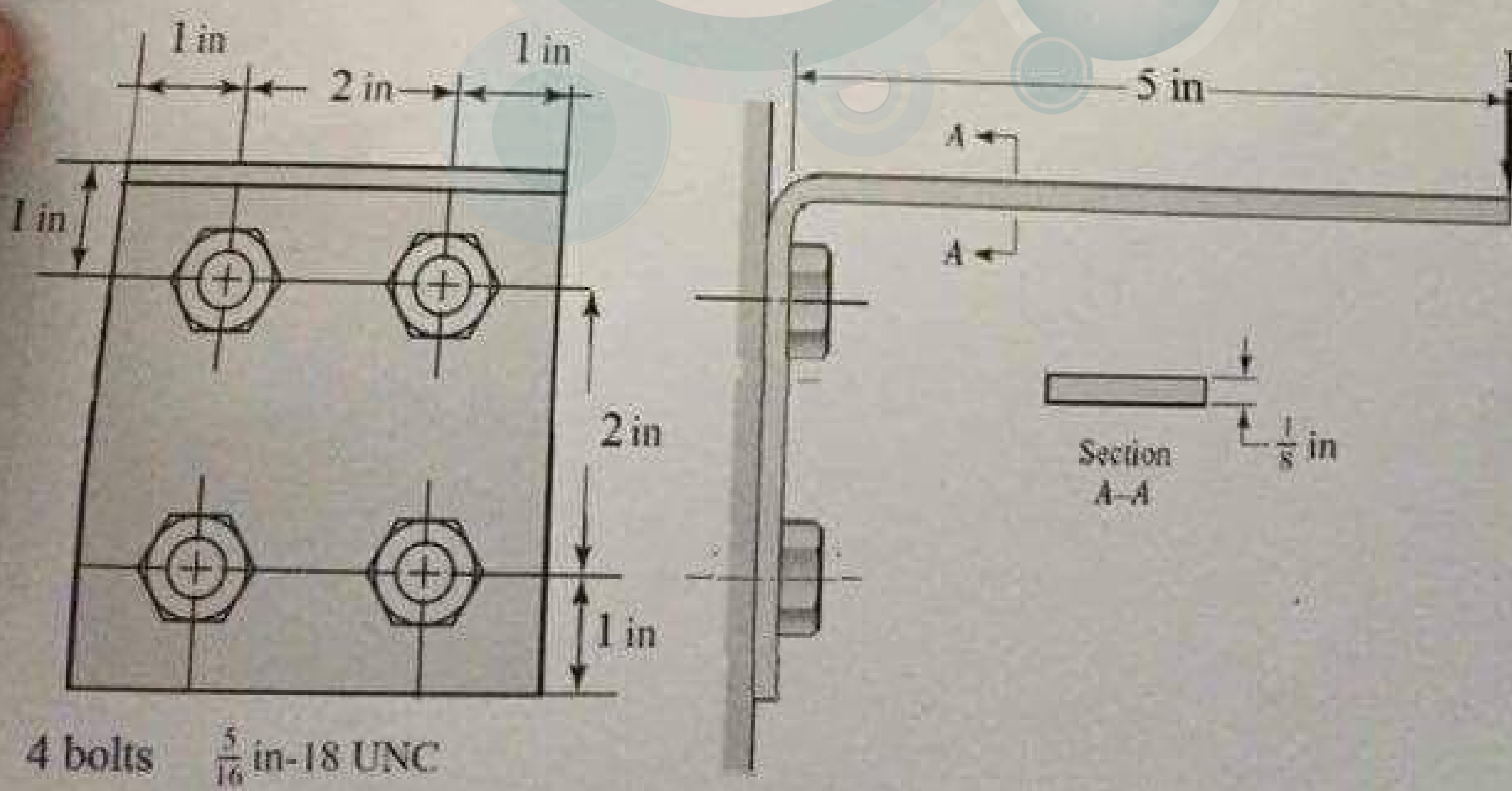
Q1(10P). In the figure shown, shaft A, made of AISI 1035 hot-rolled steel, is welded to a fixed support and is subjected to loading by equal and opposite forces F via shaft B. A theoretical stress-concentration factors Kt and K_{ts} of 2 and 1.6 respectively are induced by the 18-in fillet. The length of shaft A from the fixed support to the connection at shaft B is 2 ft. The load F cycles from 150 to 500 lbf and the load P cycles from 0 to 100 lbf. For shaft A, find the factor of safety for infinite life using the modified Goodman fatigue failure criterion.



Q2(20P). Shown in the figure is a 5 by 4-in latching spring that supports a load of $F = 50$ lbf. The inside radius of the bend is 1/8in.

(*a*) using curved-beam theory, determine the stresses at the inner and outer surfaces at the bend.

(*b*) determine the shear stress and the tensile stress in the bolts



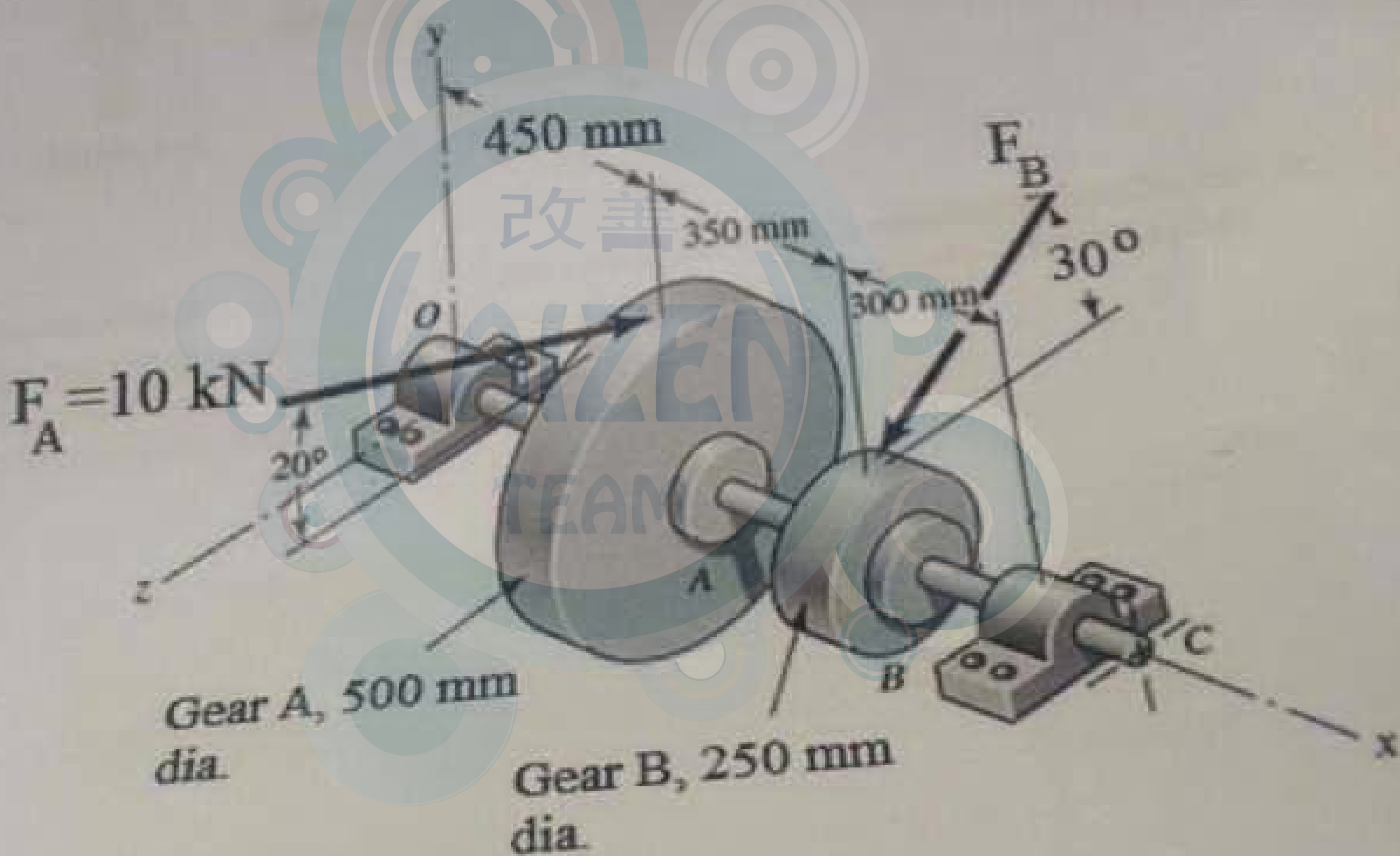
أحمد العزة
...7564

3(20P)- The shaft shown in the figure is made of AISI 1018 cold-drawn steel and is driven by a motor at 100 rpm. If the shaft is to be designed for an infinite life with a reliability of 99% and a safety factor of 2. The power is delivered to the shaft on gear A. Determine:

a-Select two bearings for O and C using an application factor of unity and a desired life for each bearing is 1 kh with a 99 percent reliability.

b-Draw shear-force and bending-moment diagrams for the shaft.

c- Using a factor of safety of 2.5 determine the minimum allowable diameter of the shaft based on a fatigue- failure analysis Modified Goodman. (Make any necessary assumptions).

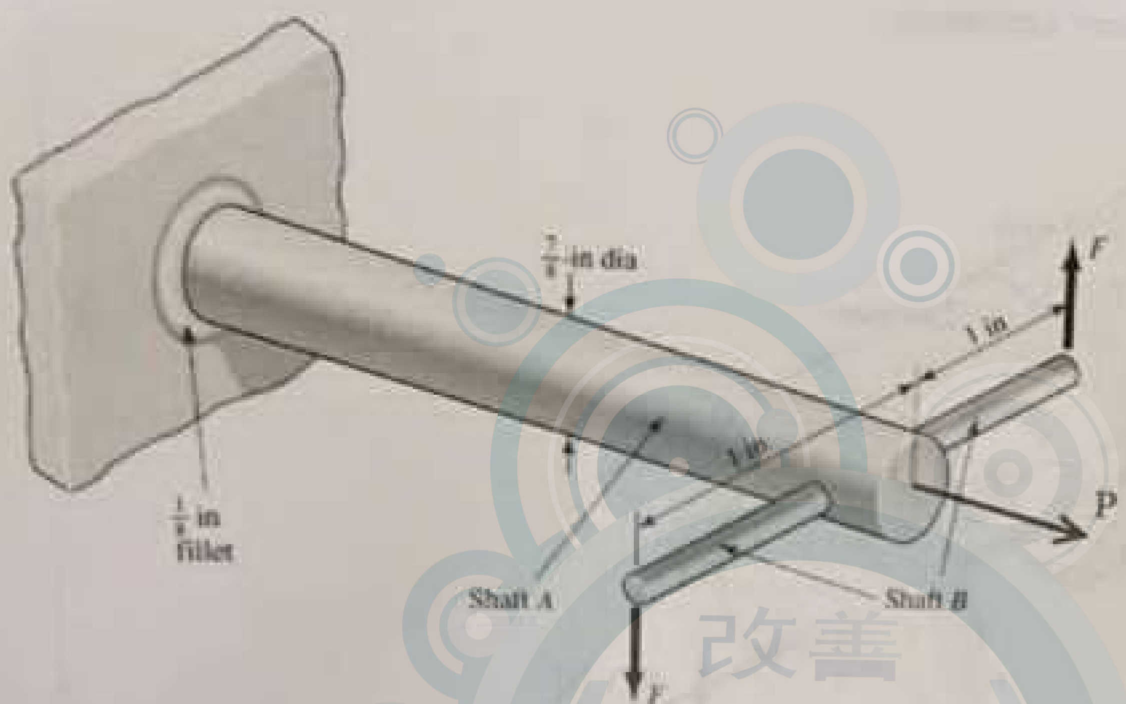


ΣM=0

Final Examination

Machine design elements

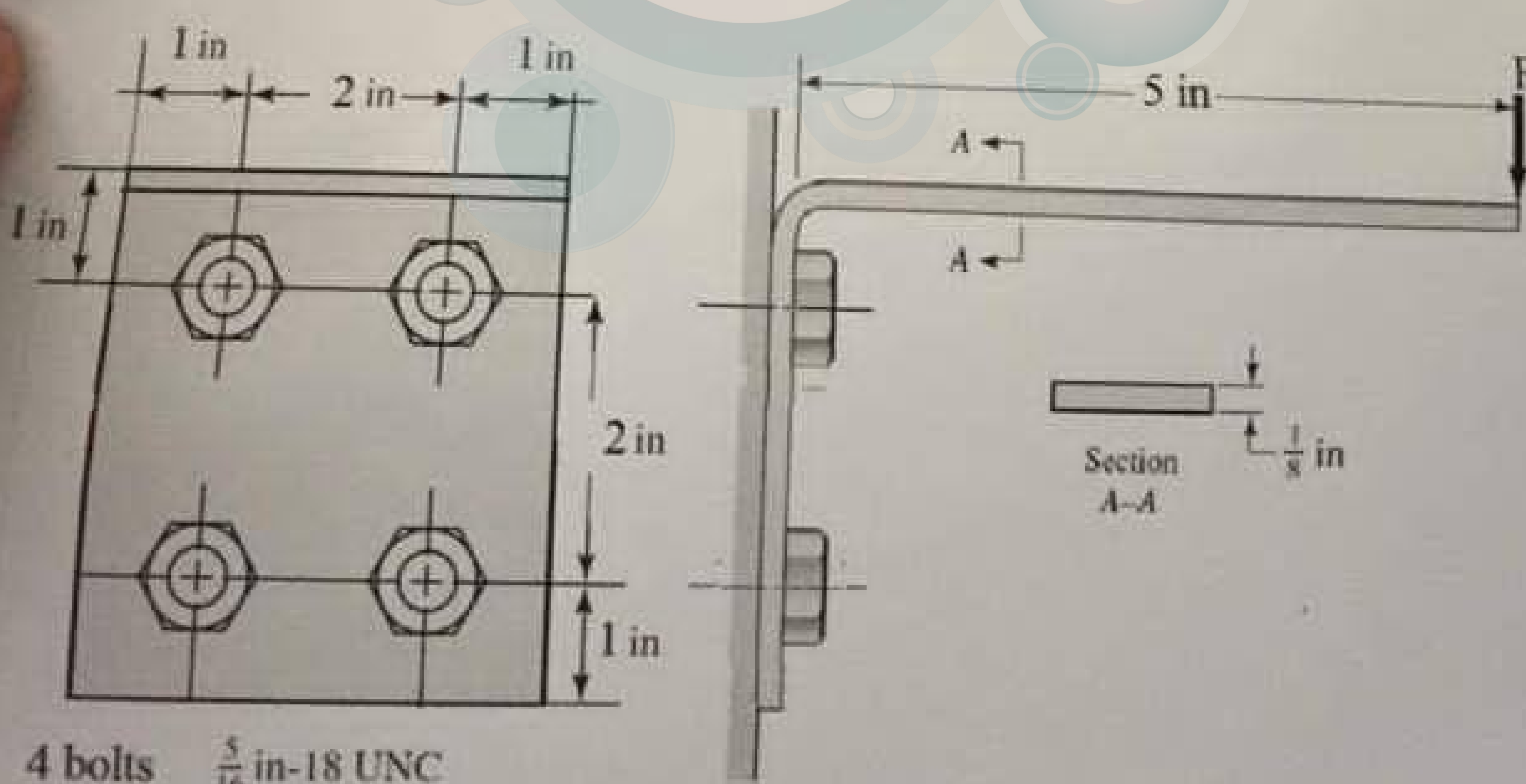
Q1(10P). In the figure shown, shaft *A*, made of AISI 1035 hot-rolled steel, is welded to a fixed support and is subjected to loading by equal and opposite forces *F* via shaft *B*. A theoretical stress-concentration factors Kt and *Kts* of 2 and 1.6 respectively are induced by the 18-in fillet. The length of shaft *A* from the fixed support to the connection at shaft *B* is 2 ft. The load *F* cycles from 150 to 500 lbf and the load P cycles from 0 to 100 lbf. For shaft A, find the factor of safety for infinite life using the modified Goodman fatigue failure criterion.



Q2(20P). Shown in the figure is a 5 by 4-in latching spring that supports a load of $F = 50$ lbf. The inside radius of the bend is 1/8in.

(*a*) using curved-beam theory, determine the stresses at the inner and outer surfaces at the bend.

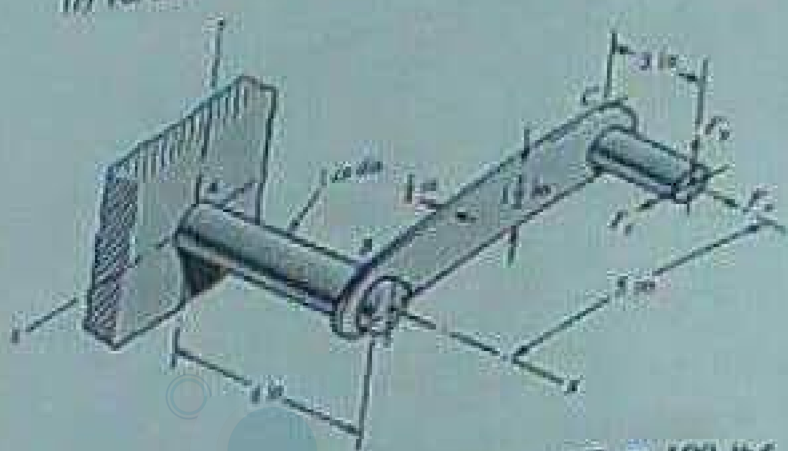
(*b*) determine the shear stress and the tensile stress in the bolts



(a) Determine the precise location of the critical stress element.

(b) Sketch the critical stress element and determine magnitudes and directions for all stresses acting on it. (Transverse shear may only be neglected if you can justify this decision.)

(c) For the critical stress element, determine the principal stresses and the maximum shear stress.



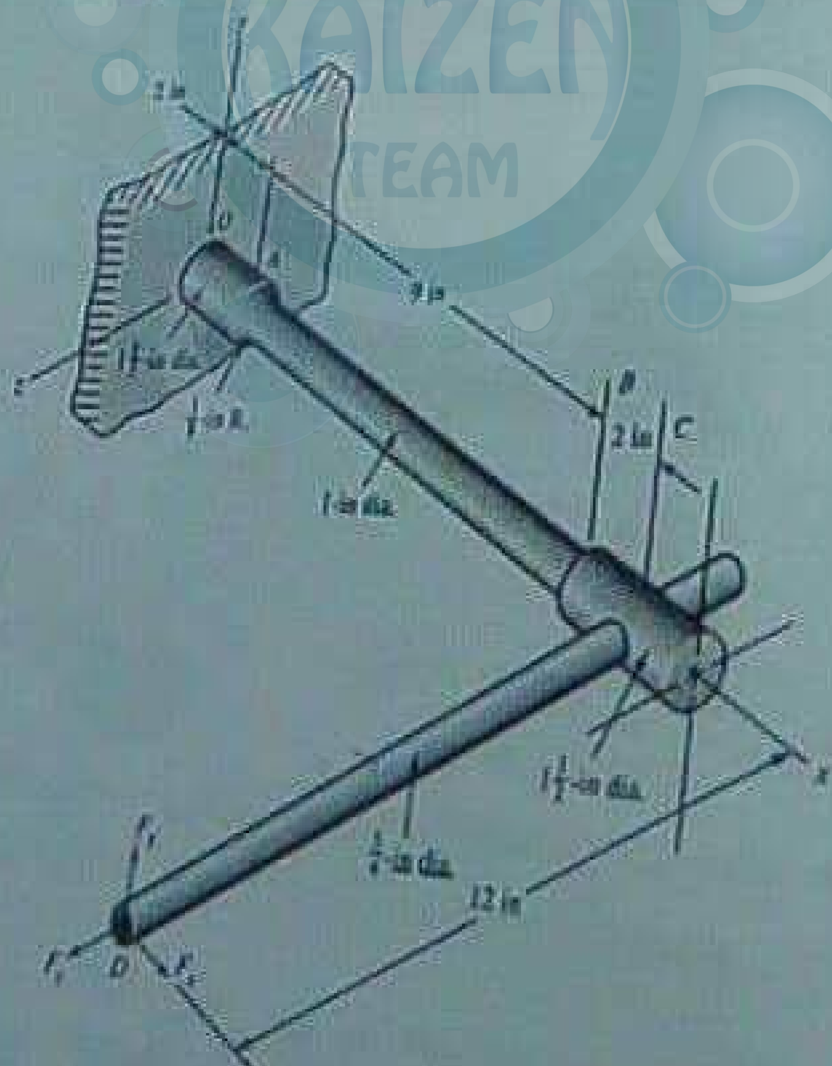
Problem 3-80*

3-81* Repeat Prob. 3-80 with $F_x = 0$, $F_y = 175$ lbf, and $F_z = 100$ lbf.

3-82* Repeat Prob. 3-80 with $F_x = 75$ lbf, $F_y = -200$ lbf, and $F_z = 100$ lbf.

3-83* For the handle in Prob. 3-80, one potential failure mode is twisting of the flat plate. Determine the maximum value of the shear stress due to torsion in the main section of the plate, ignoring the complexities of the interfaces at B and C.

3-84* The cantilevered bar in the figure is made from a ductile material and is statically loaded with $F_y = 250$ lbf and $F_x = F_z = 0$. Analyze the stress situation in the small diameter at the shoulder at A by obtaining the following information.



Problem 3-84*

* [illegible]

(3) (ep) AISI 1035 (HR) Steel

$S_{ut} = 72$ kpsi

$S_y = 39.5$ kpsi

$K_t = 2$ $\quad K_{ts} = 1.6$

$F_{min} = 150$ lb $\quad P_{min} = 0$

$F_{max} = 500$ lb $\quad P_{max} = 100$ lb

Torsion

$T_{min} = (150)(2) = 300$ lb·in

$T_{max} = (500)(2) = 1000$ lb·in

$\tau_{min} = \dfrac{(300)(\frac{7}{16})}{\frac{\pi}{2}(\frac{7}{16})^4} = 2.281$ kpsi

$\tau_{max} = \dfrac{(1000)(\frac{7}{16})}{\frac{\pi}{2}(\frac{7}{16})^4} = 7.6$ kpsi

$\tau_a = 2.66$ kpsi

$\tau_m = 4.94$ kpsi

$q_s = 0.82$

$K_{fs} = 1.5$

Axial

$\sigma_{min} = 0$

$\sigma_{max} = \dfrac{100}{\frac{\pi}{4}(\frac{7}{8})^2} = 0.1663$ kpsi

$\sigma_a = 0.08315$ kpsi

$\sigma_m = 0.08315$ kpsi

$q = 0.76$

$K_f = 1 + q(K_t - 1) = 1.76$

$\sigma_a' = \left\{\left[\dfrac{(1.76)(0.08315)}{0.85}\right]^2 + 3\left[(1.5)(2.66)\right]^2\right\}^{1/2}$

$= 6.91$ kpsi

$\sigma_m' = \left\{\left[(1.76)(0.08315)\right]^2 + 3\left[(1.5)(4.94)\right]^2\right\}^{1/2}$

$= 12.84$ kpsi

$K_c = 0.59$

$K_d = K_e = K_f = 1$

$S_e' = 0.5(72) = 36$ kpsi

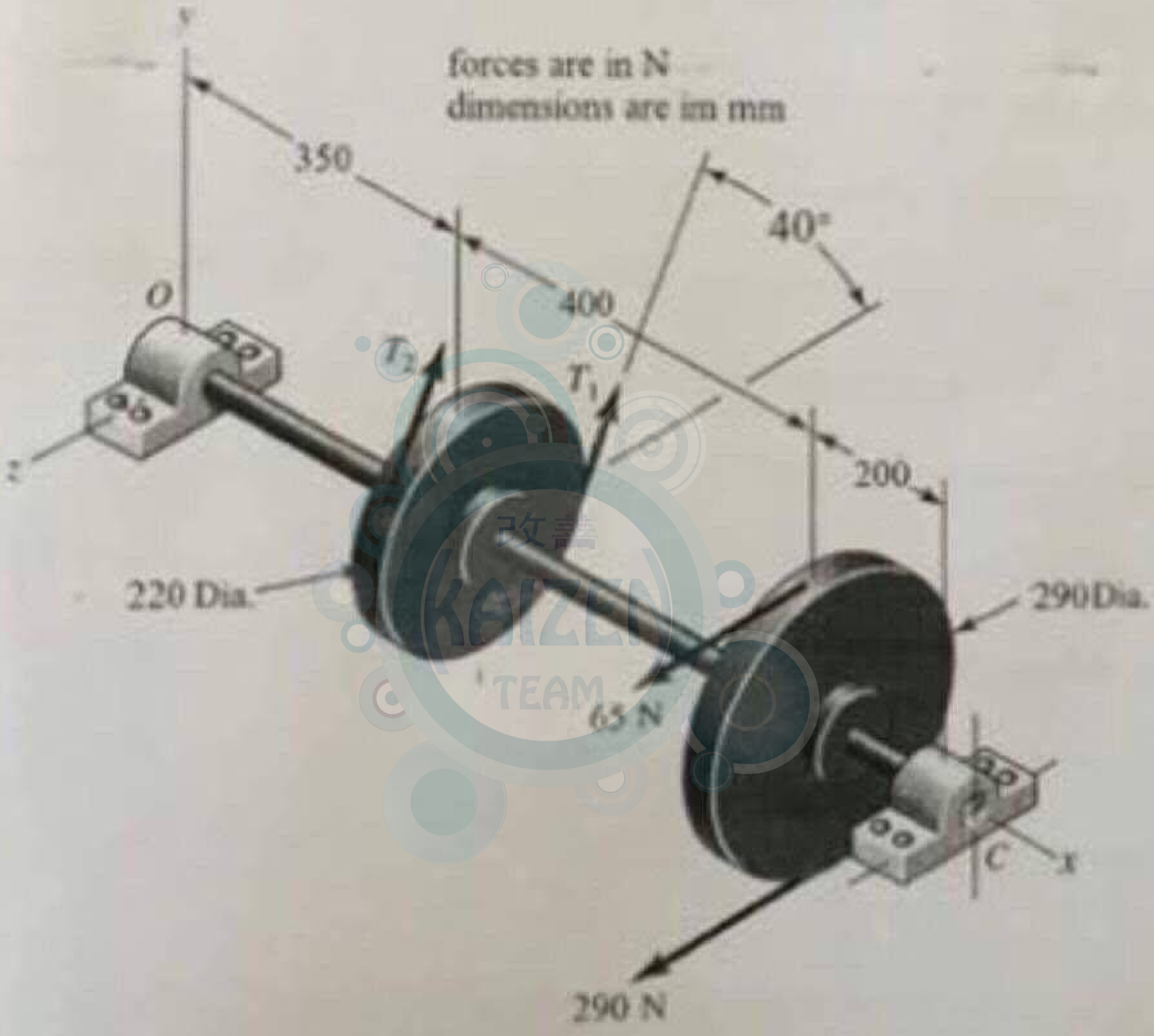
$K_b = 0.879(0.32375)^{-0.107} = 0.992$

$d_e = 0.37(\frac{7}{8}) = 0.32375$

$K_a = a\,S_{ut}^{\,b} = 14.4(72)^{-0.265\ 0.718} = 0.668$

$S_e = 14.08$ kpsi

①



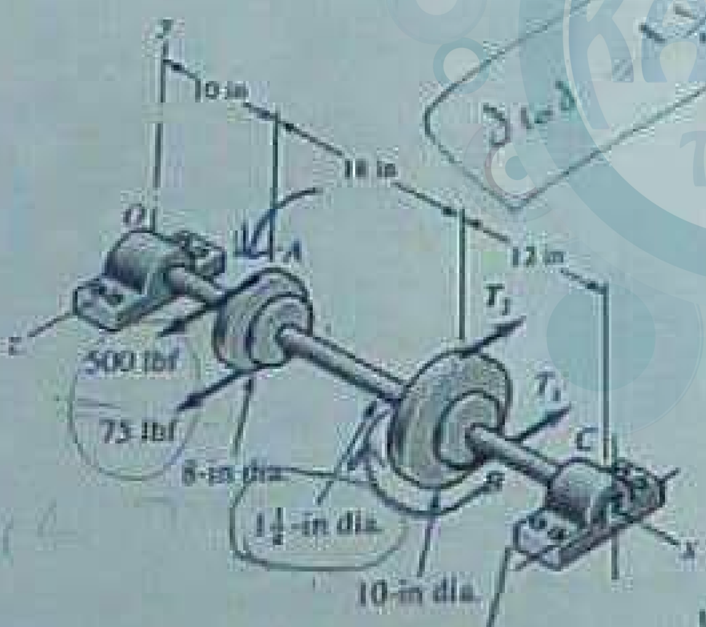
y
forces are in N
dimensions are im mm
350
40°
O
400
T_2
T_1
z
200
220 Dia.
290 Dia.
65 N
C
x
290 N

Problem 3-65

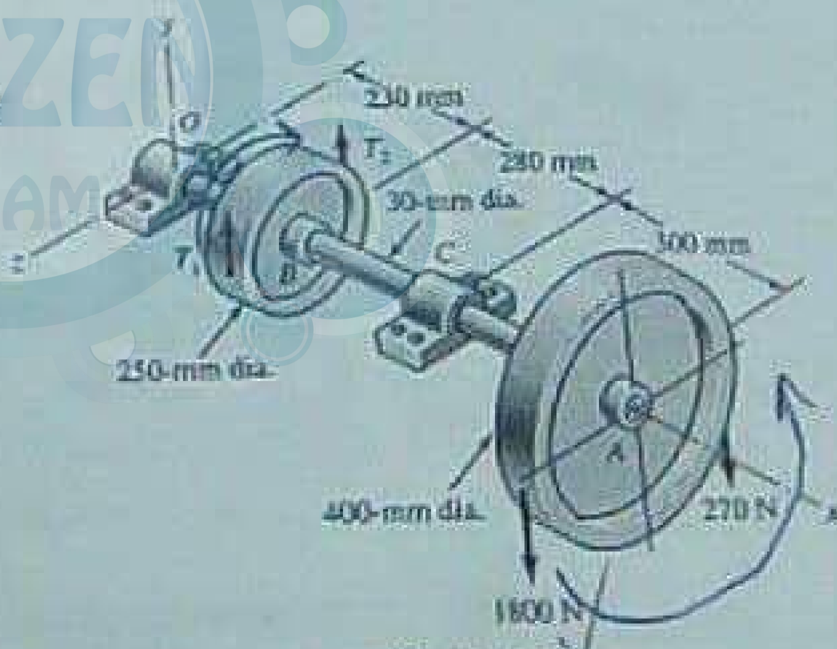
3-66 The conveyor drive roll in the figure for Prob. 3-65 is 5 in in diameter and is driven at 8 rev/min by a geared-motor source rated at 1 hp. Find a suitable shaft diameter d_C from the preferred decimal sizes in Table A-17, based on an allowable torsional stress of 15 kpsi.

3-67 Consider two shafts in torsion, each of the same material, length, and cross-sectional area. One shaft has a solid square cross section and the other shaft has a solid circular section.
(*a*) Which shaft has the greater maximum shear stress and by what percentage?
(*b*) Which shaft has the greater angular twist θ and by what percentage?

3-68* to 3-71* ✓ A countershaft carrying two V-belt pulleys is shown in the figure. Pulley *A* receives power from a motor through a belt with the belt tensions shown. The power is transmitted through the shaft and delivered to the belt on pulley *B*. Assume the belt tension on the loose side at *B* is 15 percent of the tension on the tight side.
✓ (*a*) Determine the tensions in the belt on pulley *B*, assuming the shaft is running at a constant speed.
✓ (*b*) Find the magnitudes of the bearing reaction forces, assuming the bearings act as simple supports.
✓ (*c*) Draw shear-force and bending-moment diagrams for the shaft. If needed, make one set for the horizontal plane and another set for the vertical plane.
✓ (*d*) At the point of maximum bending moment, determine the bending stress and the torsional shear stress.
✓ (*e*) At the point of maximum bending moment, determine the principal stresses and the maximum shear stress.



Problem 3-68*



Problem 3-69*

$T_1 = 0.15 T_2$

$0.15\ T_2$

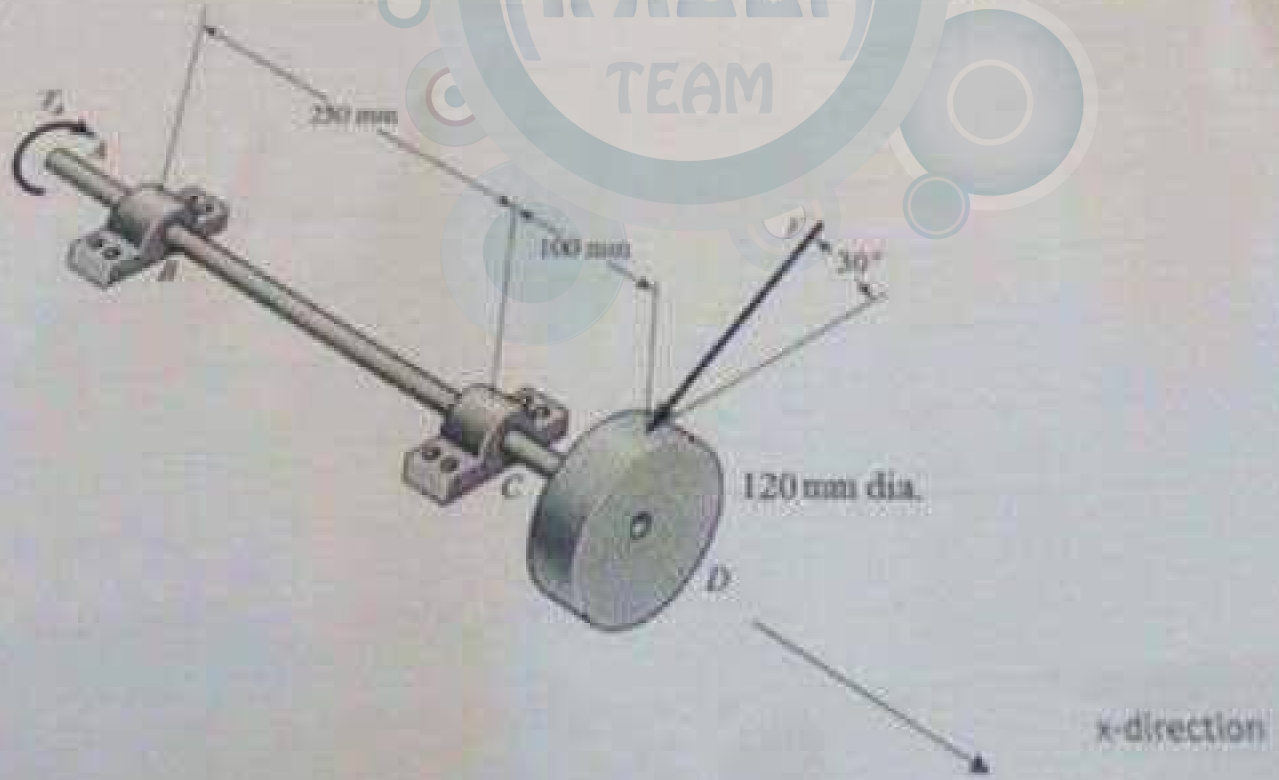
one Pulley

[illegible]

Q2(14points). *The figure shows a shaft simply supported by bearings at B and C and having a pulley at D. the bearings are to have a life of 5 kh at a combined reliability of 0.99. The shaft transmits a torque to point A of T_A = 180 N·m.*

a- Select deep-groove bearings for use at B and C, using an application factor of unity if the shaft rotates with a speed of 100 rev/min.

b-If a 70 N thrust load is applied would the bearings from part a still be appropriate and why



*Ex. 6-4: Bending

$S_{ut} = 690$ MPa

ⓐ $k_b = 1.24(32)^{-0.107} = 0.856$

ⓑ $d_e = 0.37(32) = 11.84$ mm

$k_b = 1.24(11.84)^{-0.107} = 0.952$

$k_c = \begin{cases} 1 & \text{bending} \\ 0.85 & \text{Axial} \\ 0.59 & \text{Torsion} \end{cases}$ bending → $k_c = 1$; → 0.59] 0.59] 0.59

* Stress concentration factors for fatigues

Bending / Axial: $K_f = 1 + q(K_t - 1)$ Figure 6-20

Torsion: $K_{fs} = 1 + q_s(K_{ts} - 1)$ Figure 6-21

$\sigma_{max} = K_f \sigma_o$

$\tau_{max} = K_{fs} \tau_o$

Notch sensitivity

*Ex. 6-6: Bending

$S_{ut} = 690$ MPa

$r = 3$ mm
$d = 32$ mm
$D = 38$ mm

ⓐ $K_f = 1 + q(K_t - 1)$

$q = 0.84$

$\frac{r}{d} = 0.1$

$\frac{D}{d} = 1.2$

$K_t = 1.68$

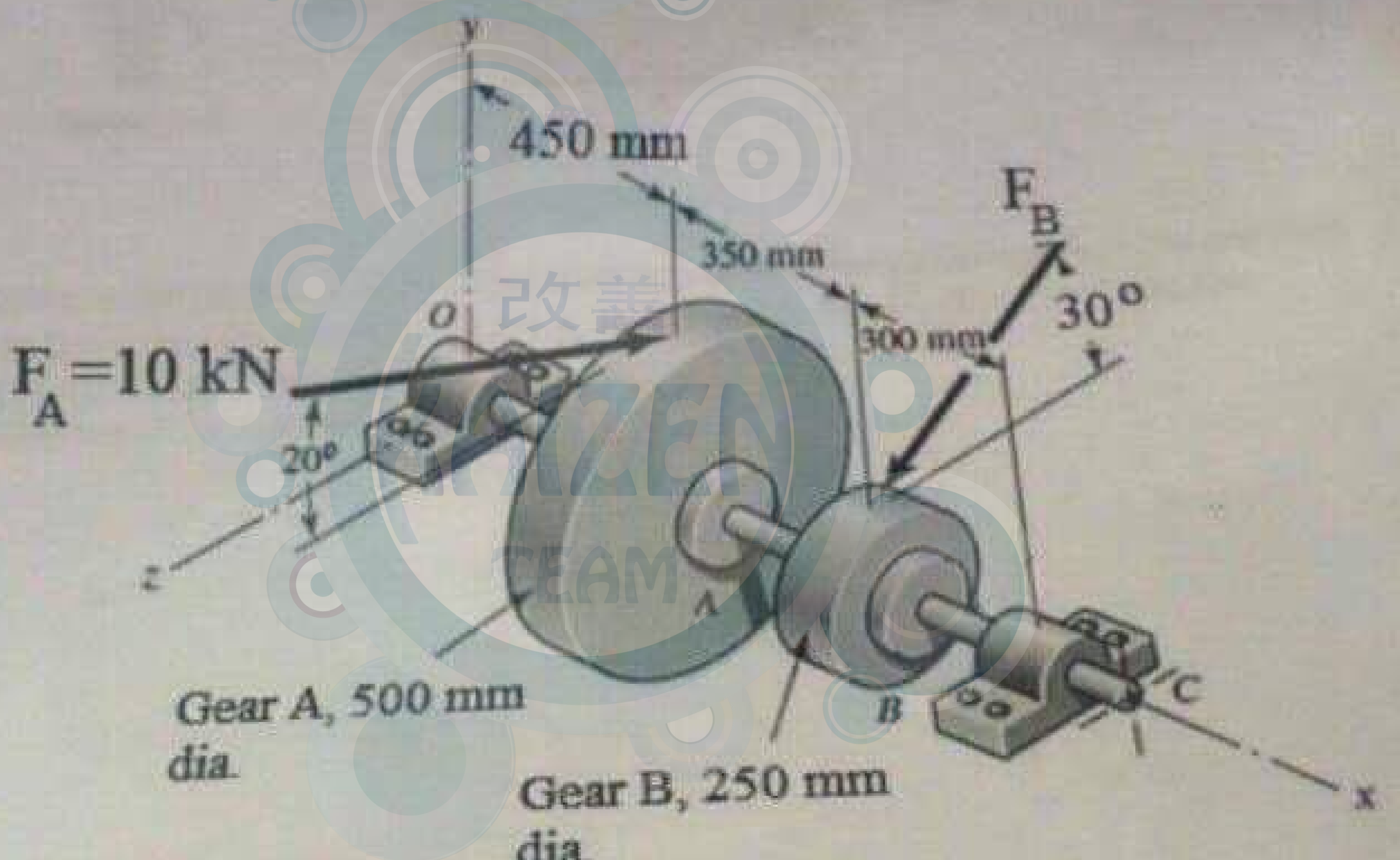
⇒ $K_f = 1.57$

5(20P)- The shaft shown in the figure is made of AISI 1018 cold-drawn steel and is driven by a moto 100 rpm. If the shaft is to be designed for an infinite life with a reliability of 99% and a safety factor of The power is delivered to the shaft on gear A. Determine:

a-Select two bearings for O and C using an application factor of unity and a desired life for each bearing is 1 kh with a 99 percent reliability.

b-Draw shear-force and bending-moment diagrams for the shaft.

c- Using a factor of safety of 2.5 determine the minimum allowable diameter of the shaft based on a fatigue- failure analysis Modified Goodman. (Make any necessary assumptions).



$\Sigma M = 0$

* Final Exam form ①:

Q1): AISI 1035 (HR) steel $r = \frac{1}{8}$ in

$K_t = 2$ $K_{ts} = 1.6$

F 150 lb → 500 lb

P 0 → 100 lb

$T_{min} = 150(1) + 150(1) = 300$ lb.in

$T_{max} = 500(1) + 500(1) = 1000$ lb.in

$\tau_{min} = \dfrac{(300)(\frac{7}{16})}{\frac{\pi}{2}(\frac{7}{16})^4} = 2.28$ KPSi

$\tau_{max} = \dfrac{(1000)(\frac{7}{16})}{\frac{\pi}{2}(\frac{7}{16})^4} = 7.6$ KPSi

$\tau_a = \dfrac{7.6 - 2.28}{2} = 2.66$ KPSi

$\tau_m = \dfrac{7.6 + 2.28}{2} = 4.94$ KPSi

$\sigma_{min} = 0$

$\sigma_{max} = \dfrac{100}{\frac{\pi}{4}(\frac{7}{8})^2} = 0.1663$ KPSi

$\sigma_a = \sigma_m = \dfrac{0.1663}{2} = 0.08315$ KPSi

$S_{ut} = 72$ KPSi

$q = 0.78$

$q_s = 0.83$

$K_f = 1 + 0.78(2-1) = 1.78$

$K_{fs} = 1 + 0.83(1.6-1) = 1.50$

$\sigma_a' = \left\{ \left[\dfrac{1.78 \times 0.08315}{0.85}\right]^2 + 3\left[1.5 \times 2.66\right]^2 \right\}^{1/2} = 6.913$ KPSi

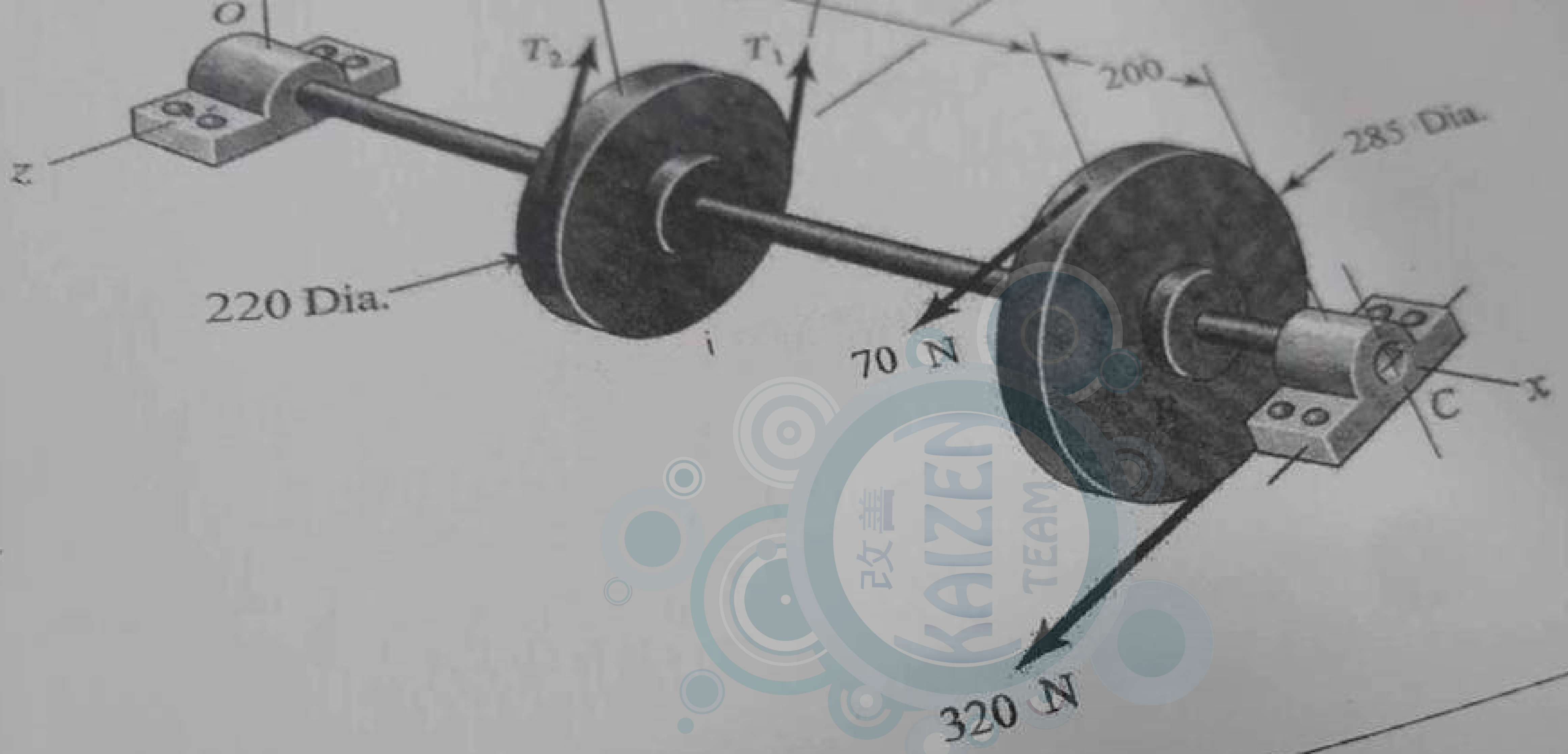
$\sigma_m' = \left\{ \left[1.78 \times 0.08315\right]^2 + 3\left[1.5 \times 4.94\right]^2 \right\}^{1/2} = 12.84$ KPSi

$S_e = \left(14.4(72)^{-0.718}\right)\left(0.879(0.32375)^{-0.107}\right)(0.59)(1)(1)(1)(0.5(72))$

$S_e = 14.07$ KPSi

$d_e = 0.37\left(\frac{7}{8}\right) = 0.32375$ in

①



O
z
T_2
T_1
200
285 Dia.
220 Dia.
70 N
C
x
320 N

P3): AISI 1018 CD steel

(b) $\Sigma T = 0;\ F_B \cos(30^\circ)(0.125) - 10(10^3)\cos(20^\circ)(0.25) = 0$

$F_B = 21.7\ KN$

$\Sigma M_O^y = 0;\ 10\cos(20^\circ)(450) - 21.7\cos(30^\circ)(800) - R_C^z(1100) = 0$

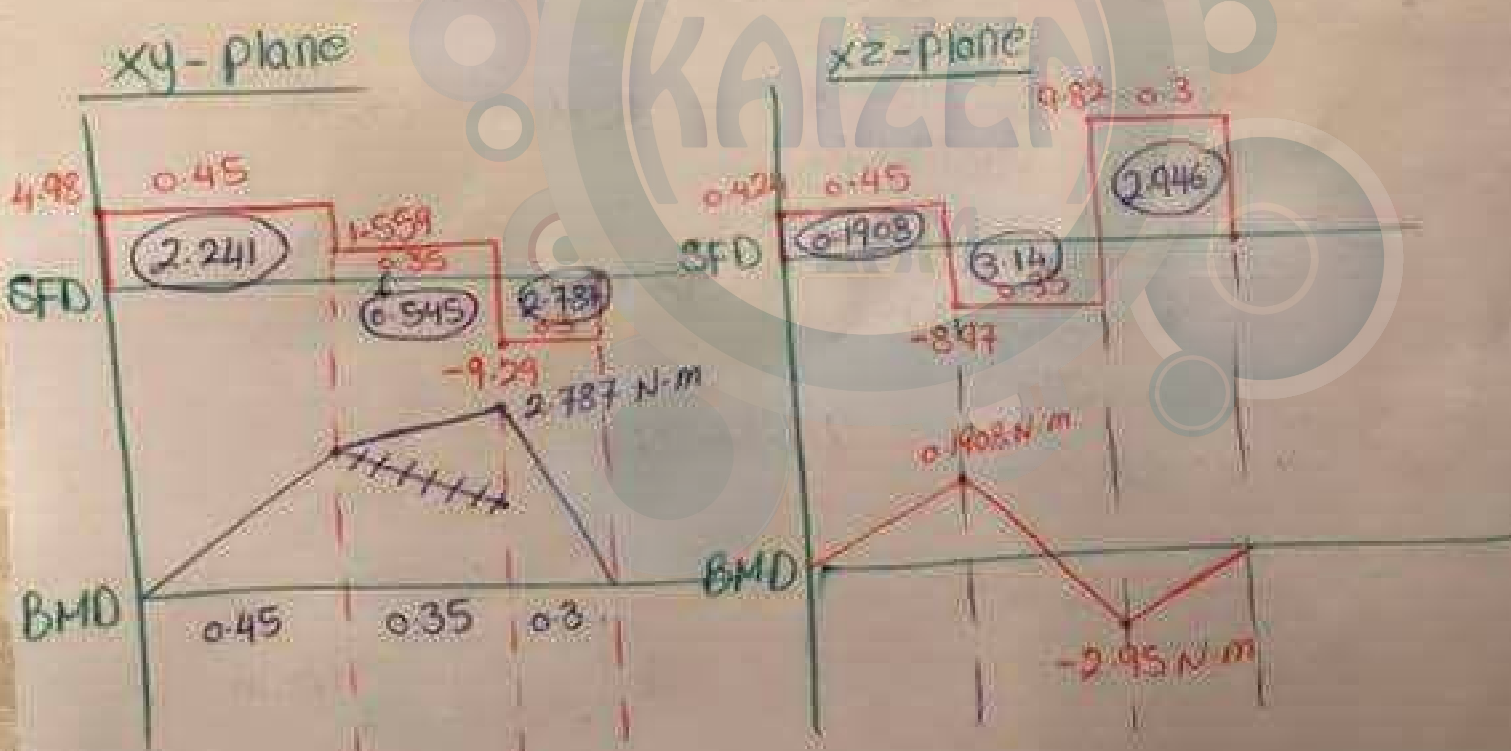
$R_C^z = -9.82\ KN$

$\Sigma M_O^z = 0;\ -10\sin(20^\circ)(450) - 21.7\sin(30^\circ)(800) + R_C^y(1100) = 0$

$R_C^y = 9.29\ KN$

$\Sigma F^y = 0;\ R_O^y - 10\sin(20^\circ) - 21.7\sin(30^\circ) + 9.29 = 0$ $\quad R_O^y = 4.98\ KN$

$\Sigma F^z = 0;\ R_O^z + 21.7\cos(30^\circ) - 10\cos(20^\circ) - 9.82 = 0$ $\quad R_O^z = 0.424\ KN$



$$M_{max} = \sqrt{(2.95)^2 + (2.787)^2} = 4.06\ N\cdot m$$

$M_a = 4.06\ KN\cdot m$ $\qquad M_m = 0$

$T_a = 0$ $\qquad T_m = 2.35\ KN\cdot m$

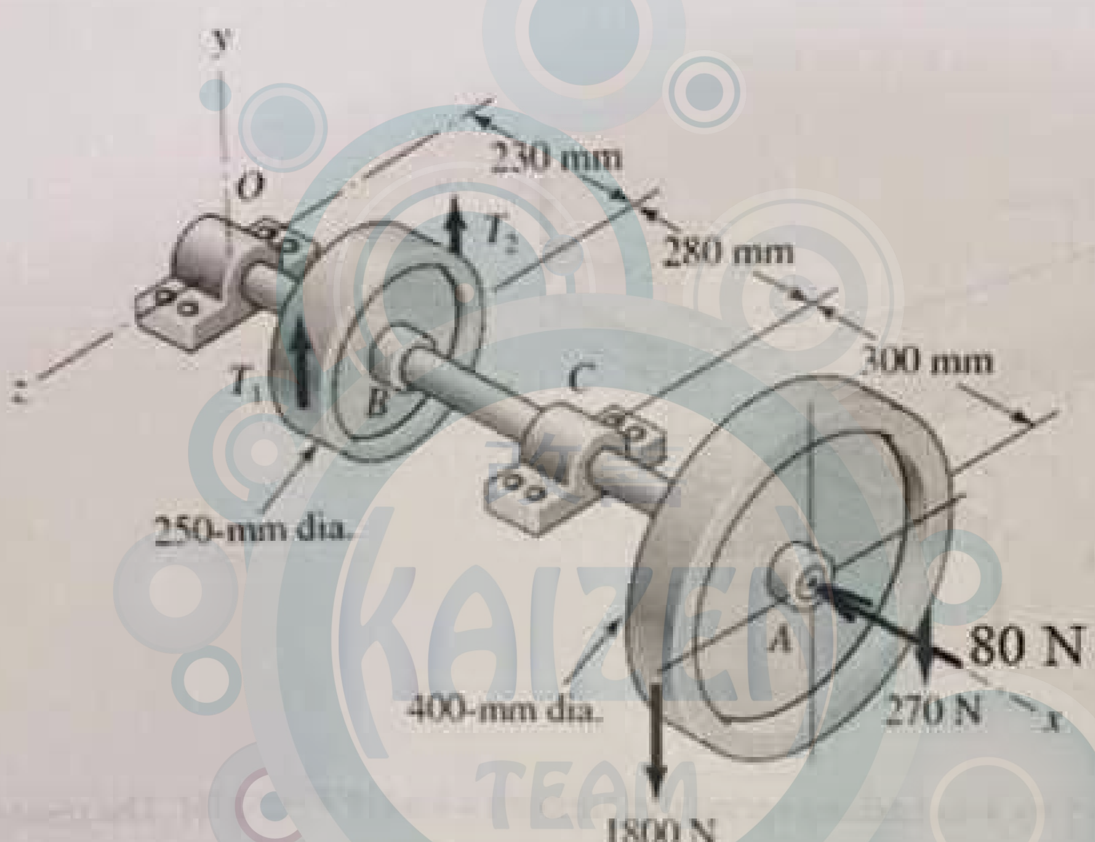
Q3(20P)- A belt-driven jack-shaft is shown in the figure below. The weight of each pulley is 900 N. The shaft is made of AISI 1050 CD (hardened steel) and is driven by a motor at 1200 rpm. All important surfaces have a ground finish. If the shaft is to be designed for an infinite life with a reliability of 99.9% and a safety factor of 1.5. The power is transmitted through the shaft and delivered to the belt on pulley *B*. Assume the belt tension on the loose side at *B* is 15 percent of the tension on the tight side. Determine:

a-Select two bearings for O and C using an application factor of unity and a desired life for each bearing is 9 kh with a 95 percent reliability for the two bearings. (use direct mount)

b-Draw shear-force and bending-moment diagrams for the shaft.

c- Using a factor of safety of 2.5 determine the minimum allowable diameter of the shaft based on a fatigue- failure analysis Modified Goodman. (Make any necessary assumptions).

d-draw the resulting shaft showing all necessary dimensions



*Ex. 6-4: (Bending)

*Ex. 6-2: 1050 HR Steel → $S_{ut} = 620$ MPa

ⓐ $S_e' = 0.5\, S_{ut} = 310$ MPa

ⓑ $N = 10^4$

$S_f = a N^b$ $f = 0.86$ $S_e = S_e' = 310$ MPa

$a = \dfrac{((0.86)(620))^2}{310} = 917.1$ MPa

$b = \dfrac{-1}{3} \log \left(\dfrac{(0.86)(620)}{310} \right) = -0.0785$

$S_f = 917.1 \,(10^4)^{-0.0785} = 445.1$ MPa

ⓒ $\sigma_{rev} = 385$ MPa

$N = \left(\dfrac{385}{917.1} \right)^{1/-0.0785} = 63.4\,(10)^3$ cycles

$S_e = K_a\, K_b\, K_c\, K_d\, K_e\, K_f\, S_e'$

K_a → Surface factor → Table 6-2

K_b → Size factor

K_c → loading factor

K_d → Temperature factor (Table 6-4)

K_e → Reliability factor Table 6-5

K_f → Miscell- factor $\boxed{K_f = 1}$

$K_a = a\, S_{ut}^{\,b}$

K_b: Axial only ⇒ $K_b = 1$

Bending / Torison { ① circular ② Rotating ⇒ K_b eq. (6-20)

↓ if Not

Table 6-3

↳ d_e (in mm) → K_b eq. (6-20)

*Ex. 6-4: (Bending)

32 mm 38 mm

*Ex. 6-2: 1050 HR Steel → $S_{ut} = 620$ MPa

ⓐ $S_e' = 0.5\, S_{ut} = 310$ MPa

ⓑ $N = 10^4$

$S_f = a N^b$ $\qquad f = 0.86$

$S_e = S_e' = 310$ MPa

$$a = \frac{((0.86)(620))^2}{310} = 917.1 \text{ MPa}$$

$$b = -\frac{1}{3} \log\left(\frac{(0.86)(620)}{310}\right) = -0.0785$$

$$S_f = 917.1\,(10^4)^{-0.0785} = 445.1 \text{ MPa}$$

ⓒ $\sigma_{rev} = 385$ MPa

$$N = \left(\frac{385}{917.1}\right)^{1/-0.0785} = 63.4\,(10)^3 \text{ cycles}$$

$$S_e = K_a\, K_b\, K_c\, K_d\, K_e\, K_f\, S_e'$$

K_a → Surface factor → Table 6-2

K_b → Size factor

K_c → loading factor

K_d → Temperature factor (Table 6-4)

K_e → Reliability factor Table 6-5

K_f → Miscell. factor $\boxed{K_f = 1}$

$K_a = a\, S_{ut}^{\,b}$

K_b: Axial only ⇒ $K_b = 1$

Bending / Torison { ① circular ② Rotating ⇒ K_b eq. (6-20)

↓ if Not

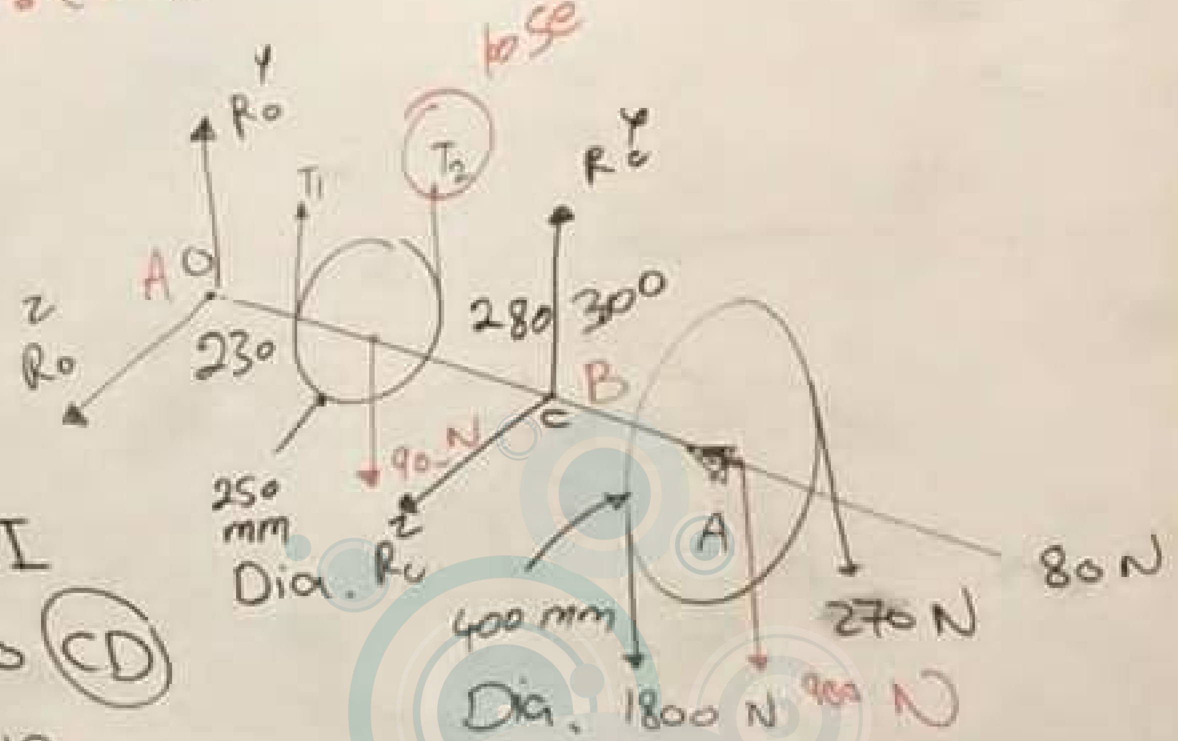
Table 6-3

↳ d_e → K_b eq. (6-20)

in mm

Q_3) : (20 P)

$2.937(10)^5$



AISI 1050 CD

$n_D = 1200$ rpm

Ground finish

99.9%

$n = 1.5$

$F_{ae} = 80$ N

$Fr_{(A)} = R_O = 3071.3$

$Fr_{(B)} = R_C = 3629.3$

$r = (0.02)(73.08) = 1.46$ mm

$K_t = 2.7$

$q = 0.79$

$K_f = 2.34$

$K_{ts} = 2.2$

$q_s = 0.82$

$K_{fs} = 1.98$

$d = 73.27$ mm $\to K_b = 0.769$

$S_e = 1419$

(c) $n = 2.5$

$$T = (2880 - 432)(0.125) = 306 \text{ N·m}$$

$T_a = 0$ $T_m = 306$ N·m

Sharp fillet Radius $K_t = 2.7$ $K_{ts} = 2.2$ $\frac{r}{d} = 0.02$

$\frac{D}{d} = 1.5$ $K_b = 0.9$

$S_e' = 0.5(690) = 345$ MPa $S_{ut} = 690$ MPa

$K_f = K_e = K_d = 1$ $K_c = 0.59$ $K_b = 0.9$

$K_a = 4.51(690)^{-0.265} = 0.798$

$S_{e①} = 146.15$ MPa

$$d = \left(\frac{16(2.5)}{\pi}\left\{3.292(10)^{-5} + 1.6898(10)^{-6}\right\}\right)^{1/3} = 76.1 \text{ mm}$$

$K_b = 1.51(76.1)^{-0.157} = 0.7649$ $S_{e②} = 124.24$ MPa

$r = 0.02(76.1) = 1.52$ mm $q = 0.81 \rightarrow K_f = 1 + 0.81(2.7-1) = 2.38$

$q_s = 0.84 \rightarrow K_{fs} = 1 + 0.84(2.2-1) = 2.01$

$$d = \left(\frac{16(2.5)}{\pi}\left\{3.414(10)^{-5} + 1.544(10)^{-6}\right\}\right)^{1/3} = 76.88 \text{ mm}$$

$K_b = 1.51(76.88)^{-0.157} = 0.7637$ $S_{e③} = 124.05$ MPa

$r = 0.02(76.88) = 1.54$ mm $K_f = 2.38$

$K_{fs} = 2.01$

$$d = \left(\frac{16(2.5)}{\pi}\left\{3.419(10)^{-5} + 1.544(10)^{-6}\right\}\right)^{1/3} = 76.91 \text{ mm}$$

$K_b = 0.7636$ $S_{e④} = 124.04$ MPa

Stop

$d = 76.91$ mm $r = 1.54$ mm $D = 115.37$ mm

Ex. 6.9: Rotating $F = 6.8\ KN$ $N = ?$

$$N = \left(\frac{\sigma_{rev}}{a}\right)^{1/b}$$

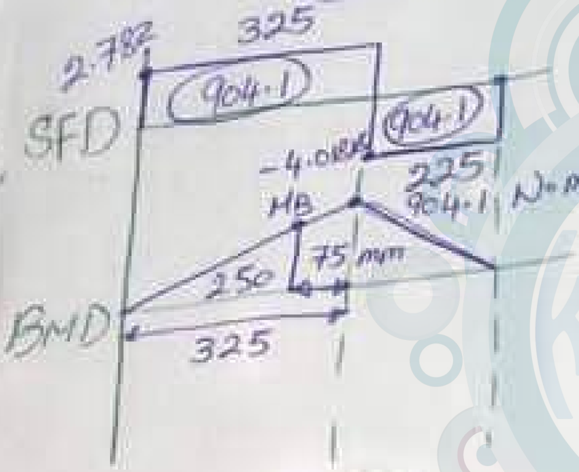
$$\sigma_{rev} = (K_f \text{ (OR) } K_{fs})\, \sigma_o$$

$$\sigma_{rev} = K_f \frac{M_{max} C_{max}}{I}$$

at stress concentration location

$\Sigma M_A = 0$:
$$6.8(325) - R_2(550) = 0$$
$$R_2 = 4.01818\ KN$$

$\Sigma F^y = 0$: $-6.8 + R_1 + 4.01818 = 0$
$$R_1 = 2.782\ KN$$



$$\frac{904.1}{325} = \frac{M_B}{250} \Rightarrow M_B = 695.5\ N \cdot m$$

$$C_{max} = \frac{d}{2} = \frac{32}{2} = 16\ mm$$

$$I = \frac{\pi}{4} r^4 = \frac{\pi}{4} (16)^4 (10)^{-12} = 5.147 (10)^{-8}\ m^4$$

$$K_f = 1.57$$

$$\sigma_{rev} = 1.57 \frac{(695.5)(16)(10)^{-3}}{5.147(10)^{-8}} = 339.44\ Mpa$$

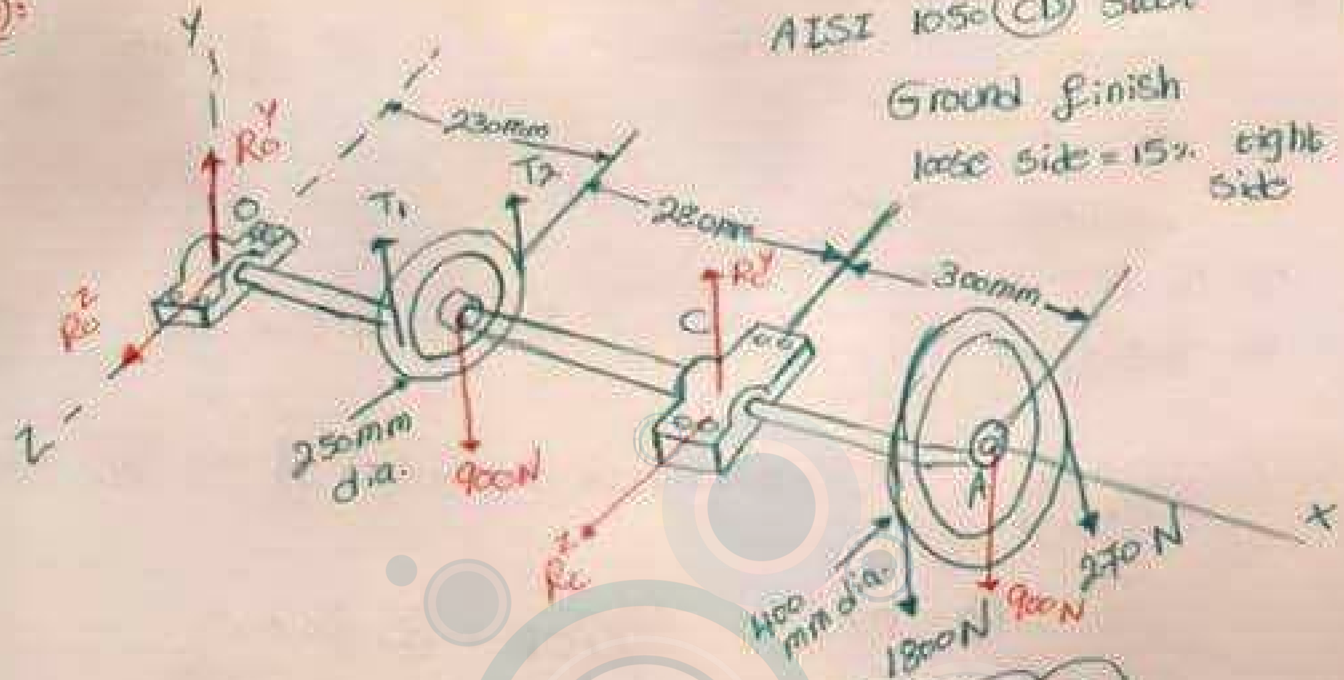
$$S_e = 235.67\ Mpa$$

$$k_a = 4.51(690)^{-0.265} = 0.798$$

$$k_b = 1.24(32)^{-0.107} = 0.856$$

$$k_c = k_d = k_e = k_f = 1 \qquad S_e' = 0.5(690) = 345\ Mpa$$

Q3:



AISI 1050 CD steel

Ground finish

loose side = 15% tight side

T_1 : tight T_2 : loose $T_2 = 0.15\,T_1$

(b) $\Sigma T = 0$; $(1800-270)(0.2) + (T_2 - T_1)(0.125) = 0$

$306 + (0.15\,T_1 - T_1)(0.125) = 0$

$T_1 = 2880\,N$ $T_2 = 432\,N$

$\Sigma M_O^y = 0$; $-R_C^z(0.51) = 0$ $R_C^z = 0$

$\Sigma M_O^z = 0$; $(2880 + 432 - 900)(0.23) + R_C^y(0.51) - (1800 + 900 + 270)(0.81) = 0$

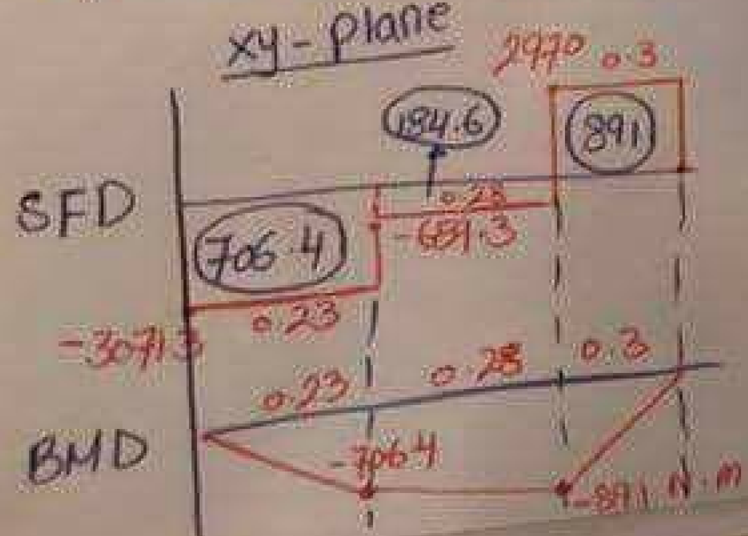
$R_C^y = 3629.3\,N$

$\Sigma F^y = 0$; $R_O^y + 2880 + 432 - 900 + 3629.3 - 1800 - 900 - 270 = 0$

$R_O^y = -3071.3\,N$

$\Sigma F^z = 0$; $R_O^z + 0 = 0$ $R_O^z = 0$

xy-plane



$M_{max} = 891\ N \cdot m$

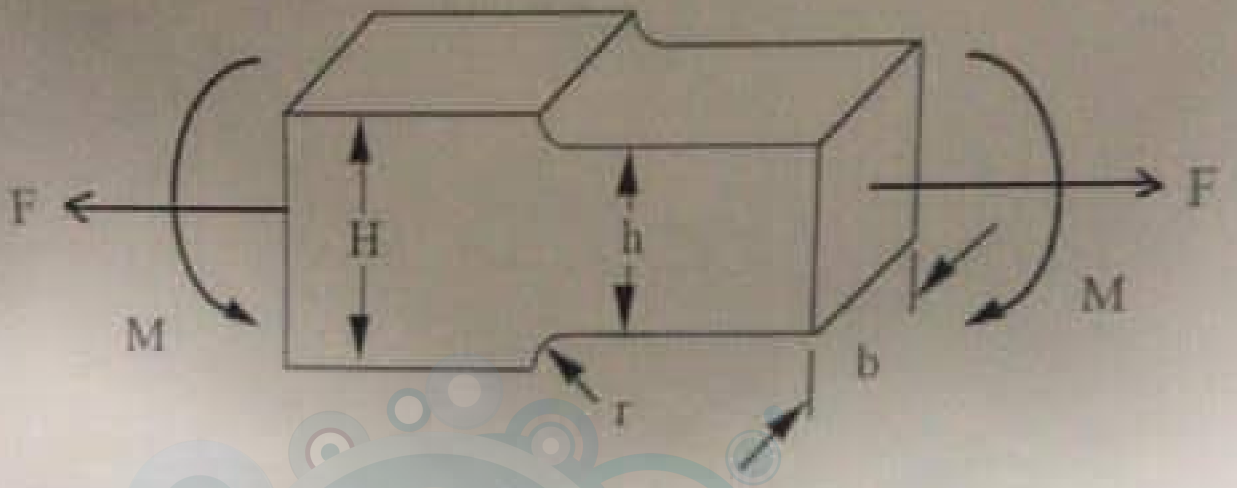
$M_a = 891\ N \cdot m$ $M_m = 0$

③ ⑥

Final Examination

Q1(15P): The figure shows the free-body diagram of a machine part. The dimensions are $r = 2.5$ m[m] $H = 35$ mm $h = 25$ mm $b = 20$ mm. The part is loaded with a force F that fluctuate between a tens[ion] of 800 N and a compression of 1 kN and a bending moment M that fluctuates between zero-to-1[...] N.m to give an infinite fatigue life with 99% reliability. The part is made of AISI 1040 CD. T[he] surface is machined. Using the modified Goodman failure theory determine:

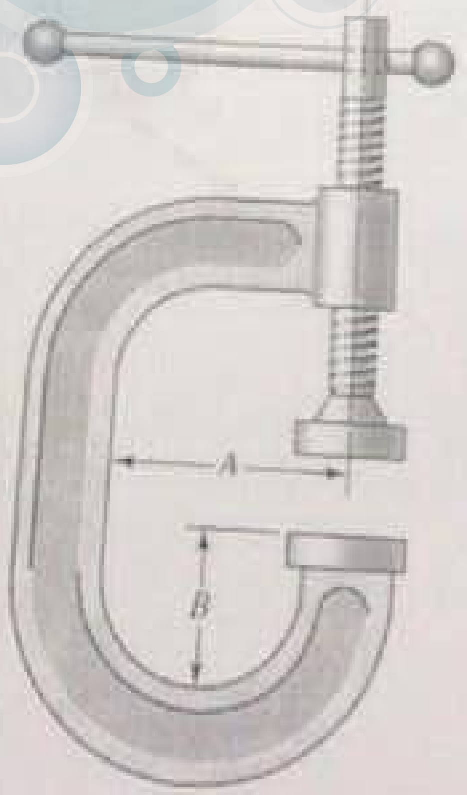
a-the fatique factors of safety for the part



Q2.(15P). A screw clamp similar to the one shown in the figure has a handle with diameter 3/16 in made of cold-drawn AISI 1006 steel. The screw has Acme threads with a major diameter 1 in and is 5 3/4 in long. The screw material is made of steel lubricated with machine oil and the nut material is made from cast iron. A force of 12 lb.f will be applied to the handle at a radius of 5 in from the screw centre line :

a- what will be the clamping force

b-Given that n_f=3 determine the von Mises stress at the root of the thread



$P_{min} = 4$ kips $\quad P_{max} = 6$ kips

$$a = \frac{(0.841(690))^2}{235.67} = 1428.85 \text{ MPa}$$

$$b = -\frac{1}{3}\log\left(\frac{0.841(690)}{235.67}\right) = -0.1304$$

$$N = \left(\frac{339.44}{1428.85}\right)^{1/-0.1304} = 61.2\,(10)^3 \text{ cycles}$$

① Completely Reversed

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

$$\sigma_a = \sigma_{max}$$

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_m = 0$$

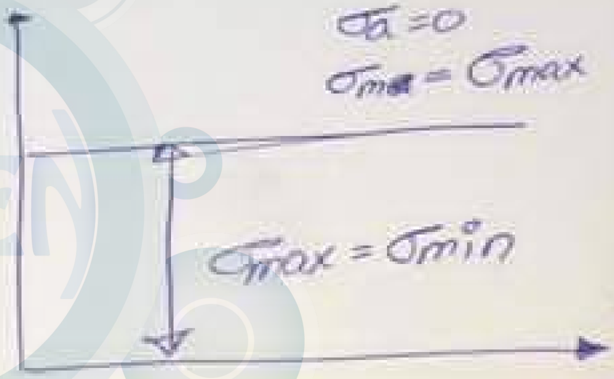
② Repeated $\quad \sigma_a = \sigma_m = \frac{\sigma_{max}}{2}$

③ Fluctuating

④ constant (Steady State)

$\sigma_a = 0$

$\sigma_m = \sigma_{max}$



pure Torsion:

$$\frac{\tau_a}{S_e} + \frac{\tau_m}{0.67 S_{ut}} = \frac{1}{n_f}$$