Machine Design Course for Communication / Electrical Department
Sheet 4 – Shaft Design

Problem 1

Figure 1 is a schematic drawing of a countershaft that supports two belt pulleys. For each pulley, the belt tensions are parallel and for pulley A, the belt tensions are inclined with angle 45and pulley A consider the loose belt tension is 15 percent of the tension on the tight side. The allowable shear stress of the shaft is 420 MPa. Determine the minimum preferred size diameter. Use the ASME equation when K_b= 1.5 and K_t=1.

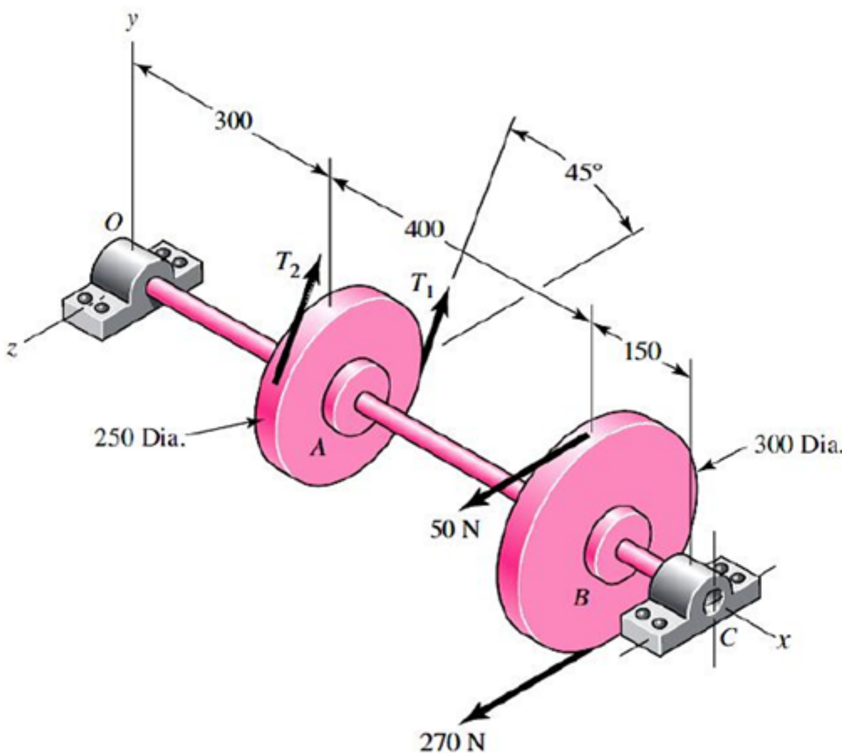


Figure 1.

Givens:

τ_{all}=420 Mpa

K_b= 1.5 and K_t=1 T_2=0.15T_1

Req: d=?

Solution

Max torque calculation:

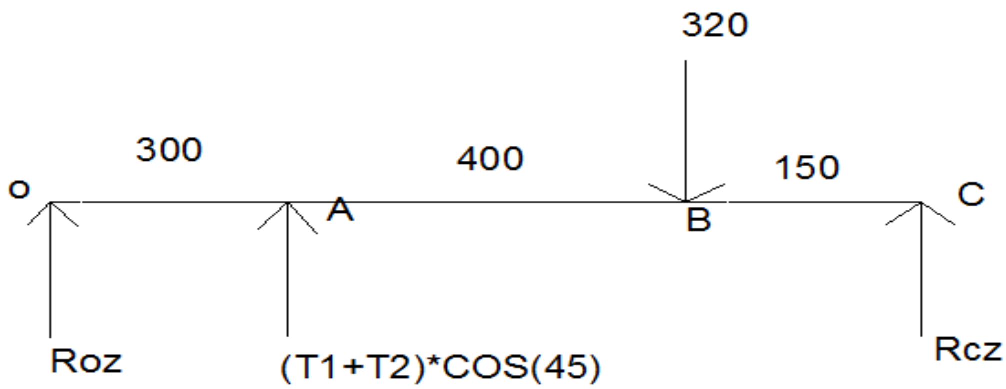
$T_A=T_B$

$(T1-T2)*\frac{250}{2}=(270-50)*\frac{300}{2}$

$(T1-0.15T1)*\frac{250}{2}=(270-50)*\frac{300}{2}$

T1=310.588 N   T2=46.5882 N

X-Z plane



$\pounds M_0=0$

(T1+T2)*COS(45)*300-320*(300+400)+Rcz*(300+400+150)=0

Rcz=174.3899 N

£Tz=0

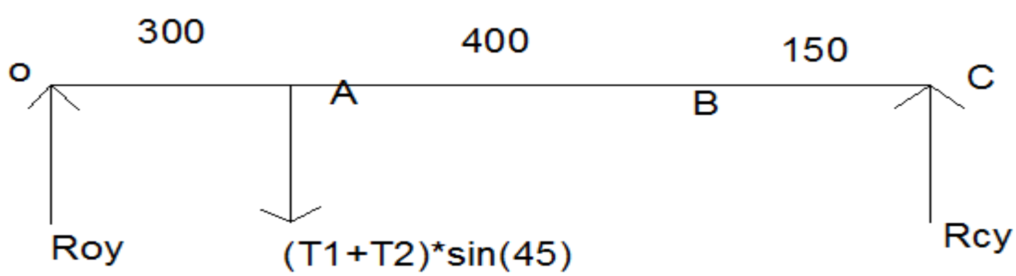
Roz+(T1+T2)*COS(45)-320+Rcz=0

Roz=-106.95 N

Maz= Roz*300=-32079 N.mm

Mbz= Rcz*150=26158.48 N.mm

X-Y plane



$\pounds M_0=0$

(T1+T2)*sin(45)*300+Rcy*(300+400+150)=0-

Rcy=89.139 N

£Fy=0

Roy-(T1+T2)*sin(45)+Rcy=0

Roy=163.4227 N

May= Roy*300=49026.8 N.mm

Mby= Rcy*150=13370.85 N.mm

so:

Ma=$\sqrt{\mathrm{Maz}^2+\mathrm{May}^2}$

=49131.71 N.mm

Mb=$\sqrt{\text{Mbz}^2 + \text{Mby}^2}$

=29377.64 N.mm

Ta=Tb=(270-50)*300/2=33000 N.mm

Design based on point (A)

$d_o=[\frac{16}{\pi * 420} * \sqrt{(1.5 * 49131.71)^2 + (33000)^2}]^{1/3}$

d_o=9.93≡10 mm

Problem 2

A gear-reduction unit uses the countershaft depicted in Figure 2. The allowable shear stress of the shaft is 420 MPa. Determine the minimum preferred size diameter. Use the ASME equation when $K_b = K_t = 1.5$.

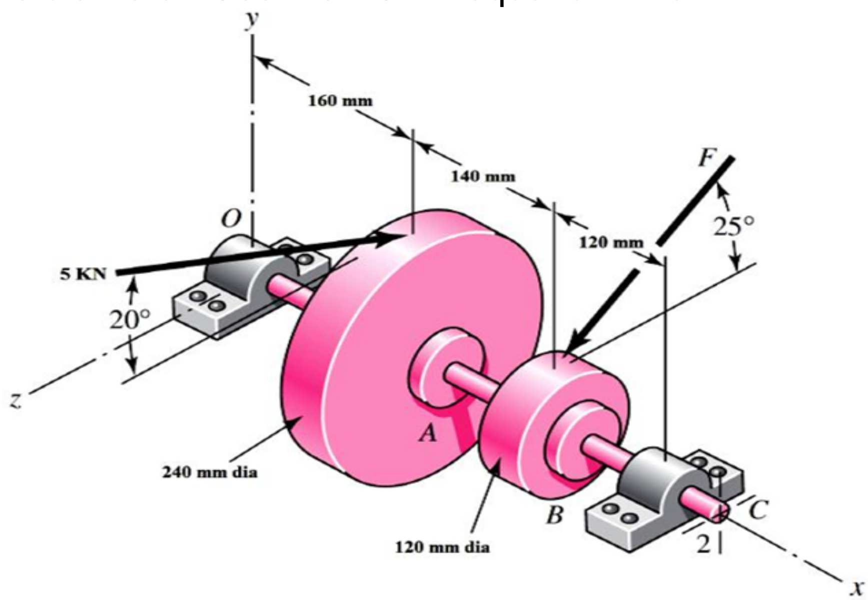


Figure 2.

Givens:

τ_{all}=420 Mpa

$K_b = K_t = 1.5$

Req: d=?

Solution

Max torque calculation:

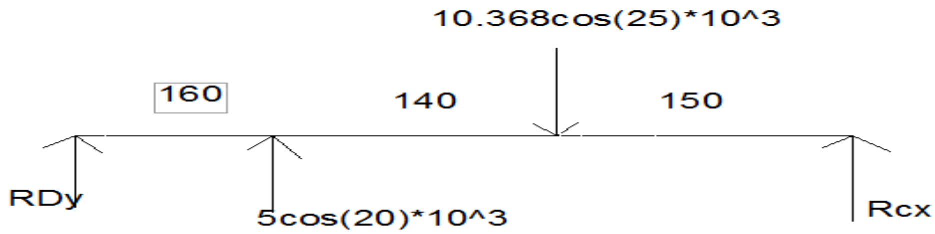
$T_A = F_A * \cos(20) * \frac{DA}{2} = 5*10^3 * \cos(20) * \frac{240}{2} = 563.815*10^3$ N.mm

$T_A=T_B$

$F_B*\cos(25)*\frac{120}{2}=563.815*10^3$

$F_B=10.36835$ N

Max moment calculations:



$£M_0=0$

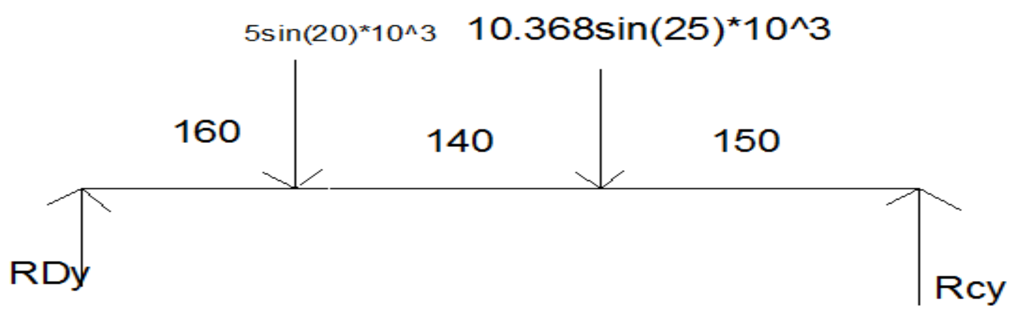
$5*\cos(20)*10^3*160-10.368*\cos(25)*10^3*(160+140)+R_{cx}*(160+140+150)=0$

$R_{CX}=4.5938*10^3$ N

$R_{O}x=0.104336*10^3$ N

Max= $R_{Ox}*160=0.104336*10^3*160=16.697376*10^3$ N.mm

Mbx= $R_{CX}*150=4.5938*10^3*150=689.07*10^3$ N.mm



$£M_0=0$

$-5*\sin(20)*10^3*160-10.368*\sin(25)*10^3*(160+140)+R_{cy}(160+140+150)=0$

$R_{Cy}=3.529*10^3$ N

$R_{Oy}=2.5628*10^3$N

May= $R_{Oy}*160=2.562*10^3*160=409.92*10^3$ N.mm

Mby= $R_{C}y*150=3.529*10^3*150=529.35*10^3$ N.mm

so:

Ma= $\sqrt{Max^2+May^2}=410.259*10^3$ N.mm

Mb= $\sqrt{Mbx^2+Mby^2}=868.92*10^3$ N.mm

Design based on point (B)

$d_o=[\frac{16}{\pi*420}*\sqrt{(1.5*868.92*10^3)^2+(1.5*563.815*10^3)^2}]^{1/3}$

d_o=26.6≡27 mm

Problem 3

A shaft made of steel receives 7.5 kW power at 1500 r.p.m. A 450 mm diameter pulley mounted on the shaft as shown in Figure 3 has ratio of belt tensions of 4. The allowable shear stress of the shaft is 420 MPa. The gear diameter is 200 mm and F_r = 0.2 F_t . Design the shaft diameter. Use the ASME equation when K_b= 1.5 and K_t=1.

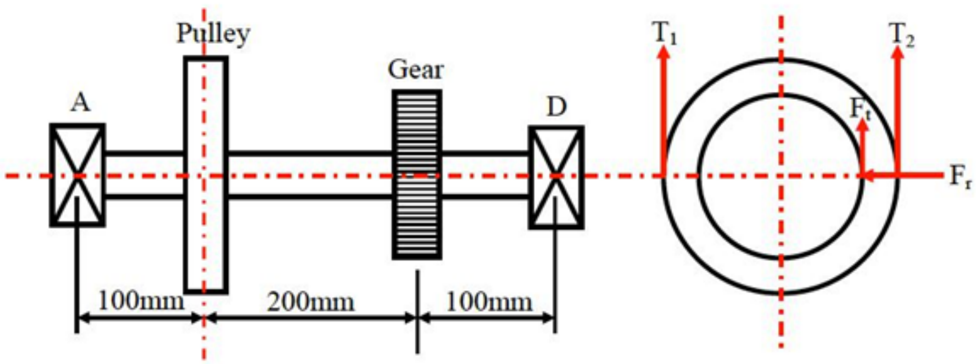


Figure 3.

Givens:

P=7.5 Kwatt K_b= 1.5 and K_t=1

N=1500 rpm τ_{all}=420 Mpa

Fr=0.2Ft T1=4*T2

Req: d=?

Solution

Max torque calculation:

P=T*ω → 7.5*10^3=T*(2*π*1500/60)

T=47.746*10^3 N.mm

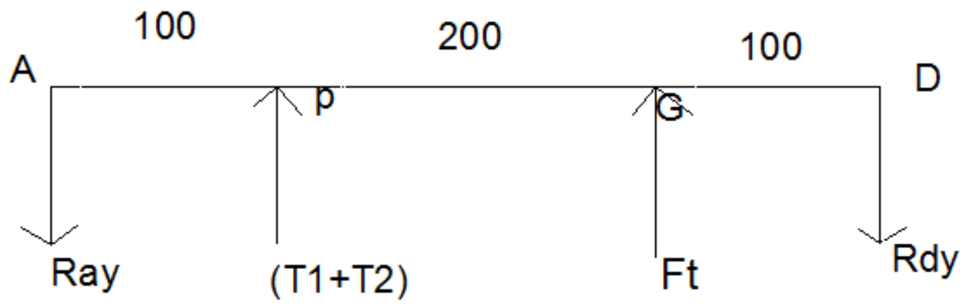
T_{Pulley}=(T1-T2)*450/2 →47.746*10^3 =(4T2-T2)*450/2

T1=4T2=282.93 N

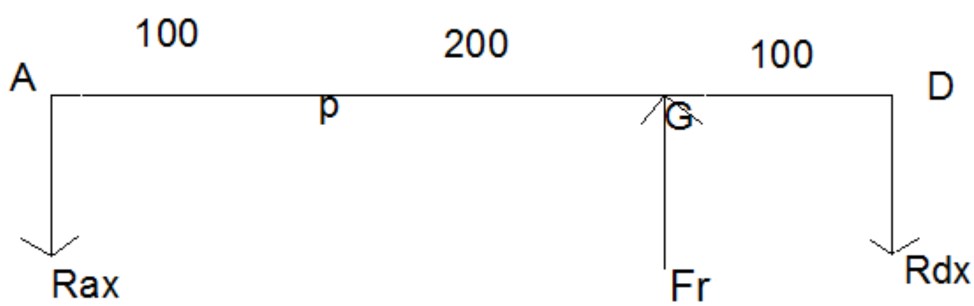
T=Tbar=Ft*200/2=47.746*10^3

Ft=477.46 N Fr=0.2Ft=95.492 N

y-z plane



£M_{Ax}=0
(T1+T2*100+Ft*(100+200)-Rdy*(100+200+100)=0
Rdy=446.511 N
£Fy=0
Ray-(T1+T2-Ft+Rdy=0
Ray=384.613 N
Mpy= -Ray*100=-38.46*10^3 N.mm
MGy= -Rdy*100=-44.6511*10^3N.mm
X-Z plane



£M_Ay=0
Fr*(100+200)-Rdx*(100+200+100)=0
Rdx=71.619 N
£Fx=0
Rax-Fr+Rdx=0
Rax=23.873 N
Mpx= -Rax*100=-2.3873*10^3 N.mm
MGx= -Rdx*100=-7.1619*10^3N.mm
G have the maximum moment so:

$M_G = \sqrt{M_{G,x}^2 + M_{G,y}^2}$ = 45.2218*10^3 N.mm

T_G=47.746*10^3 N.mm

Design based on point (G)

$d_o = [\frac{16}{\pi * 420} * \sqrt{(1.5 * 45.2218 * 10^3)^2 + (1 * 47.746 * 10^3)^2}]^{1/3}$

d_o=0.5288≡1 mm

Problem 4

A horizontal shaft AD supported in bearings at A and B and carrying pulleys at C and D is to transmit 75 kW at 500 r.p.m. from drive pulley D to off-take pulley C, as shown in Figure 4. Calculate the diameter of shaft. The data given is: P_1 = 3 P_2 (both horizontal), Q_1 = 2 Q_2 (both vertical), radius of pulley C is 220 mm, radius of pulley D is 160 mm, The allowable shear stress of the shaft is 420 MPa. Use the ASME equation when K_b= 1.5 and K_t=1.

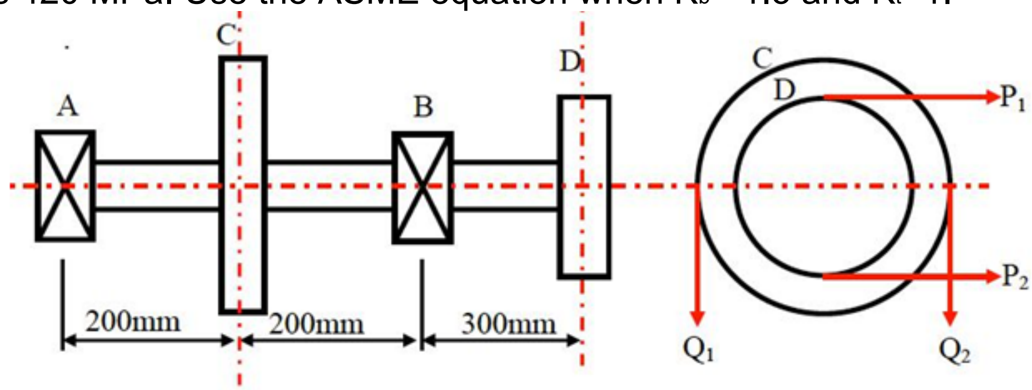


Figure 4.

Givens:

P=75 Kwatt K_b= 1.5 and K_t=1

N=500 rpm τ_{all}=420 Mpa

Req: d=?

Solution

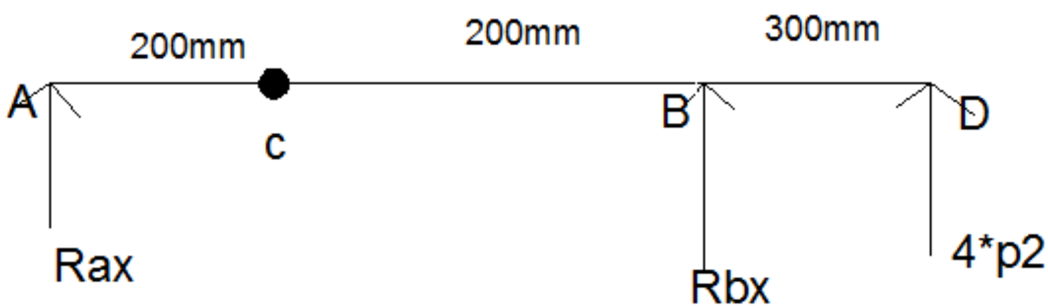
Max torque calculation:

P=T*ω → 75*10^3=T*(2*π*500/60)

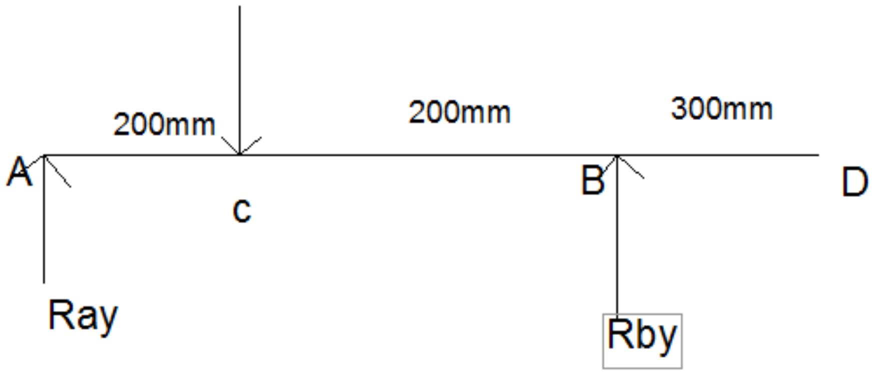
T=1.43239*10^6 N.mm

$T_D=(P1-P2)*r_D$
1.43239*10^6=(3P2-P2)*160
P2=4.4762*10^3 N
P1=13.4286*10^3 N
$T_A=(Q1-Q2)*r_c$
1.43239*10^6=(2Q2-Q2)*220
Q2=6.51086*10^3 N
Q1=13.0217*10^3 N

Max moment calculations:



£Max=0
Rbx*(200+200)-4*(4.4762*10^3)*(200+200+300)=0
Rbx=31.3334*10^3 N
Rax+Rbx=4*p2
Rax=4*4.4762*10^3-31.3334*10^3=-13.4292*10^3 N
Mcx=Rax*200=-13.4292*10^3*200=-2.68584*10^6 N.mm
Mbx=4*p2*300=5.37144*10^6 N.mm



£May=0

Rby*(200+200)-3*(6.5108*10^3)*(200)=0

Rby=9.7662*10^3 N

Ray+Rby=3*Q2

Ray=3*6.5108*10^3-9.7662*10^3=9.7662*10^3 N

Mcy=Ray*200=9.7662*10^3*200=1.95324*10^6 N.mm

Mby=0 N.mm

so:

Mc=$\sqrt{\mathrm{Mcx}^2 + \mathrm{Mcy}^2}$ =3.3209*10^ N.mm

Mb=$\sqrt{\mathrm{Mbx}^2 + \mathrm{Mby}^2}$ = 5.37144 *10^6 N.mm

Design based on point (B)

d_o=[$\frac{16}{\pi * 45} * \sqrt{(1.5 * 5.37144 * 10^6)^2 + (1 * 1.43239 * 10^6)^2}]^{1/3}$

d_o=97.47≡98 mm