Answer Key

Coupling, Clutch and Brakes

1

for the shaft

$$S_s = \frac{16T}{\pi d^3}$$

$$30000\ kPa = \frac{16T}{\pi (0.090m)^3}$$

$$T = 7.1569\ kN\text{-}m$$

solving for the bolt diameter

$$S_s = \frac{2T}{\#\left[\frac{\pi}{4}h^2\right]N_b}$$

$$40000\ kPa = \frac{2(7.1569\ kN\text{-}m)}{(0.70m)\left[\frac{\pi}{4}h^2\right](6)}$$

$$h = 0.01042\ m \quad (\text{bolt diameter})$$

Hence; from the compression between bolts & Flange

$$S_c = \frac{2T}{\#\, h_g\, N_b}$$

$$75000\ kPa = \frac{2(7.1569\ kN\text{-}m)}{(0.70m)(0.01042m)g(6)}$$

$$g = 4.3609 \times 10^{-3}\ m$$

$$g = 4.3609\ mm$$

$$S_c = \frac{2T}{\pi h g N_b}$$

$$18000\,KPa = \frac{2(18\,kN\text{-}m)}{(0.260m)(0.025m)g(8)}$$

$$g = 0.03846\ m$$

$$g = 38.46\ mm$$

$$S_s = \frac{F_b}{A_c}; \qquad A_s = \frac{\pi h^2}{4}$$

$$S_s = \frac{F_b}{\frac{\pi h^2}{4}}$$

$$38000 \frac{kN}{m^2} = \frac{130\ kN}{\frac{\pi h^2}{4}(6)}$$

$$h = 0.02694\ m$$

$$\boxed{h = 26.94\ mm}$$

$$F_b = \frac{2T}{\#N_b} \quad ; \quad \eta_T = \frac{W_T'}{W_T}$$

$$0.85 = \frac{50\,MW}{W_T}$$

$$W_T = 58.8235\,MW$$

and ;

$$P = \frac{2\pi TN}{60}$$

$$58823.5\,kW = \frac{2\pi T\,(3600\,rpm)}{60}$$

$$T = 156.0343\,kN\text{-}m$$

subst ;

$$F_b = \frac{2\,(156.0343\,kN\text{-}m)}{(0.520m)(18)}$$

$$\boxed{F_b = 33.34\,KN}$$

$$\frac{0.6S_y}{F.S.} = \frac{2T}{\#hg N_b} \quad ; \quad P = \frac{2\pi TN}{60}$$

$$80\,kW = \frac{2\pi T(200\,rpm)}{60}$$

$$T = 3.8197\ kN\text{-}m$$

Substj

$$\frac{0.6(450\,000\,kPa)}{F.S.} = \frac{2(3.8197\ kN\text{-}m)}{(0.2m)(0.016m)(0.020m)(8)}$$

$$F.S. = 18.0957$$

$$P = \frac{2\pi TN}{60} \; ; \qquad T = f\,Fa\left[\frac{D^3 - d^3}{3(D^2 - d^2)}\right] N_c$$

$$= (0.18)(1.5\,kN)\left[\frac{(0.225\,m)^3 - (0.020\,m)^3}{3(0.225^2 - 0.020^2)}\right] 8$$

$$T = 0.1632\ kN\text{-}m$$

Substi

$$P = \frac{2\pi(0.1632\ kN\text{-}m)(800\,rpm)}{60}$$

$$P = 13.67\ kW$$

$$T = 2 f P_{max} w r^2 \sin\frac{\theta}{2} (N_s)$$

$$P = \frac{2\pi T N}{60}$$

$$(20 hp)\left(\frac{550 \frac{ft\text{-}lb}{sec}}{1 hp}\right) = \frac{2\pi T (280 rpm)}{60}$$

$$T = (375.1509 \text{ ft-lb})\left(\frac{12 in}{1 ft}\right)$$

$$T = 4501.8112 \text{ in-lb}$$

subst;

$$4501.8112 \text{ in-lb} = 2(0.40)\left(40\frac{16}{in^2}\right) w \left(\frac{1.3}{2} in\right)^2 \sin\left(\frac{80°}{2}\right)(4)$$

$$w = 1.2950 \text{ in}$$

$$P = \frac{2\pi T N}{60}$$

$$(50\ hp)\left(\frac{550\ \frac{ft\text{-}lb}{sec}}{1\ hp}\right) = \frac{2\pi T\ (1200\ rpm)}{60}$$

$$T = 218.8380\ ft\text{-}lb$$

and;

$$T = \frac{f F_a r_f}{\sin\alpha}$$

$$(218.8380\ ft\text{-}lb)\left(\frac{12\ in}{1\ ft}\right) = \frac{(0.30)\,F_a\left(\frac{15}{2}\ in\right)}{\sin 12^\circ}$$

$$F_a = 242.6613\ lbs$$

and;

$$F_a = F_n \sin\alpha$$

$$242.6613\ lb = F_n \sin 12^\circ$$

$$F_n = 1167.1362\ lbs$$

Hence;

$$P_n = \frac{F_n}{A} = \frac{F_n}{\pi D W}$$

$$13\ \frac{lb}{in^2} = \frac{1167.1362\ lbs}{\pi\,(15\ in)\,W}$$

$$W = 1.9052\ in$$

$$P = \frac{2\pi TN}{60} \; ; \quad T = f F_a \left[\frac{D^3 - d^3}{3(D^2 - d^2)}\right] N_c$$

$$= (0.30)(0.90\,kN)\left[\frac{(0.180m)^3 - (0.110m)^3}{3(0.180^2 - 0.110^2)}\right] (1)$$

$$T = 0.01996\ kN\text{-}m$$

Subst;

$$P = \frac{2\pi\,(0.01996\,kN\text{-}m)(1100\,rpm)}{60}$$

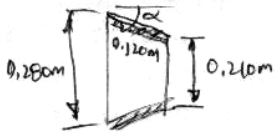
$$P = 2.2987\ kW$$

$$P = \frac{2\pi TN}{60} \; ; \; T = \frac{f F_a r_f}{\sin\alpha} \; ; \; r_f = \frac{1}{3}\left[\frac{D^3 - d^3}{D^2 - d^2}\right]$$

$$= \frac{1}{3}\left[\frac{(0.280\text{m})^3 - (0.210\text{m})^3}{(0.280\text{m})^2 - (0.210\text{m})^2}\right]$$

$$r_f = 0.1233\ \text{m}$$

from Geometry



$$\sin\alpha = \frac{(0.280 - 0.210)\text{m}}{2(0.120\text{m})}$$

$$\sin\alpha = 0.2917$$

Subst;

$$T = \frac{(0.28)(0.60\ \text{kN})(0.1233\ \text{m})}{0.2917} = 0.0710\ \text{kN-m}$$

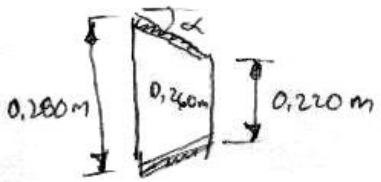
Hence;

$$P = \frac{2\pi(0.0710\ \text{kN-m})(850\ \text{rpm})}{60}$$

$$P = 6.3210\ \text{kW}$$

Exponential LEAP ONLINE REVIEW

by Geometry:



$$\sin\alpha = \frac{(0.280 - 0.220)}{2(0.260\,m)}$$

$$\alpha = \sin^{-1}(0.1154)$$

$$\alpha = 6.6258^\circ$$

$P = \frac{2\pi TN}{60}$; $T = \frac{f F_a r_f}{\sin\alpha} = f F_n r_f$

$\sin\alpha = \frac{(0.220 - 0.180)\,m}{2\,(0.120\,m)}$

$\sin\alpha = 0.1667$

$\alpha = 9.5960°$

and ; $F_n = P_n A = \pi D_m w$

$D_m = \frac{D+d}{2} = \frac{(0.220 + 0.180)\,m}{2}$

$D_m = 0.20\,m$

$F_n = \left(80\,\frac{kN}{m^2}\right)\pi\,(0.20\,m)(0.120\,m)$

$F_n = 6.0319\,kN$

for r_f ; $r_f = \frac{1}{3}\left[\frac{D^3 - d^3}{D^2 - d^2}\right]$

$= \frac{1}{3}\left[\frac{(0.220m)^3 - (0.180m)^3}{(0.220m)^2 - (0.180m)^2}\right]$

$r_f = 0.10\,m$

subst, to solve for Torque

$T = 0.35\,(6.0319\,kN)(0.1\,m)$

$T = 0.21111\,kN\text{-}m$

Hence;

$P = \frac{2\pi\,(0.21111\,kN\text{-}m)(880\,rpm)}{60}$

$P = 19.4551\,kW$

$$P = \frac{2\pi TN}{60} \; ; \; T = \frac{f E_{ar} r}{\sin\alpha} = \frac{0.25(0.5\,kN)(0.260\,m)}{2\sin(8.5°)}$$

$$T = 0.1099\ kN\text{-}m$$

Subst;

$$P = \frac{2\pi(0.1099\ kN\text{-}m)(220\ rpm)}{60}$$

$$\boxed{P = 2.5328\ kW}$$

$$T = f F_a \left[\frac{D^3 - d^3}{3(D^2 - d^2)}\right] N_c$$

$$= (0.30)(1.30\ kN)\left[\frac{(0.220\ m)^3 - (0.110\ m)^3}{3(0.220^2 - 0.110^2)}\right]$$

$$T = 0.03337\ kN\text{-}m$$

$$T = 33.37\ N\text{-}m$$

$P = \frac{2\pi TN}{60}$; $T = (F_1 - F_2)r$; $\frac{F_1}{F_2} = e^{f\theta}$

from; $S_d = \frac{F_1}{wt}$

$8500 \frac{lb}{in^2} = \frac{F_1}{\left(\frac{1}{16} in\right)(2in)}$

$F_1 = 1062.5 \text{ lbs}$

and;

$\frac{1062.5 \text{ lbs}}{F_2} = e^{(0.35)(260°)\left(\frac{\pi \text{ rad}}{180°}\right)}$

$F_2 = 217.0506 \text{ lbs}$

subst;

$T = (1062.5 - 217.0506)\text{lbs}\left(\frac{15}{2} in\right)$

$T = \left(6340.8709 \text{ in-lbs}\right)\left(\frac{1 ft}{12 in}\right) = 528.4059 \text{ lb-ft}$

Hence;

$P = \frac{2\pi (528.4059 \text{ lb-ft})(360 rpm)}{60}$

$P = \left(19920.4333 \frac{\text{lb-ft}}{s}\right)\left(\frac{1 hp}{550 \frac{\text{lb-ft}}{s}}\right)$

$P = 36.2197 \text{ hp}$

$$S_b = \frac{F_1}{wt} \; ; \; P = \frac{2\pi T N}{60}$$

$$(10\,hp)\left(\frac{550\,ft\text{-}lb}{1\,hp\text{-}s}\right) = \frac{2\pi T (260\,rpm)}{60}$$

$$T = (202.0044\,ft\text{-}lb)\left(\frac{12\,in}{1\,ft}\right)$$

$$T = 2424.0522\,in\text{-}lb$$

and;

$$T = (F_1 - F_2)r$$

$$2424.0522\,in\text{-}lb = (F_1 - F_2)\left(\frac{16\,in}{2}\right)$$

$$F_1 - F_2 = 303.0065\,lbs$$

then;

$$\frac{F_1}{F_2} = e^{f\theta}$$

$$F_1 = F_2 e^{f\theta}$$

subst; to solve for F_2 & F_1

$$F_2 e^{f\theta} - F_2 = 303.0065\,lbs$$

$$F_2 = \frac{303.0065\,lbs}{(e^{f\theta} - 1)}$$

$$F_2 = \frac{303.0065\,lbs}{e^{(0.35)(260^\circ)\left(\frac{\pi\,rad}{180^\circ}\right)} - 1}$$

$$F_2 = 77.7903\,lbs$$

$$F_1 = 380.7970\,lbs$$

Hence;

$$4800\,\frac{lb}{in^2} = \frac{380.7970\,lbs}{w\left(\frac{1}{16}\,in\right)}$$

$$w = 1.2693\,in$$

$$P = \frac{2\pi TN}{60}; \qquad T = f F_a r_f N_L = (0.28)(120\ lbs)(2.5\ in)(6)$$

$$T = 504\ in\text{-}lbs$$

Substitute:

$$P = \frac{2\pi (504\ in\text{-}lbs)\left(\frac{1\ ft}{12\ in}\right)(380\ rpm)}{60}$$

$$P = \left(1671.3273\ \frac{lb\text{-}ft}{s}\right)\left(\frac{1\ hp}{550\ \frac{lb\text{-}ft}{sec}}\right)$$

$$P = 3.0385\ hp$$

$$T = f F_a \left[\frac{D^3 - d^3}{3(D^2 - d^2)}\right] N_c$$

$$= (0.30)(600\,\text{lbs})\left[\frac{(9\,\text{in})^3 - (4\,\text{in})^3}{3(9^2 - 4^2)}\right](1)$$

$$T = 613.8462\ \text{in-lb}$$

$$T = \frac{f\, F_a\, r_f}{\sin\alpha} = \frac{(0.40)(300\,N)\left(\frac{0.180\,m}{2}\right)}{\sin(12^\circ)}$$

$$T = 86.5752\ N\text{-}m$$

$$T = \frac{f\, F_a r_f}{\sin\alpha} \quad ; \quad P = \frac{2\pi T N}{60}$$

$$12\,kW = \frac{2\pi T (520\ rpm)}{60}$$

$$T = 0.2204\ kN\text{-}m$$

substituting:

$$0.03673\ kN\text{-}m = \frac{(0.40) F_a \left(\frac{0.310\ m}{2}\right)}{\sin(10^\circ)}$$

$$F_a = 0.6172\ kN$$

$$\boxed{F_a = 617.2\ N}$$

$$Q = f F_r V$$

$$\frac{220{,}000}{18}\ \frac{\text{lb-ft}}{\text{s}} = (0.30)\, F_r \left(40\ \text{ft/sec}\right)$$

$$F_r = 1018.5185\ \text{lbs}$$

$$P = \frac{2\pi TN}{60} \quad ; \quad T = (F_2 - F_1)r$$

$$= (820\ kg)\left(\frac{9.81\ m/s^2}{1000\ \frac{kg-m}{kN-s^2}}\right)\left(\frac{0.80\ m}{2}\right)$$

$$T = 3.2177\ kN-m$$

Substi;

$$P = \frac{2\pi (3.2177\ kN-m)(200\ rpm)}{60}$$

$$P = 94.3473\ kW$$

$$S_b = \frac{F_1}{wt} \quad ; \quad F_1 = 4F_2 \quad ; \quad T = (F_1 - F_2)r$$

$$T = (4F_2 - F_2)r$$

$$T = 3F_2 r$$

$$3\ kN\text{-}m = 3F_2\left(\frac{0.9}{2}\ m\right)$$

$$F_2 = 2.2222\ kN$$

Substi;

$$F_1 = 4(2.2222\ kN)$$

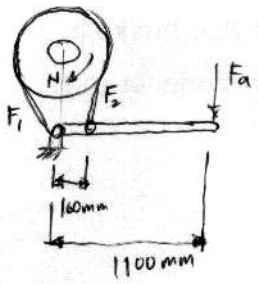
$$F_1 = 8.8889\ kN$$

Hence;

$$70\,000\ kPa = \frac{8.8889\ kN}{w(0.003\ m)}$$

$$w = 0.0423\ m$$

$$w = 42.3\ mm$$



$N = 260\ rpm$

$r = \frac{880\ mm}{2} = 440\ mm$

$\theta = 1.5\pi\ rad$

$f = 0.30$

$$F_a = \frac{F_2 a}{L}\ ;\quad \frac{F_1}{F_2} = e^{f\theta}$$

$$F_1 = F_2 e^{(0.3)(1.5\pi)}$$

$$F_1 = 4.1112\ F_2$$

and,

$$P = \frac{2\pi TN}{60}$$

$$70\ kW = \frac{2\pi T(260\ rpm)}{60}$$

$$T = 2.5709\ kN\text{-}m$$

then,

$$T = (F_1 - F_2)r$$

$$2.5709\ kN\text{-}m = (4.1112F_2 - F_2)(0.440m)$$

$$F_2 = 1.8781\ kN$$

Hence;

$$F_a = \frac{(1.8781\ kN)(0.160m)}{1.100m}$$

$$F_a = 0.2731\ kN$$

$$F_a = 273.1\ N$$

$$T = (F_1 - F_2)r \quad ; \quad \frac{F_1}{F_2} = e^{f\theta} = e^{(0.35)(250°)\left(\frac{\pi}{180°}\right)}$$

$$F_1 = 4.6051 F_2$$

Substy

$$12000 \text{ in-lbs} = (4.6051 F_2 - F_2)(15 \text{ in})$$

$$F_2 = 221.9079 \text{ lbs}$$

Hence;

$$\boxed{F_1 = 1021.9079 \text{ lbs}}$$

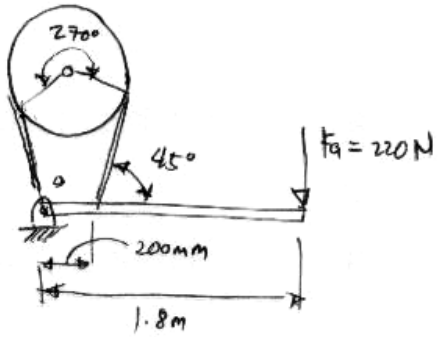
$$\frac{F_1}{F_2} = e^{f\theta}$$

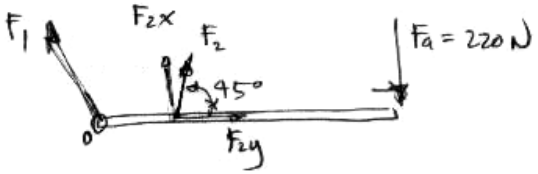
$$5 = e^{f(260°)\left(\frac{\pi}{180°}\right)}$$

$$5 = e^{4.5379f}$$

$$\ln 5 = 4.5379f$$

$$\boxed{f = 0.3547}$$





$[\Sigma M_O = 0]\ \circlearrowleft$

$(0.220\,kN)(1.8\,m) - F_{2x}(0.2\,m) = 0$

$0.396\,kN\text{-}m = F_2 \sin(45°)(0.2\,m)$

$F_2 = 2.800\,kN$

$$S_b = \frac{F_1}{wt}$$

$$60\ \frac{N}{mm^2} = \frac{8000\ N}{w(5\ mm)}$$

$$w = 26.6667\ mm$$

$(F_1 - F_2) = 8\ kN$; $\frac{F_1}{F_2} = 4$

$F_1 = 4F_2$

Substi;

$4F_2 - F_2 = 8\ kN$

$F_2 = 2.6667\ kN$

Hence;

$F_1 = 10.6667\ kN$

$F_1 = 3F_2 \quad ; \quad f = 0.3$

$$\frac{F_1}{F_2} = e^{f\theta}$$

$$\frac{3F_2}{F_2} = e^{(0.3)\theta}$$

$$3 = e^{0.3\theta}$$

$$\ln 3 = 0.3\theta$$

$$\theta = (3.6620 \text{ rad})\left(\frac{180^\circ}{\pi}\right)$$

$$\theta = 209.8171^\circ$$

$$P = \frac{2\pi TN}{60} \quad ; \quad T = (F_1 - F_2)r$$

$$= (5\ kN)(1.5\ m)$$

$$T = 7.5\ kN\text{-}m$$

Substitute

$$P = \frac{2\pi (7.5\ kN\text{-}m)(280\ rpm)}{60}$$

$$P = 219.9115\ kW$$