Answer Key

Shaft Design

1

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

$$320\ kW = \frac{2\pi T\,(850\ rpm)}{60}$$

$$T = 3.5950\ kN\text{-}m$$

Based on yeild stress

$$S_y = \frac{16T}{\pi D^3}$$

$$280000\ \frac{kN}{m^2} = \frac{16\,(3.5950\ kN\text{-}m)}{\pi D^3}$$

$$D = 0.0403\ m$$

Based on ultimate stress

$$S_u = \frac{16T}{\pi D^3}$$

$$380000\ \frac{kN}{m^2} = \frac{16\,(3.5950\ kN\text{-}m)}{\pi D^3}$$

$$D = 0.0364\ m$$

Choose :

$D = 40.3\ mm$

For Short Shafts

$$P = \frac{D^3 N}{38}$$

$$(120\,kW)\left(\frac{1\,hp}{0.746\,kW}\right) = \frac{\left[60\,mm\left(\frac{1\,in}{25.4\,mm}\right)\right]^3 N}{38}$$

$$\boxed{N = 463.7388\ rpm}$$

For Main SHAFT

$$P = \frac{D^3 N}{80} = \frac{(3.5\text{ in})^3(630\text{ rpm})}{80}$$

$$\boxed{P = 337.6406\text{ hp}}$$

For line shaft

$$P = \frac{D^3 N}{53.5}$$

$$130\ hp = \frac{(3\ in)^3 N}{53.5}$$

$$N = 257.5926\ rpm$$

for the tangential speed

$$v = \pi D N = \pi\left(18\text{-}in\right)\left(\frac{1\ ft}{12\ in}\right)\left(\frac{1\ m}{3.28\ ft}\right)\left(\frac{257.5926\ rpm}{60}\right)$$

$$\boxed{v = 6.1681\ m/s}$$

Exponential LEAP ONLINE REVIEW

$$\theta = \frac{TL}{JG} \quad ; \quad \frac{\theta}{L} = \frac{T}{JG} \quad ; \quad J = \frac{\pi D^4}{32} = \frac{\pi (0.060 m)^4}{32}$$

$$J = 1.2723 \times 10^{-6} \ m^4$$

Hence;

$$\frac{\theta}{L} = \frac{(1800 \text{ kN-mm})\left(\frac{1 m}{1000 mm}\right)}{(1.2723 \times 10^{-6} m^4)(80 \times 10^6 \ kN/m^2)}$$

$$\frac{\theta}{L} = \left(0.01768 \frac{rad}{m}\right)\left(\frac{180°}{\pi \ rad}\right)$$

$$\boxed{\frac{\theta}{L} = 1.0132 \frac{deg}{rad}}$$

7

$$hp = \frac{2\pi TN}{33000}$$

$$30hp = \frac{2\pi T(1300\,rpm)}{33000}$$

$$T = (121.2026\ ft\text{-}lb)\left(\frac{12\,in}{1ft}\right)$$

$$\boxed{T = 1454.4313\ in\text{-}lb}$$

Solid shaft ; Hollow shaft

$$S_s = \frac{16T}{\pi D_s^3} \quad ; \quad S_s = \frac{16TD}{\pi(D^4 - d^4)}$$

equating ;

$$\frac{16T}{\pi D_s^3} = \frac{16TD}{\pi(D^4 - d^4)}$$

$$\frac{1}{D_s^3} = \frac{D}{D^4 - d^4}$$

$$D_s^3 = \frac{D^4 - d^4}{D}$$

$$D_s^3 = \frac{(5\,in)^4 - (3.5\,in)^4}{5\,in}$$

$$\boxed{D_s = 4.5627\ in}$$

$$\theta = \frac{TL}{JG} \;;\; J = \frac{\pi D^4}{32} = \frac{\pi\,(1/4\text{ in})^4}{32} = 3.8349 \times 10^{-4}\text{ in}^4$$

substi;

$$\theta = \frac{(28\text{ in-lb})(10\text{ in})}{(3.8349 \times 10^{-4}\text{ in}^4)(11000000\text{ lb/in}^2)}$$

$$\theta = (0.06638\text{ rad})\left(\frac{180^\circ}{\pi\text{ rad}}\right)$$

$$\boxed{\theta = 3.8030^\circ}$$

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

$$50\,\frac{N}{mm^2} = \frac{16\,(100\,N\text{-}m)\left(\frac{1000\,mm}{1\,m}\right)}{\pi D^3}$$

$$\boxed{D = 21.6770\ mm}$$

$$L = 8.95\sqrt[3]{D^2}$$

$$15\text{ ft} = 8.95\sqrt[3]{D^2}$$

$$D = 2.1697\text{ in}$$

and;

$$D = 4.6\sqrt[4]{\frac{P}{N}}$$

$$2.1697\text{ in} = 4.6\sqrt[4]{\frac{P}{280\text{ rpm}}}$$

$$\boxed{P = 13.8588\text{ hp}}$$

$$L = 8.95\sqrt[3]{D^2}$$

$$8\,ft = 8.95\sqrt[3]{D^2}$$

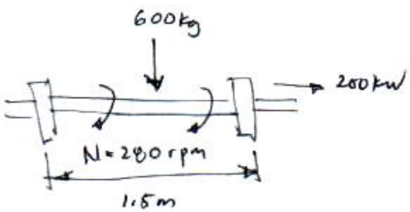
$$\boxed{D = 0.8451\ in}$$

$$S_t = \frac{16}{\pi D^3}\left(M + \sqrt{M^2 + T^2}\right)$$

$$= \frac{16}{\pi(0.120\ m)^3}\left(3\ kN\text{-}m + \sqrt{(3\ kN\text{-}m)^2 + (8\ kN\text{-}m)^2}\right)$$

$$S_t = 34023.8011\ kPa$$

$$\boxed{S_t = 34.0238\ MPa}$$



$$M = \frac{FL}{4} = \frac{(600\ \text{kg})\left(\dfrac{9.81\ \text{m/s}^2}{1000\ \frac{\text{kg-m}}{\text{kN-s}^2}}\right)(1.5\ \text{m})}{4} = 2.2073\ \text{kN-m}$$

and;

$$P = 2\pi T N$$

$$200\ \frac{\text{kN-m}}{\text{s}} = 2\pi T\left(\frac{280\ \text{rpm}}{60}\right)$$

$$T = 6.8209\ \text{kN-m}$$

Hence;

$$S_s = \frac{16}{\pi D^3}\sqrt{M^2 + T^2}$$

$$45000\ \text{kPa} = \frac{16}{\pi D^3}\sqrt{(2.2073)^2 + (6.8209)^2}$$

$$D = 0.09327\ \text{m}$$

$$\boxed{D = 93.27\ \text{mm}}$$

SOLID SHAFT

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

HOLLOW SHAFT

$$S_s = \frac{16TD}{\pi(D^4 - d^4)}$$

EQUATING;

$$\frac{16T}{\pi D_s^3} = \frac{16TD}{\pi(D^4 - d^4)}$$

$$\frac{1}{(2.5\,in)^3} = \frac{3.5\,in}{[(3.5\,in)^4 - d^4]}$$

$$\boxed{d = 3.1251\ in}$$

Short SHAFT ;

$$P = \frac{D^3 N}{38}$$

$$45\ hp = \frac{(1.8\ in)^3 N}{38}$$

$$N = (293.2099\ rpm)\left(\frac{1\ min}{60\ s}\right)$$

$$\boxed{N = 4.8868\ rps}$$

Main Shaft

$$P = \frac{D^3 N}{80} = \frac{\left[(60\,\text{mm})\left(\frac{1\,\text{in}}{25.4\,\text{mm}}\right)\right]^3 (280\,\text{rpm})}{80}$$

$$\boxed{P = 46.1339\ \text{hp}}$$

exponential LEAP
ONLINE REVIEW

Line Shafts

$$P = \frac{D^3 N}{53.5}$$

$$(180\,kW)\left(\frac{1\,hp}{0.746\,kW}\right) = \frac{D^3\left(\frac{20\,rev}{sec}\right)\left(\frac{60\,sec}{1\,min}\right)}{53.5}$$

$$\boxed{D = 2.2075\ in}$$

$$S_s = \frac{16T}{\pi D^3} = \frac{16\,(25\,000 \text{ in-lb})}{\pi\,(3 \text{ in})^3}$$

$$\boxed{S_s = 4715.7020 \text{ psi}}$$

Exponential LEAP
ONLINE REVIEW

$$\theta = \frac{TL}{JG} \quad ; \quad S_s = \frac{16T}{\pi D^3} \quad ; \quad J = \frac{\pi D^4}{32}$$

equating $T = T$

$$\frac{G\theta J}{L} = \frac{\pi S_s D^3}{16}$$

$$\frac{G\pi\theta D^4}{32L} = \frac{\pi S_s D^3}{16}$$

$$D = \frac{2 S_s L}{\theta G} = \frac{2(80\text{ MPa})(5\text{ m})}{(5^\circ)\left(\frac{\pi}{180^\circ}\right)(90\times10^3\text{ MPa})}$$

$$D = 0.1019\text{ m}$$

$$\boxed{D = 101.9\text{ mm}}$$

$$\theta = \frac{TL}{JG}$$

$$(4\ \text{deg})\left(\frac{\pi}{180^\circ}\right) = \frac{(15\ \text{kN-m})(8\ \text{m})}{J\,(85\times10^6\ \text{kPa})}$$

$$J = 2.0222\times10^{-5}\ \text{m}^4$$

for solid ~~sHaf~~ shaft:

$$J = \frac{\pi D^4}{32}$$

$$2.0222\times10^{-5}\ \text{m}^4 = \frac{\pi D^4}{32}$$

$$D = 0.1198\ \text{m}$$

$$\boxed{D = 119.8\ \text{mm}}$$

$$\frac{\theta}{L} = \frac{T}{JG} = \frac{F(D/2)}{JG}$$

$$J = \frac{\pi D^4}{32} = \frac{\pi\left[2.5\,in\left(\frac{1\,ft}{12\,in}\right)\left(\frac{1\,m}{3.28\,ft}\right)\right]^4}{32}$$

$$J = 1.5979 \times 10^{-6}\ m^4$$

then;

$$\frac{\theta}{L} = \frac{(6\,kN)\left(\frac{1}{2}\,ft\right)\left(\frac{1\,m}{3.28\,ft}\right)}{(1.5979 \times 10^{-6}\,m^4)(83 \times 10^6\,kPa)}$$

$$\frac{\theta}{L} = \left(6.8964 \times 10^{-3}\ \frac{rad}{m}\right)\left(\frac{180°}{\pi}\right)$$

$$\boxed{\frac{\theta}{L} = 0.3951\ deg/m}$$

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

$$28\,000\ kPa = \frac{16\,(2\ kN\text{-}m)}{\pi D^3}$$

$$D = 0.07139\ m$$

then;

$$S_s = \frac{Tc}{J} = \frac{TD}{2J}$$

$$28000\ kPa = \frac{(2\ kN\text{-}m)(0.07139\ m)}{2J}$$

$$\boxed{J = 2.5495 \times 10^{-6}\ m^4}$$

$$S_s = \frac{16TD}{\pi(D^4 - d^4)} \quad ; \quad P = \frac{2\pi TN}{60}$$

$$120\ kW = \frac{2\pi T(700\ rpm)}{60}$$

$$T = 1.6370\ kN\text{-}m$$

subst;

$$S_s = \frac{16(1.6370\ kN\text{-}m)\left(\frac{1000\ N}{1\ kN}\right)\left(\frac{1000\ mm}{1\ m}\right)(110\ mm)}{\pi(110^4 - 90^4)\ mm^4}$$

$$\boxed{S_s = 11.3503\ MPa}$$

$$S_s = \frac{16TD}{\pi(D^4 - d^4)}$$

$$50\,000 \text{ kPa} = \frac{16(6 \text{ kN-m})(0.090\text{m})}{\pi(0.090^4 - d^4)\text{m}^4}$$

$$d = 0.0571 \text{ m}$$

$$\boxed{d = 57.10\text{mm}}$$

exponential LEAP ONLINE REVIEW

$$\theta = \frac{584TL}{D^4G} \; ; \quad L = 20D \; ; \quad T = \text{in-lb}, \; G = \text{psi}, \; \theta = \text{deg}$$

$$\theta = \frac{584T(20D)}{D^4G} = \frac{11680T}{D^3G}$$

$$1\text{ deg} = \frac{11680(2.5\text{ kN-m})\left(\frac{778\text{ ft-lb}}{1.055\text{ kN-m}}\right)\left(\frac{12\text{ in}}{1\text{ ft}}\right)}{D^3(80\times10^6\text{ kPa})\left(\frac{14.6\text{ psi}}{101.325\text{ kPa}}\right)}$$

$$D = (2.8196\text{ in})\left(\frac{25.4\text{ mm}}{1\text{ in}}\right)$$

$$\boxed{D = 71.6179\text{ mm}}$$

alternate solution:

Shaft Deflection of 1 deg for a length 20 times its diameter (for steel)

$$D = 0.10\sqrt[3]{T}$$

$$D = 0.10\sqrt[3]{(2.5\text{ kN-m})\left(\frac{778\text{ ft-lb}}{1.055\text{ kN-m}}\right)\left(\frac{12\text{ in}}{1\text{ ft}}\right)}$$

$$D = (2.8073\text{ in})\left(\frac{25.4\text{ mm}}{1\text{ in}}\right)$$

$$\boxed{D = 71.3054\text{ mm}}$$

$$S_s = \frac{16T}{\pi D^3} \; ; \quad hp = \frac{2\pi T N}{33000}$$

$$60\,hp = \frac{2\pi T(1500\text{ rpm})}{33000}$$

$$T = 210.0845 \text{ lb-ft}$$

Subst;

$$550\frac{\text{lb}}{\text{in}^2} = \frac{16(210.0845\text{ lb-ft})\left(\frac{12\text{ in}}{1\text{ ft}}\right)}{\pi D^3}$$

$$\boxed{D = 2.8579\text{ in}}$$

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

$$30 \times 10^3 \frac{kN}{m^2} = \frac{16T}{\pi(0.064m)^3}$$

$$T = 1.5442 \text{ kN-m}$$

Then;

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

$$80 \text{ kW} = \frac{2\pi(1.5442 \text{ kN-m})N}{60}$$

$$\boxed{N = 494.7323 \text{ rpm}}$$

$$S_d = \frac{S_y}{F.S.} \quad ; \quad S_s = \frac{16TD}{\pi(D^4 - d^4)}$$

$$\frac{16TD}{\pi(D^4 - d^4)} = \frac{S_y}{F.S.}$$

$$\frac{16(4000\ N\text{-}m)\left(\frac{1000\ mm}{1\ m}\right)(90\ mm)}{\pi(90^4 - d^4)\ mm^4} = \frac{380\ mPa}{4}$$

$$\boxed{d = 82.4935\ mm}$$

exponential LEAP ONLINE REVIEW

$$S_s = \frac{16T}{\pi D^3} \quad ; \quad P = 2\pi T N$$

$$120\ kW = 2\pi T \left(6\ \frac{rev}{sec}\right)$$

$$T = 3.1831\ kN\text{-}m$$

subst;

$$100 \times 10^3 \frac{kN}{m^2} = \frac{16(3.1831\ kN\text{-}m)}{\pi D^3}$$

$$D = 0.05453\ m$$

$$\boxed{D = 54.53\ mm}$$

exponential LEAP
ONLINE REVIEW

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

$$230\ kw = \frac{2\pi\ T\ (380\ rpm)}{60}$$

$$T = 5.7798\ kN-m$$

then;

$$T = Fr$$

$$5.7798\ kN-m = F\left(\frac{0.210\ m}{2}\right)$$

$$F = 55.0461\ kN$$