A8: Gearbox Design

Gear Ratio 24:9
Output Torque = 1.25 in-lbf
Output Speed = 1100 rpm

Input (pinion, power-transmission) ⌀ 0.125 in
Output (gear, short shaft) ⌀ 0.25 in

lengths = 1 in

Assumptions:
- appropriate strength of shafts (Machinery's Handbook)
- Gear train is ideal
- moment of radial force from gear train is small enough to be ignored

Note:
- shafts are press fit through the hubs of the gears
- Make sure enough clearance b/w gears + gearbox
- Use running sliding fit for size of hole for the shafts

04 01 2026

Input Shaft: power-transmission

known

$\phi = 0.125$ in

$\ell = 1.00$ in

$S_s = 4{,}000\,psi$ (machinery's handbook)

$N_{input} = 1100\left(\frac{24}{9}\right) = 2933.33\ rpm$

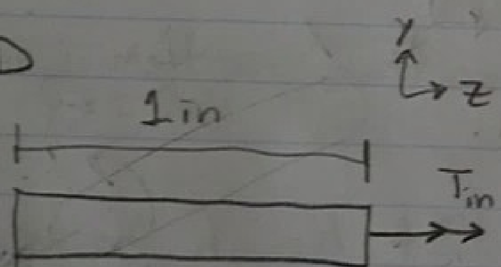
$T_{input} = 1.25\left(\frac{9}{24}\right) = 0.46875\ in\text{-}lb_f$

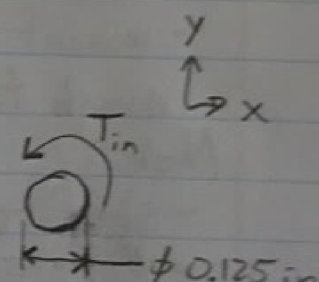
Unknowns

P

τ - shear stress

FBD





$$P = \frac{D^3 N}{80} = \frac{(0.125)^3(2933.33)}{80} = 0.0716\ hp$$

$$\sqrt[3]{\frac{5.1T}{S_s}} = D_{req_{Torque}} = \sqrt[3]{\frac{5.1(0.46875\ lb\text{-}ft)}{4{,}000\ psi}} = \phi\, 0.0842\ in \checkmark$$

$$\sqrt[3]{\frac{321000P}{NS_y}} = D_{req_{Power}} = \sqrt[3]{\frac{321000(0.0716hp)}{(2933.33rpm)(4000psi)}} = \phi\, 0.12512\ in \checkmark$$

$$\tau = \frac{Tr}{J} = \frac{T\frac{d}{2}}{\frac{\pi d^4}{32}} = \frac{32(0.46875\ lb\text{-}in)\left(\frac{0.125in}{2}\right)}{\pi(0.125)^4}$$

$$\boxed{\tau = 1222.31\ psi \ll \underset{S_s}{4{,}000\ psi}}$$

Output Shaft: short shaft

$$S_s = 8{,}500\,psi$$ (machinery's handbook)

<u>known</u>

$\phi = 0.25\,in$

$l = 1.00\,in$

$N_{out} = 1100\,rpm$

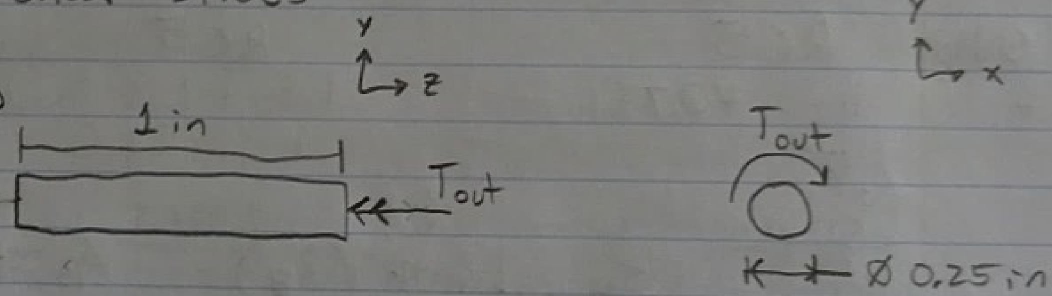
$T_{out} = 1.25\,in\text{-}lbf$

<u>Unknowns</u>

P

τ - shear stress

FBD



$$P = \frac{D^3 N}{38} = \frac{(0.25)^3(1100)}{38} = 0.4523\,hp$$

$$\sqrt[3]{\frac{5.1T}{S_s}} = D_{req\,Torque} = \sqrt[3]{\frac{5.1(1.25\,in\text{-}lbf)}{8{,}500\,psi}} = \underline{0.0909\,in} \checkmark$$

$$\sqrt[3]{\frac{321000P}{NS_s}} = D_{req\,Power} = \sqrt[3]{\frac{321000(0.4523\,hp)}{(1100\,rpm)(8{,}500\,psi)}} = 0.24948\,in \checkmark$$

$$\tau = \frac{Tr}{J} = \frac{T\frac{d}{2}}{\frac{\pi d^4}{32}} = \frac{16T}{\pi d^3} = \frac{16(1.25\,in\text{-}lb)}{\pi(0.25\,in)^3}$$

$$\boxed{\tau = 407\,psi \ll 8{,}500\,psi}$$

Journal Bearing

PV-rating

Known

$N_{in} = 2933.33\ rpm$ $\quad$ $N_{out} = 1100\ rpm$

$T_{in} = 0.46875\ in\text{-}lb_f$ $\quad$ $T_{out} = 1.25\ in\text{-}lb_f$

Bearing depth << 1 in $\quad$ " $\quad$ "

Shaft $\phi = 0.125\ in$ $\quad$ Shaft $\phi = 0.25\ in$

Running-Sliding Fit $\quad$ RC5 $\quad$ RC5

hole +0.7 thou $\quad$ hole + 1.8 thou

Uknown

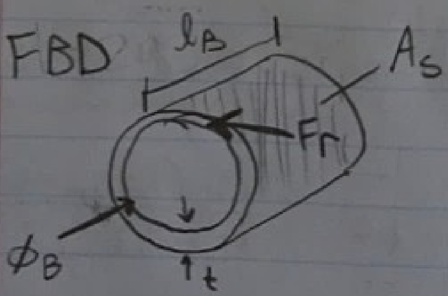
P $\quad$ Bearing Length (l_B) $\quad$ ϕ_B - Bearing diameter

V $\quad$ Surface Area (A_s)

PV $\quad$ F_r - radial load

Input Bearing

FBD



$$V = 2933.33\ \frac{rev}{min}\left(\frac{\pi\ \phi_B\ in}{1\ \cancel{rev}}\right)\left(\frac{1 ft}{12 \cancel{in}}\right)$$

$$\phi_B = 0.125 in + 0.0007 in$$

$$\phi_B = 0.1257 in$$

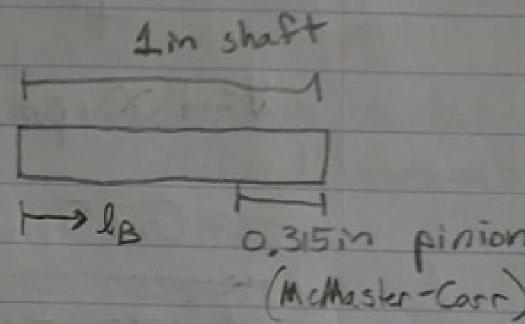
$$\boxed{V = 96.5\ ft/min}$$

Input Bearing: continued

$$\boxed{P = \frac{F}{A}} \qquad F_r = \frac{T}{r} = \frac{T}{\phi/2} = \frac{2T}{\phi_B}$$

$$F_r = (0.46875\ \text{in-lb})(2)/(0.1257\ \text{in})$$

$$F_r = 7.458\ lb_f$$



$$A_s = l_B \times \pi \phi_B$$

<u>Assumption</u>: $l_B = 1/4''$

$$A_s = 0.25\ \text{in}(\pi(0.1257\ \text{in})) = 0.0987\ \text{in}^2$$

$$P = \frac{F_r}{A_s} = \frac{7.458\ lbf}{0.0987\ \text{in}^2} = \boxed{P = 75.56\ psi}$$

$$\boxed{PV = 2735.272\ psi - \frac{ft}{min}}$$

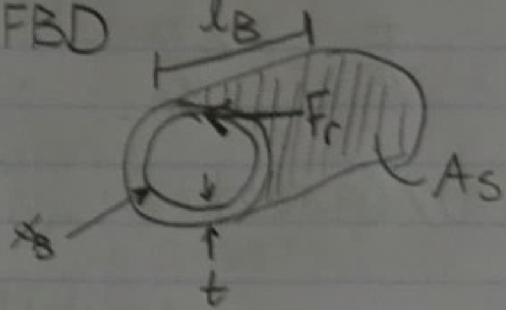
Bearing Material → Anything but Rubber or TFE

$$\boxed{\text{Graphite (dry)}}$$

$P = 600\ psi$ ✓ $\qquad V = 2500\ \frac{ft}{min}$ ✓ $\qquad PV = 15{,}000$ ✓

Output Bearing

FBD



$$V = 1100\,rpm\left(\pi \phi_B\right)\left(\frac{1\,ft}{12\,in}\right)$$

$$\phi_B = 0.25\,in + 0.0018\,in = 0.2518\,in$$

$$\boxed{V = 72.51\ \frac{ft}{min}}$$

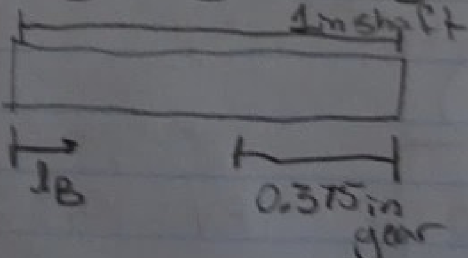
$$\boxed{P = \frac{F}{A}} \qquad F_r = \frac{T}{r} = \frac{2T}{\phi_B}$$

$$F_r = (1.25\,in\text{-}lb_f)(2)/(0.02518\,in)$$

$$F_r = 99.285\ lb_f$$

$$A_S = l_B \times \pi\,\phi_B$$

Assumption: $l_B = 1/4''$



$$A_S = (0.25\,in)(\pi(0.2518\,in)) = 0.1978\,in^2$$

Output Bearing: continued

$$P = \frac{F_r}{A_s} = \frac{99.285\ lbf}{0.1978\ in^2} = \boxed{502.04\ psi = P}$$

$$\boxed{PV = 36402.95\ psi - \frac{ft}{min}}$$

Bearing Material ⟶ Anything but rubber, TFE, Acetal, or Nylon, Polycarbonate

Graphite (dry)

$P = 600\,psi$ ✓ $V = 2500\,\frac{ft}{min}$ ✓ $PV = 15,000$ ✓

Bearing Thickness

Knowns

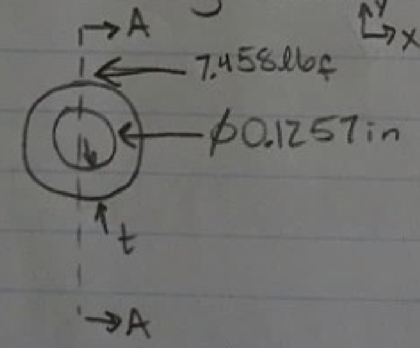
$P_{in} = 75.56\,psi$
$\phi_B = 0.1257\,in$
$l_B = 0.25\,in$
$F_r = 7.458\,lbf$

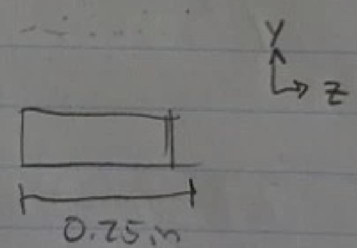
$P_{out} = 502\,psi$
$\phi_B = 0.2518\,in$
$l_B = 0.25\,in$
$F_r = 99.285\,lbf$

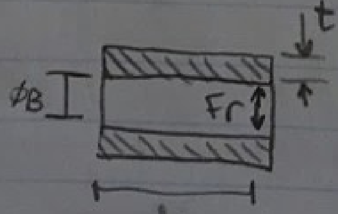
Unknowns

t

Input Bearing Thickness







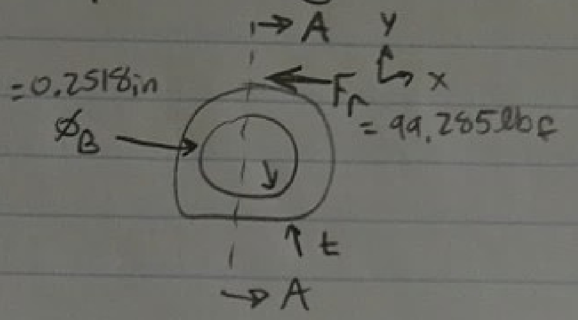
$$P = \frac{F}{A} \qquad A = 2t \times l_B$$

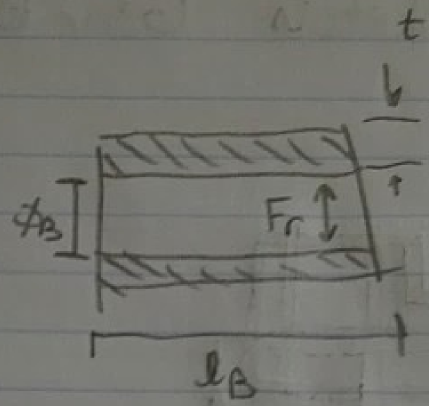
$$P = \frac{F}{2t\,l_B}$$

$$t = \frac{F}{2P\,l_B} = \frac{(7.458)}{2(75.56)(0.25)}$$

$$t_{min} \approx 0.1974\,in$$

Output Bearing Thickness





$$P = \frac{F}{A} \qquad A = 2t \times l_B$$

$$t = \frac{F}{2Pl_b} = \frac{(99.285)}{2(502)(0.25)}$$

$$t_{min} \approx 0.3956 \text{ in}$$

Bearing Selection McMaster-Carr

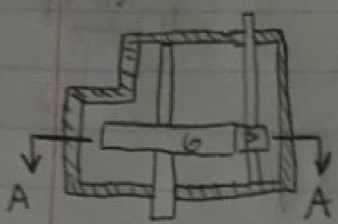
Input

9368T96

Output

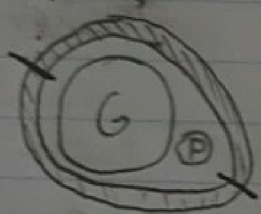
9368T13

Sketch Gearbox

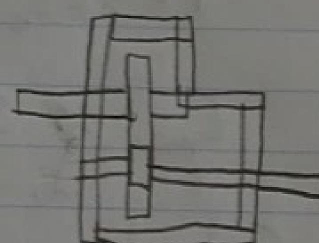


Top

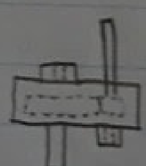
A-A



Front

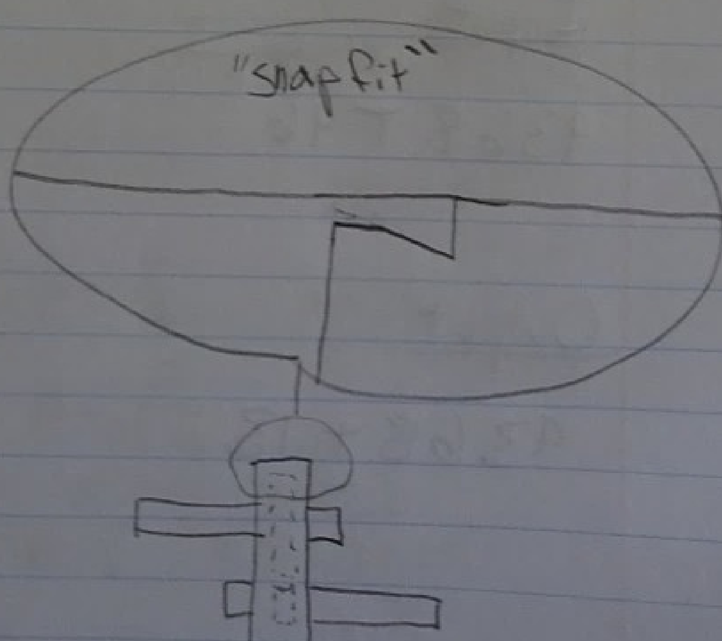


side



TOP

FRONT



SIDE