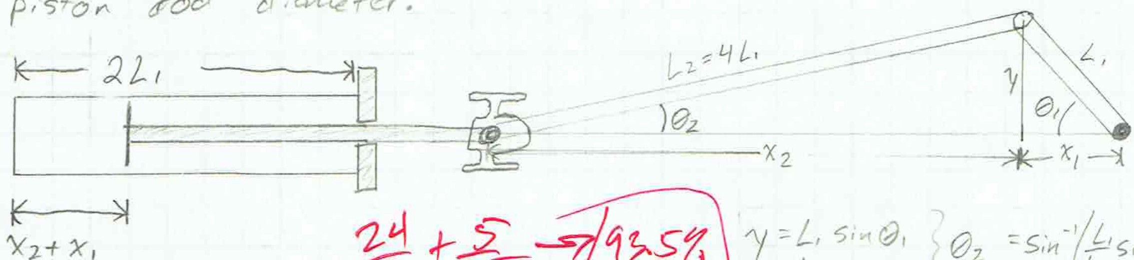
1 Design a steam engine that produces avg net $HP = 3.00 \pm 0.1$ @ 240 rpm. Neglect friction + inertial losses. Ratio of $L_2/L_1 = 4$. The calc. of avg net power must account for piston rod diameter.



$\frac{24}{26} + \frac{5}{5} \rightarrow \boxed{93.5\%}$

$y = L_1 \sin\theta_1 = L_2 \sin\theta_2 \Big\} \theta_2 = \sin^{-1}\left(\frac{L_1}{L_2}\sin\theta_1\right)$

$x_1 = L_1 \cos\theta_1$

$x_2 = L_2 \cos\theta_2 = L_2\cos\left(\sin^{-1}\left(\frac{L_1}{L_2}\sin\theta_1\right)\right)$

$$v = \frac{(L_1+L_2)-(x_2+x_1)}{2L_1}$$

$$v = \frac{(L_1+L_2) - L_2\cos\left(\sin^{-1}\left(\frac{L_1}{L_2}\sin\theta_1\right)\right) - L_1\cos\theta_1}{2L_1}$$

$\downarrow$

$$\theta_1 = \cos^{-1}\left(\frac{L_1(2v-2v^2-1)+L_2(2v-1)}{L_1(2v-1)-L_2}\right)$$

Guess
Bore = 3"
Piston Dia = 1"
Crank length = 5"

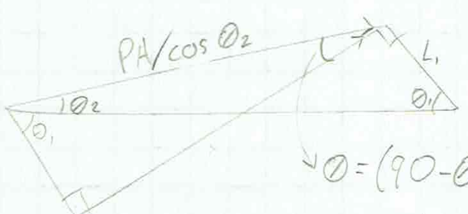
piston rod $F = PSI \cdot Area$

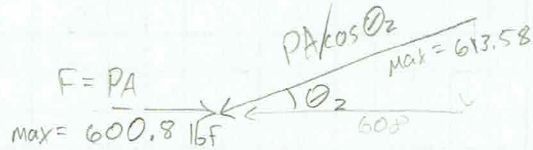
$F_{max} = 85\text{ psi} \cdot \pi\, 1.5^2$
$= 600.83$ lbf comp

↳ will not fail in tension, neglect "return" stroke

Work on stroke $= \Sigma(PSI)\cdot(\Delta Vol)$

Force in conrod





$\varnothing = (90 - \theta_1 - \theta_2)$

$$T_{\text{on crank}} = \left(\frac{PA}{\cos\theta_2}\right)\cos(90-\theta_1-\theta_2)\,L_1$$

1018 steel
$S_y = 32$ Kpsi
$S_u = 49.5$ Kpsi
$E = 29 \times 10^6$ psi

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PISTON ROD

guess $d = 3/8''$

$\sigma_a = \frac{F}{A} = \frac{600.8}{\frac{\pi}{4} d^2}$

$r^2 = \frac{d^2}{4}$

$K = \sqrt{\frac{I}{A}} = \sqrt{\frac{\pi r^4}{4 \pi r^2}} = \sqrt{\frac{r^2}{4}} = \sqrt{\frac{d^2}{16}} = \frac{d}{4}$

$2 = n = \frac{S_e}{\sigma_a} = \frac{(0.5 \cdot 49.5)(.96)(.879 d^{-.107})(.85)(1.022)(.814)\frac{\pi}{4} d^2}{600.8} \rightarrow d = 0.301''$

$\boxed{d = \frac{3}{8} = .375''}$

$\left(\frac{l}{k}\right) = \left(\frac{9}{\frac{.375}{4}}\right) = 96 < 133 = \left(\frac{2\pi^2 E}{S_y}\right)^{1/2}$

Johnson formula solved for d

$d = \pm \frac{2\sqrt{l^2 S_y^2 + \pi n P E}}{\pi \sqrt{S} \sqrt{E}} = 0.289''$

CONNECTING ROD

1 for axial

-1

$n = \frac{S_e}{\sigma_a} = 2 = \frac{(24.75)(.96)\cancel{\left(\frac{d}{.3}\right)^{-.107}}(.85)(1)(.814)\frac{\pi}{4} d^2}{613.58} \longrightarrow d = .308''$

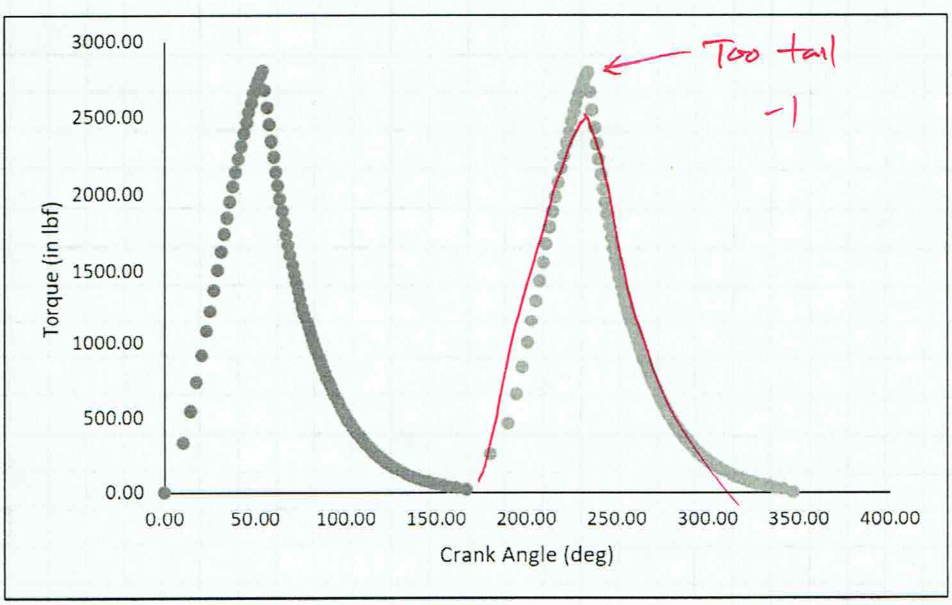
$\left(\frac{l}{k}\right) = \left(\frac{20}{\frac{.625}{4}}\right) = 128 < 133 = \left(\frac{l}{k}\right)_1 = \left(\frac{2\pi^2 E}{S_y}\right)^{1/2}$

$d = \pm \frac{2\sqrt{l^2 S_y^2 + \pi n P E}}{\pi \sqrt{S_y} \sqrt{E}} = 0.477'' \longrightarrow d = \frac{4}{8} = \frac{1}{2}''$

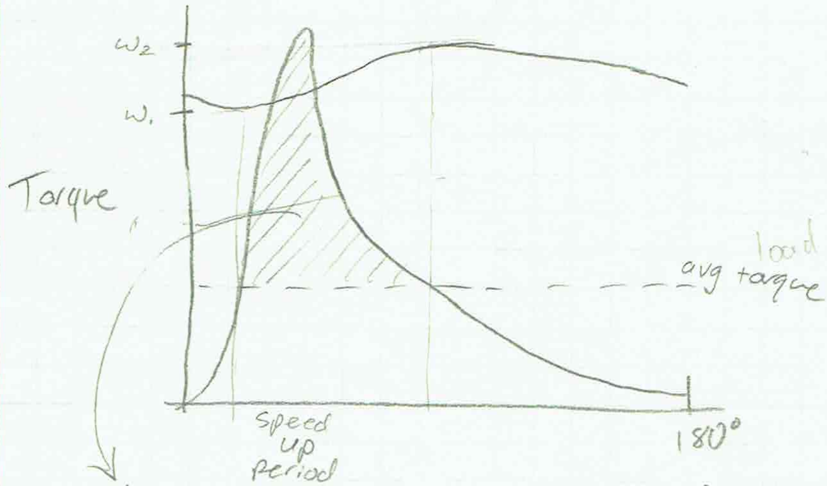
(a) $\boxed{\text{Piston Rod dia.} = .375''}$ $\boxed{\text{Con Rod dia.} = .500''}$

(b) $\boxed{\text{Bore Dia.} = 3.00''\quad \text{Crank Arm Length} = 5.00''\quad \text{ConRod Length} = 20.0''\quad \text{Stroke} = 10.0''}$

(c)



2 Design a flywheel for the steam engine so it provides constant torque w/ fluctuation of 0.005.



r=6

Area represents $E_2 - E_1 = 72.59\,ft\,lb = C_s I \omega^2$

$C_s = .005$

$I = 23\,ft\,lbf\,s^2 = \frac{1}{2} M R^2$

$\rho = .258 \frac{lb}{in^3}$

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$\rho \pi r^2 t = M = 5946\,lb$

$t = 203''$

(a) Det. the energy that must be store & restored, for largest torque fluctuation.

$\boxed{E_2 - E_1 = 72.59\ ft\ lbf}$

(b) Det. the req. flywheel inertia

$\boxed{I = 275.87\ in\ lbf\ s^2}$

(c) Det the flywheel thickness if it's a solid disk, 12" diameter from ASTM no. 20 gray cast iron.

$\boxed{t = 203''}$

$23\,ft\,\cancel{lbf}\,\cancel{s^2} \cdot \frac{32\,ft\,lb}{1\,\cancel{lbf}\,\cancel{s^2}}$