Pumps

Def: A mechanical device which transforms the mechanical energy to the hydraulic energy and transfer it to liquid through the pipeline.

Types:

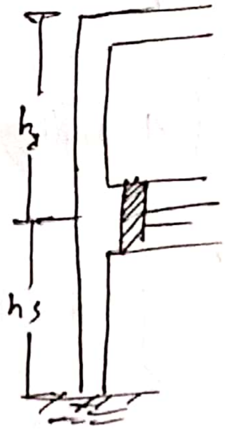
(i) Rotodynamic - Provide pressure by expanding and contracting.

(ii) Positive displacement - uses rotation of or impeller to provide velocity to the liquid

Diff between - Reiprocating & contrifugal pumps

wer Input:

h_s = static head = suction head
= diff between center of cylinder and water level



h_d = derivery head

h_v = velocity head

H_{st} = Total static head
$= H_s + h_d + h_v$

theoretical work-done, $W = \cancel{H_{st} \times Q}\ PQ$

$= \rho g H_{st} Q_{th}$

$$\boxed{\therefore W = \rho\left(\frac{ALN}{60}\right) g\,(h_s + h_d)}$$

$\therefore$ Power Input

Actual $\boxed{\text{Power Input} = \frac{1}{\eta} W}$

Problem 1: A single acting reciprocating pump discharge 0.018 m³/s of water per second when running at 60 rpm. Stroke length is 50 cm and the diameter of the piston is 22 cm. If the total lift is 15 m

(i) Q_{th}

(ii) Slip and percentage of slip

(iii) co eff of discharge

(iv) power

4 Reciprocating Pumps:

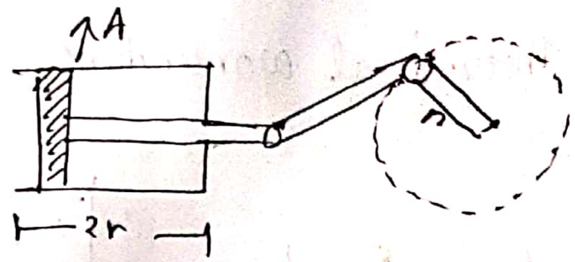
Types:

(i) Single acting
(ii) Double acting } According use of piston sides

(i) single cylinder
(ii) Double "
(iii) Triple " } " piston. number

Discharge:

A = area of cylinder
r = crank radius
L = stroke length
N = rpm



∴ for single acting, $Q_{th} = \frac{ALN}{60}$

" Double " , $Q_{th} = \frac{2ALN}{60}$

Slip:

$\% \text{ Slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$

$\text{Slip} = Q_{th} - Q_a$

ere:

$Q_a = 0.018\ m^3/s$

$N = 60$

$A = 0.038\ m^2$

$H_{st} = 15\ m$

$L = 0.5\ m$

(a): $Q_{th} = \frac{ALN}{60} = 0.017\ m^3/s$

(b) $Slip = Q_{th} - Q_a = 0.001\ m^3/s$

(c) $\%\ Slip = \frac{0.001}{0.017} = 5.21\%$

(d) $Power = \rho g H_{st} Q_{th} = 1000 \times 9.8 \times 15 \times 0.019$

$= 2793 = 2.796\ kW$ $\boxed{Ans}$

Problem 2: A three row reciprocating pump delivering 0.1 m³/s of water against a head of 100 m. Diameter and stroke length are 25 cm and 50 cm. Friction losses amount to 1 m in the suction pipe and 16 m in the delivery pipe. If the velocity of water in the delivery pipe is 1.4 m/s, pump efficiency 90%, slip 2%, determine rotational speed and power

Ans:

$Q_a = 0.1$

$H_{st} = 100$

$h_f = \cancel{0.45m}\ 1m$

$h_d = 16m$

$V = 1.4$

$L = 50cm$

$\eta = 0.9$

$A =$

$\% Slip = 0.02 = \frac{Q_{th} - Q_A}{Q_{th}}$

$\Rightarrow Q_{th} = 0.98 \times 0.1$

$\Rightarrow \frac{3ALN}{60} = 0.02 \times 0.1$

$\therefore N =$

$\% \text{Slip} = \frac{Q_{th} - Q_a}{Q_{th}}$

$\Rightarrow 0.02 = 1 - \frac{Q_a}{Q_{th}}$

$\Rightarrow \frac{Q_a}{Q_{th}} = 1 - 0.02 = 0.98$

$\Rightarrow Q_{th} = \frac{Q_a}{0.98}$

$\Rightarrow \frac{3ALN}{60} = \frac{0.1}{0.98}$

$\therefore N = 83.15$

Total head $= H = H_{st} + H_s + H_d + H_v = 117 + \frac{1.4^2}{2 \times 9.8} = 117.1$ m

$\therefore P = \frac{1}{\eta} \rho g H_{st} Q_{th} = \frac{1000 \times 9.8 \times 117.1 \times \frac{3 \times ALN}{60}}{0.9}$

$= 130110.58 \approx 130.11$ kW

Ans.

Problem 2:

A ~~three throw~~ double acting reciprocating pump has a stroke of 300 mm and a piston of diameter 150 mm. The delivery and suction heads are 26 m and 4 m respectively including friction heads. If the pump is working at 60 rpm, find the power required to drive the pump with 80% efficiency. Take dia of piston ~~are~~ rods are 25mm.

$L = 3m$

$A = 0.0176 m^2$

$h_s = 4m$

$h_d = 26$

$N = 60$

$\eta = 0.8$

Area of piston rod $= A_p = \frac{\pi \times (25\times10^{-3})^2}{4} = 4.9 \times 10^{-4} m^2$

$\therefore Q_{th} = \frac{ALN}{60} + \frac{(A-A_p)LN}{60}$

$= \frac{LN}{60} \times (2A - A_p)$

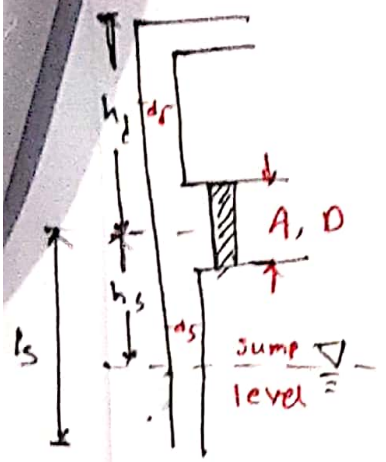
$= 0.01\ m^3/s$

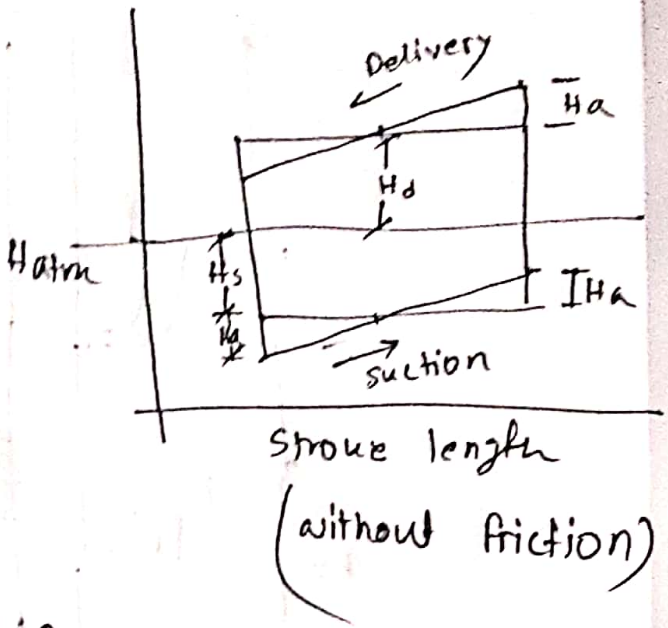
$\therefore H_{st} = h_s + h_d = 4+26 = 30m$

$\therefore P = \frac{1}{\eta} \rho g H_{st} Q_{th}$

$= \frac{1}{0.8} \times 1000 \times 9.81 \times 30 \times 0.01 = 3.678\ kW$ Ans.

Indicator Diagram with acceleration:





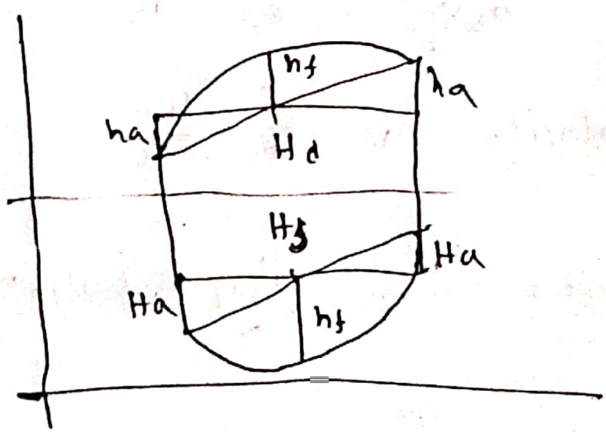
Velocity in pipe $= \frac{A}{a} \omega r \sin\theta$

Acceleration pressure head, $H_a = \frac{l}{g} \frac{A}{a} \omega^2 r \cos\theta$

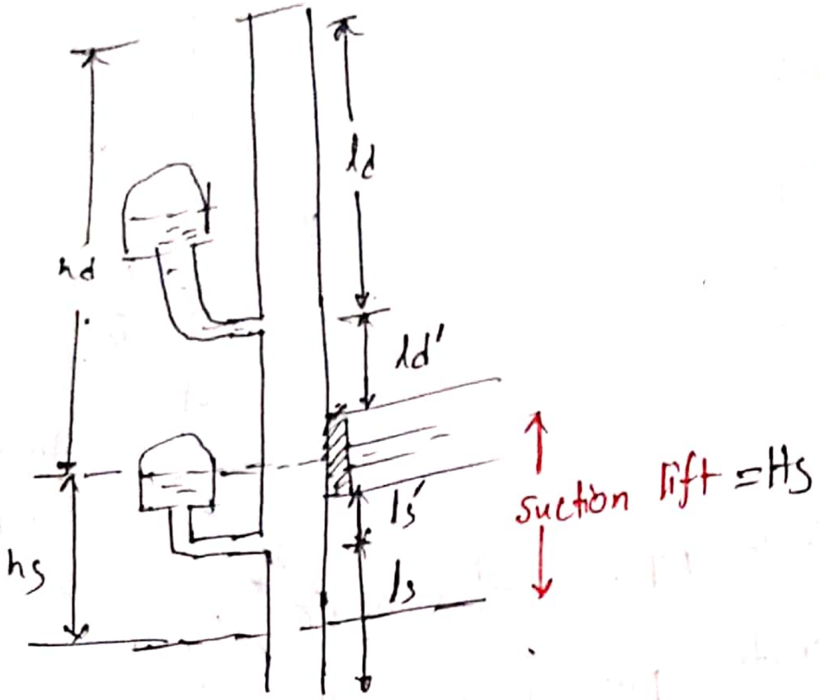
loss of head, $H_f = \frac{4flv^2}{2gd}$

$$H_f = \frac{4fl}{2gd}\left(\frac{A}{a}\omega r \sin\theta\right)^2$$

Combination of friction & acceleration:



Air Vessels:



Because of the vessel, acceleration only happens between the cylinder and vessel.

∴ pressure head due to acc. in (vessel-cylinder) $H_a = \frac{l_s'}{g} \times \frac{A}{a_s} \omega^2 r$

Suction lift = Hs

loss of head below vessel,

$$H_f = \frac{4 f l_s}{d_s \times 2g} \left(\frac{A}{a_s} \frac{W n}{\pi} \right)^2$$

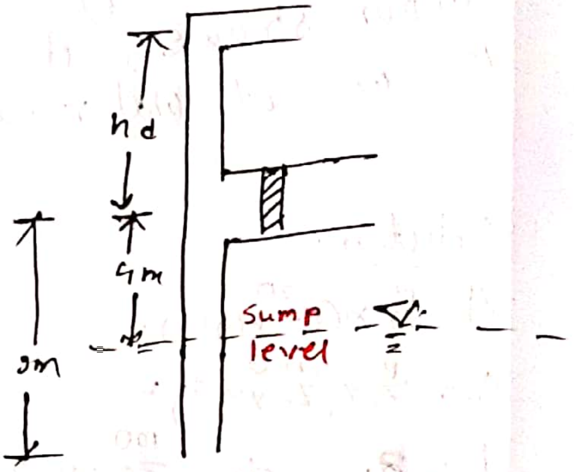
Mean velocity, $\bar{v} = \frac{A}{a_s} \frac{W n}{\pi}$

∴ Seperation Head, $H_{sep} = H_{atm} - \left[H_{suc} + H_a + H_f \right]$

Sir

Problem: A single acting reciprocating pump, having plunger dia 125mm and stroke length 300mm is drawing water from a depth of 4m from the axis of cylinder at 24 r.p.m. The length and diameter of suction pipe is 9m and 75mm respectively. Find the pressure head on the piston at the beginning and end of the stroke, if the barometer reads 10.3 m of water.

Solⁿ:



$A = \frac{\pi}{4} \times (125 \times 10^{-3})^2 =$

$L = 300mm \quad \therefore r = 0.15m$

$a_s = \frac{\pi}{4} \times (75 \times 10^{-3})^2 =$

$l_s = 9m, \; h_s = 4m$

Atmospheric pressure, $= 10.3m$

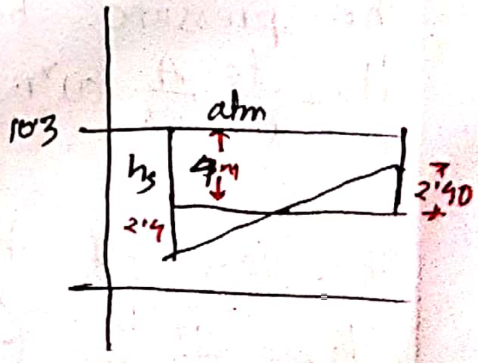
$\therefore \omega = \frac{2\pi N}{60} = \frac{2\pi \times 24}{60} = 2.51 \text{ rads}^{-1}$

∴ The pressure head due to acceleration ~~due to~~ in the suction pipe, $H_a = \frac{l_s}{g} \times \frac{A}{a_s} \times \omega^2 r \cos\theta$

∴ At the begining of stroke, $\theta = 0°$

$\therefore H_a = \frac{9}{9.81} \times \left(\frac{125 \times 10^{-3}}{75 \times 10^{-3}}\right)^2 \times 2.51^2 \times 0.15 \times 1$

$\therefore H_a = 2.40$

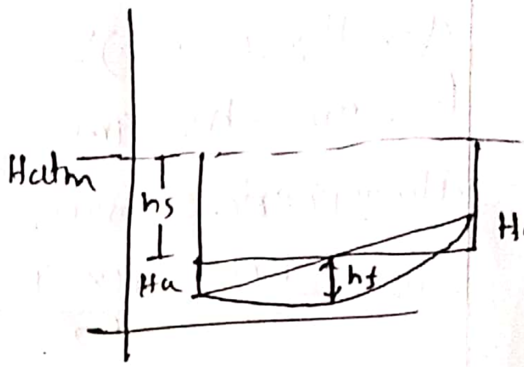


∴ Pressure head at the begining $= 10.3 - (h_s + 2.4) = 3.9m$

At the end,

$= 10.3 - \cancel{2.4}\,(h_s - 2.4) = 8.7m$

Problem: A single acting reciprocating pump, having plunger dia 200 mm and stroke length 300 mm. The length and dia of suction pipe is 8m and 100 mm respectively. The pump draws water from a depth of 4m below the axis of the cylinder at 30 r.p.m. Find the pressure head on the piston at the beginning, in the middle and end of the suction stroke, if the atmospheric pressure head 10·3 m of water and $f = 0.01$.



Solution:

$A = \frac{\pi}{4} \times (\cancel{125}\,200 \times 10^{-3})^2 =$

$a_s = \frac{\pi}{4} \times (\cancel{75}\,100 \times 10^{-3})^2$

$l_s = 8m$, $d_s = \cancel{75}\,100 \times 10^{-3} m$

$h_s = 4m$

$L = 0.3m$

$r = L/2 = 0.15 m$

$\omega = \frac{2\pi \times 30}{60} = \pi$

$f = 0.01$

$H_{atm} = 10.3$

The pressure head due to acceleration in suction pip

$H_a = \frac{l_s}{g} \frac{A}{a_s} \omega^2 r \cos\theta = \cancel{25.17 \cos\theta}\ \cancel{3.77 \cos\theta} = 4.83 \cos\theta$

The loss of head due to friction,

$h_{fs} = \frac{4 f l_s}{d_s \times 2g} \left(\frac{A}{a_s} \omega^2 r \sin\theta\right)^2 = \cancel{1.489 \sin^2\theta}$

$=$

(i) $\therefore$ At the beginning, $\theta = 0^\circ$ $\therefore H_a = \cancel{2.647}\ \overset{4.83}{\cancel{3.77}}$, $h_s = 0$

$\therefore$ from diagram, suction pressure at begining,

$$H_p = H_{atm} - (h_s + h_a) = 10.3 - (4 + 4.83) = 1.47$$

$\therefore H_p = 1.47\ m$, $H_a = 4.83$

(ii) At the middle, $\theta = 90^\circ$, $\therefore \cos\theta = 0$, $\therefore H_a = 0$

$\sin\theta = 1$, $\therefore H_f = \overset{0.58}{\cancel{1.47}} \times 1^2$

$= 0.58\ m$

$\therefore$ from diagram,

$$H_p = 10.3 - (H_s + h_f) = \cancel{10.3}(10.3 - (\overset{4}{\cancel{4.83}} + 0.58)$$

$\therefore H_p = 5.72\ m$

(iii) At the end, $\theta = 180^\circ$

$\cos\theta = 1$, $H_a = 4.83$, $h_f = 0$

$$\therefore H_p = 10.3 - (h_s - H_a) = 11.13$$

Suction Hatm এর চেয়ে বেশি হতে পারে?

Problem: A single acting reciprocating has a plunger diameter of 250 mm and stroue length of 450 mm. The suction pipe is y's 125mm diameter and 12m long with a suction lift of 3m. An air vessel is fitted to the suction pipe at a distance of 1.5m from cylinder and 10.5m from the sump of water level. If the barometer reads 10m of water and seperation toues place at 2.5 m vaccum find the speed at which the cranu can operate without seperation to occur. $f = 0.01$

Ans:

$A = \frac{\pi}{4} \times 0.25^2 =$ | $\omega = ??$ $N = ?$

$L = 0.45 m$ | $H_{sep} = ?$

$r = 0.225$

$a = \frac{\pi}{4}(125 \times 10^{-3})^2 =$

l_s = length of suc pipe below vessel $= 12 - 1.5 = 10.5 m$

l'_s = length " " betwee " & cylinder $= 1.5 m$

$\therefore$ Mean velocity $\bar{v} = \left(\frac{A}{a_s} \times \frac{\omega r}{\pi}\right) = \left(\frac{0.250}{0.125}\right)^2 \times \frac{\omega \times 0.225}{\pi}$

$= \cancel{0.014}\ 0.286\, \omega$

Pressure head due to accelration between vessel and cylinder, $H_a = \frac{l'_s}{g} \frac{A}{a_s} \omega^2 r = \frac{1.5}{9.8} \left(\frac{0.25}{0.125}\right)^2 \times \omega^2 \times 0.225$

$\therefore H_a = 0.137 \omega^2$

h_f = loss of head below vessel $= \frac{4 f l_s}{d_s \, 2g} \bar{V}^2$

$$= \frac{4 \times 0.01 \times 1.5}{125 \times 10^{-3} \times 2 \times 9.8} \times (\cancel{0.014^2 \omega})^2 \quad 0.286\omega$$

$$= 0.014\, \omega^2$$

Now,

$$H_{sep} = H_{atm} - [H_a + H_f + H_s]$$

$H_{atm} = 10$ m

$H_a = 0.137\omega^2$

$H_f = 0.014\omega^2$

H_s = suction lift = 3 m

$$\therefore H_{sep} = H_{atm} - [0.137\omega^2 + 0.014\omega^2 + 3]$$

$$\Rightarrow \omega^2 = \frac{10 - 2.5 - 3}{0.137 + 0.014}$$

$$\therefore \omega = 5.459 \approx 5.46 \text{ rads}^{-1}$$

$$\therefore N = \frac{60 \times \omega}{2\pi} = 52$$