Reciprocating Pump – Useful equations

Discharge

$$Q = \frac{LAN}{60} \;\; for\ a\ single\ acting\ pump$$

$$Q = \frac{2LAN}{60} \; for\ a\ double\ acting\ pump$$

Work done by a reciprocating pump per second

$$W = \ \rho g Q H = \frac{\rho g LAN(hs + hd)}{60} \;\; for\ a\ single\ acting\ pump$$

$$W = \ 2\rho g Q H = 2\rho g LAN(h"s" \ + hd)/60 \;\; for\ a\ double\ acting\ pump$$

Slip

$$slip = Qthe - Qact$$

$$\%slip = \frac{Qthe - Qact}{Qthe} * 100$$

Pressure head due to acceleration in the suction and delivery pipe

$$has = \frac{l_s}{g}\frac{A}{a_s} r\omega^2 cos\theta$$

$$had = \frac{l_d}{g}\frac{A}{a_d} r\omega^2 cos\theta$$

Pressure head inside the cylinder due to acceleration

Suction Stroke

$$starting\ of\ the\ suction\ stroke, = \ h_s + h_{as}\ \ below\ atmospheric\ pressure$$

$$= \ Hatm - (h_s + h_{as}\,)\ absolute\ pressure$$

$$middle\ of\ the\ suction\ stroke, = \ h_s\ below\ atmospheric\ pressure$$

$$= \ Hatm - h_s\ absolute\ pressure$$

$$end\ of\ the\ suction\ stroke, = \ h_s - h_{as}\ \ below\ atmospheric\ pressure$$

$$= \ Hatm - (h_s - h_{as}\,)\ absolute\ pressure$$

Delivery Stroke

$Starting\ of\ the\ delivery\ stroke, =\ h_d + h_{ad}\ \ above\ atmospheric\ pressure$

$$=\ Hatm + (h_d + h_{ad}\ )\ absolute\ pressure$$

$middle\ of\ the\ delivery\ stroke, =\ h_d\ above\ atmospheric\ pressure$

$$=\ Hatm + h_d\ absolute\ pressure$$

$end\ of\ the\ delivery\ stroke, =\ h_d - h_{ad}\ \ above\ atmospheric\ pressure$

$$=\ Hatm + (h_d - h_{ad}\ )\ absolute\ pressure$$

<u>Work done by the pump per second due to acceleration</u>

$$W = \frac{\rho gALN}{60}(h_s + h_d), \qquad single\ acting\ pump$$

<u>Loss of head due to friction in the suction and delivery pipe</u>

$$hf = \frac{4flv^2}{2gd}$$
$$= \frac{4fl}{2gd}\left(\frac{A}{a}r\omega sin\theta\right)^2, general\ equation\ (substitute\ l, d\ and\ a\ corresponding\ to\ the\ required\ side)$$

<u>Pressure head inside the cylinder due to acceleration and friction</u>

Suction Stroke

$starting\ of\ the\ suction\ stroke, =\ h_s + h_{as}\ \ below\ atmospheric\ pressure$

$$=\ Hatm - (h_s + h_{as}\ )\ absolute\ pressure$$

$middle\ of\ the\ suction\ stroke, =\ h_s + h_{fs}\ below\ atmospheric\ pressure$

$$=\ Hatm - (h_s + h_{fs})\ absolute\ pressure$$

$end\ of\ the\ suction\ stroke, =\ h_s - h_{as}\ \ below\ atmospheric\ pressure$

$$=\ Hatm - (h_s - h_{as}\ )\ absolute\ pressure$$

Delivery Stroke

$Starting\ of\ the\ delivery\ stroke, =\ h_d + h_{ad}\ \ above\ atmospheric\ pressure$

$$=\ Hatm + (h_d + h_{ad}\ )\ absolute\ pressure$$

$$middle\ of\ the\ delivery\ stroke, = \ h_d + h_{fd}\ above\ atmospheric\ pressure$$

$$= \ Hatm + (h_d + h_{fd})\ absolute\ pressure$$

$$end\ of\ the\ delivery\ stroke, = \ h_d - h_{ad}\ \ above\ atmospheric\ pressure$$

$$= \ Hatm + (h_d - h_{ad}\ )\ absolute\ pressure$$

Work done by the pump per second due to acceleration and friction is given by

$$W = \frac{\rho gALN}{60}\left(h_s + h_d + \frac{2}{3}h_{fs} + \frac{2}{3}h_{fd}\right), single\ acting\ pump$$

Maximum Speed of a reciprocating pump

At the suction side,

$$H_{atm} - (h_s + h_{as}) = \ h_{sep}\ , absolute$$

At the delivery side,

$$H_{atm} + (h_d - h_{ad}) = \ h_{sep}\ , absolute$$

Find the speed corresponding to suction side as well as delivery side.

Take the minimum speed of the two as the maximum speed at which pump can be operated without separation.

Air Vessel

Mean velocity for a single acting reciprocating pump

$$\bar{V} = \frac{A}{a}\frac{r\omega}{\pi}$$

Work done by reciprocating pump with air vessels fitted to the suction and delivery pipes

$$\approx \frac{\rho gLAN}{60}\left[h_s + h_d + h_{fs} + h_{fd}\right]$$