Indicator diagram of a reciprocating pump is the plot between Pressure head at suction and delivery vs stroke length. The area of plot is proportional to the work done by the pump

Define ideal indicator diagram?
Work done by the pump is proportional to the area of the Indicator diagram.

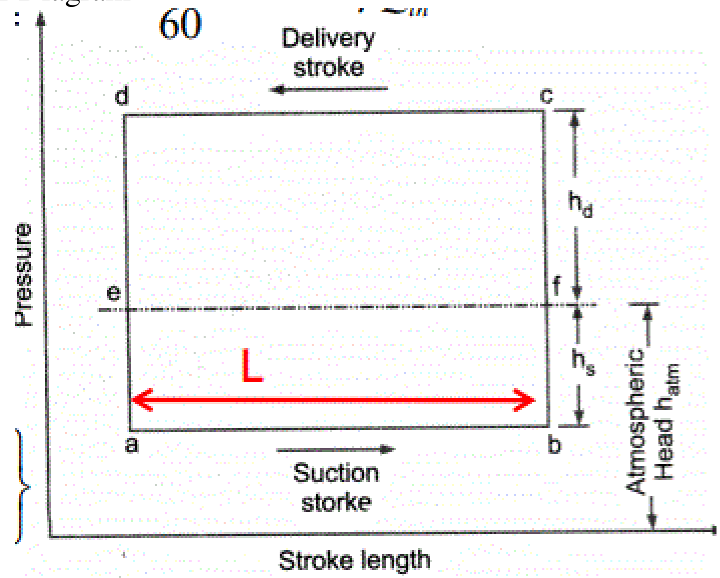
What is the relation between Work done of a Pump and Area of Indicator Diagram? Work done by the pump is proportional to the area of the Indicator diagram.

Firstly indicator diagram is nothing but p-v curve (pressure volume) used to calculate pressure acting inside a closed chamber

while designing pump, they will give specifications even at higher pressure,

it will produce required flow rate pressure is a phenomena created due to pressure gradient main objective of pump to transfer fluid

Theoretical Indicator Diagram



Ideal indicator diagram of reciprocating pump

Ideal indicator diagram of reciprocating pump is basically a graph between the absolute pressure head in the cylinder and the distance travelled by the piston from inner dead centre for one complete revolution of the crank.

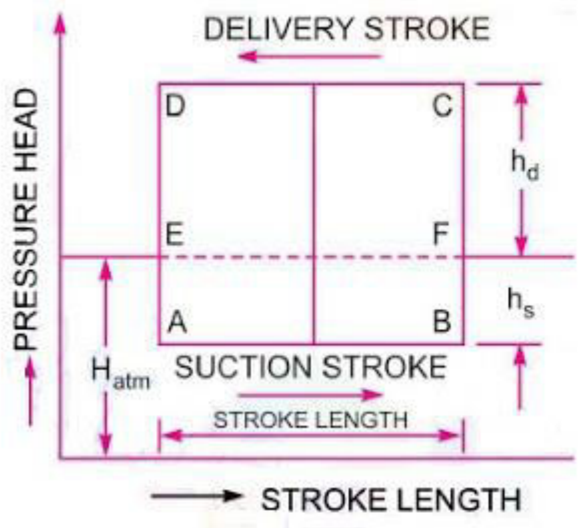
As the maximum distance travelled by the piston will be equal to the stroke length and hence we can also say that ideal indicator diagram of reciprocating pump will be basically a graph between the absolute pressure head in the cylinder and stroke length of the piston for one complete revolution.

As we know that volume of water delivered in one revolution will be the product of area of cross section of the piston or cylinder and length of stroke i.e. V = A x L

Where, cross sectional area of the piston or cylinder will be constant and therefore volume of water delivered in one revolution will be directionally proportional to the length of stroke i.e. V α L.

Therefore, ideal indicator diagram of reciprocating pump could also be considered as graph between the absolute pressure head and volume for one complete revolution of the crank.

Following figure indicates the ideal indicator diagram of reciprocating pump, where line EF shows the atmospheric pressure head.



In ideal case, if we neglect the velocity and acceleration of fluid in cylinder piston and suction pipe, the suction pressure should be sufficient enough to lift the liquid i.e. water by a vertical height h_s.

Therefore, suction pressure head will be equal to the vertical depth h_s. In ideal case, the pressure head inside the cylinder will be constant throughout the process of suction stroke where piston moves towards outer dead centre.

Therefore, AB line will indicate here the suction stroke and it will be below than the atmospheric pressure head EF as displayed in above figure.

At the end of suction stroke, piston will push the liquid i.e. water. If we assume the liquid as fully incompressible, there will be instant increase in pressure of liquid as soon as piston will push the liquid.

Because, if we recall the property of a fully incompressible liquid, liquid will be pressurised instantly without change in volume. BC line shows the instant pressure rise of liquid up to delivery pressure head when piston will push the liquid at the end of suction stroke.

CD shows the delivery stroke in above figure. During delivery stroke, the pressure head in the cylinder will be constant and will be equal to the delivery head h_d and it will be above the atmospheric pressure head by a height of h_d as displayed in above figure.

Total static lift of the pump will be $h_s + h_d$.

Similarly, at the end of delivery stroke when piston will come to inner dead centre, there will be instant pressure drop when piston start to move towards outer dead centre. This instant pressure drop, when piston start to move towards outer dead centre, is shown by DA in above diagram of reciprocating pump.

Therefore, for one complete revolution of the crank, pressure head in the cylinder will be indicated by the diagram A-B-C-D-A. This diagram is known as ideal indicator diagram of reciprocating pump.

As we have already seen, in ore previous post, that work done by the reciprocating pump per second will be given by following equation as mentioned below.

Work done by the reciprocating pump = ρ g A L N x ($h_s + h_d$) / 60
Work done by the reciprocating pump = K x L x ($h_s + h_d$)

Because, ρ g A N / 60 = Constant = K

Therefore, we can say that

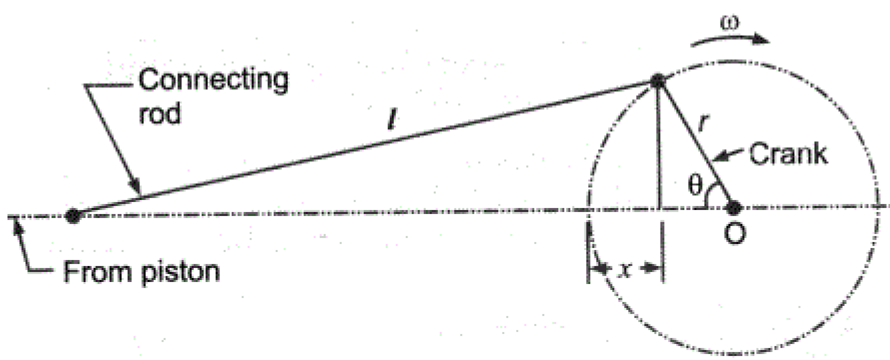
Work done by the reciprocating pump = K x AB x BC
Work done by the reciprocating pump = K x Area of indicator diagram
Because,
Length of stroke L = AB
Total static lift of the pump will be $h_s + h_d$ = BC

Therefore, we have seen here the ideal indicator diagram of reciprocating pump and also we have concluded that work done by the reciprocating pump will be directly proportional to the area of indicator diagram.

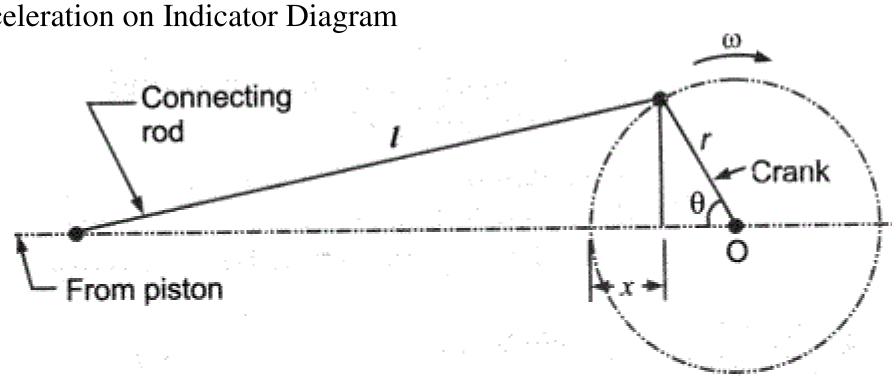
Do you have any suggestions? Please write in comment box and also drop your email id in the given mail box which is given at right hand side of page for further and continuous update from www.hkdivedi.com.

Further we will find out, in our next post, effect of acceleration and friction on indicator diagram of reciprocating pump.

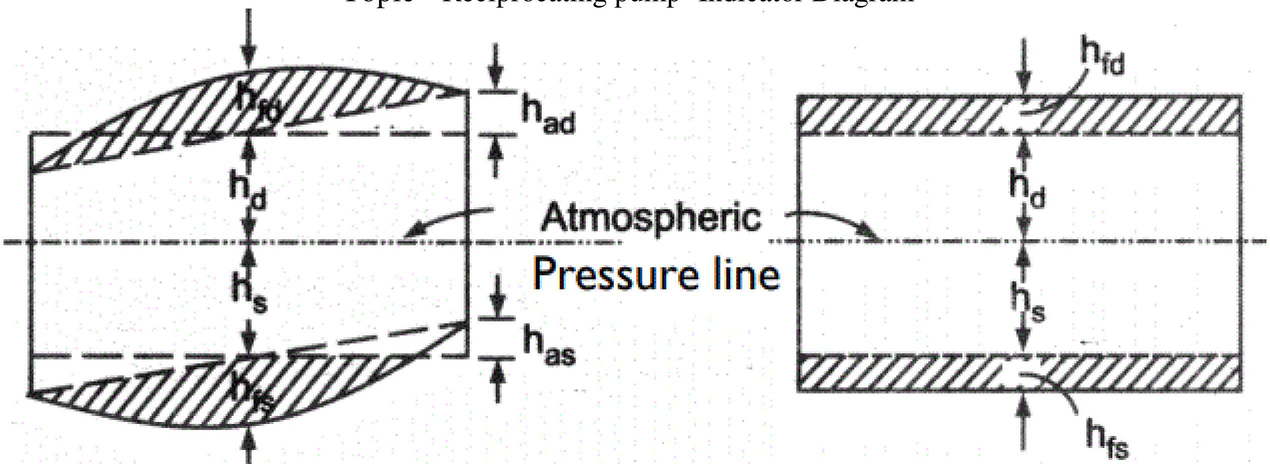
Effect of Acceleration on Indicator Diagram



Effect of Acceleration on Indicator Diagram



Effect of Air Vessel



Indicator diagram without or with air vessel

Reference:
Fluid mechanics, By R. K. Bansal
Fluid machines, By Prof. S. K. Som
Image courtesy: Google

Problems on Reciprocating pump

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(6) The piston area of single acting reciprocating Pump 0.15 m² and stroke is 30 cm. The water is lifted through a total head of 15 m. The area of delivery pipe is 0.03 m², If the pump is running at 50 rpm, find the percentage slip, Coefficient of discharge and the power required to drive the pump. The actual discharge is 35 litre/second. Take mechanical efficiency is 0.85.

(AU Dec 2011)

Given

Area of piston $A = 0.15 m^2$

$L = 30 cm = 0.3 m$

$h_s + h_d = 15 m$

Delivery pipe area $A_d = 0.03 m^2$

$N = 50 rpm$

$Q_{actual} = 35 \text{ litre/sec} = 0.035 m^3/s$

$\eta_{mech} = 20 m$

Theoretical discharge $Q_{th} = \frac{ALN}{60}$

$$Q_{th} = \frac{0.15 \times 0.3 \times 50}{60}$$

$$Q_{th} = 0.0375 \text{ m}^3/\text{sec}$$

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

$$Q_{th} = \frac{0.0375 - 0.03}{0.0375} \times 100$$

$$Q_{th} = 20\%$$

Co-efficient of discharge $C_d = \frac{Q_{act}}{Q_{th}}$

$$C_d = \frac{0.03}{0.0373}$$

$$C_d = 0.8$$

Power required to drive the pump

$$P = w Q_{th} (h_s + h_d)$$

$$= 9810 \times 0.0375 \times 15$$

$$= 5518.125 \, W$$

$$P = 5.52 \, kW$$

A pump has to supply water which is at 70° C water at 90 m³/min and 1800 rpm Find the type of pump needed, the power required and the impeller diameter, if the required pressure rise for one stage is 200 kpa and 1250 kpa. (AU Dec 2011)

(19)

Given

$Q = 90\ m^3/min = 1.5\ m^3/s$

$N = 1800\ rpm$

$P_1 = 200\ kpa$

$P_2 = 1250\ kpa$

Head $H = \frac{P_2 - P_1}{w} = \frac{P_2 - P_1}{\rho g} = \frac{1250 - 200}{9.81}$

$H = 107.034\ m$.

Specific Speed

$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$

$N_s = \frac{1800 \times \sqrt{1.5}}{107.034^{3/4}}$

$N_s = 66.25$

Specific lies between 50 and 80, so High Speed radial flow pump is recommended

Power output of the pump $= WQH$

$= 9.81 \times 1.5 \times 107.034$

$= 1575\ KW$

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(10) In a Single acting reciprocating pump the bore and stroke are 100mm and 150mm respectively. The static head requirements are 4m suction and 18m delivery. If the Pressure at the end of delivery is atmospheric Calculate the operating speed.

The diameter of the delivery pipe is 75mm and the length of the delivery pipe is 24m. determine the acceleration head at $\theta = 33^\circ$ from the start of delivery. (AU Dec 2011)

Diameter of the piston $D = 100mm = 0.1m$

Stroke of the piston $L = 150mm = 0.15m$

Crank radius $r = 0.15/2 = 0.075m$

Suction head $h_s = 4m$

Delivery head $h_d = 18m$

Pressure head at the end of delivery stroke

$P_{atm} = 1.013 bar$

$H_m = 10.3m$

Diameter of pipe $d_d = 75mm = 0.075 m$

Length of delivery pipe $L_d = 24m$

$\theta = 33^\circ$

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Solution:

Pressure head on the delivery pipe

a) At the end of delivery stroke

Pressure head $H_{atm} = h_d + h_{ad}$

$10.3 = 18 + h_{ad}$

$h_{ad} = -7.7$ m of water

Acceleration head $h_{ad} = \frac{-l_d}{g} \frac{A}{a_s} \omega^2 r$

$[\because \theta = 180°]$

$$-7.7 = -\frac{24}{9.81} \times \frac{\frac{\pi}{4} \times 0.1^2}{\frac{\pi}{4} \times 0.075^2} \times \left(\frac{2\pi N}{60}\right)^2 \times 0.075$$

$N = 46.39$ rpm.

(b) At the beginning of delivery stroke when $\theta = 33°$

The acceleration head $h_{ad} = \frac{l_d}{g} \frac{A}{a_d} \omega^2 r \cos\theta$

$$h_{ad} = \frac{24}{9.81} \times \frac{\frac{\pi}{4} \times 0.1^2}{\frac{\pi}{4}\, 0.075^2} \times \left(\frac{2\pi \times 46.39}{60}\right)^2 \times 0.075 \times \cos 33°$$

$h_{ad} = 6.46$ m