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MADE EASY PUBLICATIONS

MECHANICAL ENGINEERING

CONVENTIONAL Practice Sets

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FLUID MECHANICS AND FLUID MACHINERY

16 CHAPTER

Reciprocating Pump

Q.1 A double acting reciprocating pump having piston area 0.16 m^2 has a stroke 0.40 m long. The discharge of water through the pump is 6.0 m^3 per minute at a speed of 50 rpm through a height of 12 m. Find the slip of the pump and power required to drive the pump.

Solution:

Given : $N = 50$ rpm; $Q_{act} = \frac{6}{60} = 0.1\,m^3 s$; $L = 0.40$ m

$$h = h_s + h_d = 12 \text{ m}$$

$$A = 0.16\,m^2$$

Theoretical discharge,

$$\boxed{Q_{Th} = \frac{2ALN}{60}} = \frac{2 \times 0.16 \times 0.40 \times 50}{60} = 0.11\,m^3/s$$

$\therefore$

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

$$= 0.11 - 0.10 = 0.01 \text{ m}^3/\text{s}$$

Power Required,

$$\boxed{P = \frac{2 \times S_g \times ALN \times (h_s + h_d)}{60000}\text{kW}}$$

$$= \frac{2 \times 10^3 \times 9.81 \times .016 \times 0.4 \times 50 \times 12}{60000}\text{kW} = 12.56 \text{ kW}$$

Q.2 A single acting reciprocating pump has a plunger diameter 200 mm and stroke length 300 mm. It draws water from a sump 3.6 m below the pump centre line with a pipe 4.8 long and 180 mm in diameter and lift water to a location 20 m above the pump with a pipe 25 m long and 100 mm diameter. The pump is driven with SHM. If the atmospheric pressure head is 10.3 meter of water and separation occurs at 2.6 m of water absolute. Find the maximum operational speed of the pump.

Solution:

Given:

For reciprocating pump,

Length of suction pipe, $l_s = 4.8$ m

Diameter of suction pipe, $d_s = 180$ mm $= 0.18$ m

Area of suction pipe, $a_s = \frac{\pi}{4}d_s^2 = \frac{\pi}{4} \times (0.18)^2 = 0.0254\ m^2$

Diameter of plunger, $D = 200$ mm $= 0.2$ m

Area of plunger, $A = \frac{\pi}{4}D^2 = \frac{\pi}{4} \times (0.2)^2 = 0.03141\,m^2$

Length of delivery pipe, $l_d = 25$ m

Diameter of delivery pipe, $d_d = 100$ mm $= 0.1$ m

Area of delivery pipe, $a_d = \frac{\pi}{4} \times (0.1)^2 = 7.85 \times 10^{-3}\ m^2$

Head for separation, $H_{sep} = 10.3 - 2.6 = 7.7$ m

$$\boxed{H_{as} = \frac{L_s}{g} \times \frac{A}{a_s} \times \omega^2 r \cos\theta}$$

where A = area of cross-section of piston,

a_s = area of cross-section of suction pipe

ω = angular velocity = $\frac{2\pi N}{60}$

r = radius of crank = $\frac{L}{2} = \frac{180}{2}$ = 90 mm

θ = angular distance travelled by crank.

$$\therefore \quad H_{as} = \frac{L_s}{g} \times \frac{\pi D^2}{4} \times \frac{4}{\pi (d_s)^2} \times \omega^2 r \cos\theta$$

$$\Rightarrow \quad H_{as} = \frac{L_s}{g} \times \left(\frac{D}{d_s}\right)^2 \times \omega^2 r \cos\theta$$

The head loss due to friction in suction pipe is given by

$$H_{fs} = \frac{f_s L_s}{2 g d_s} \times \left(\frac{A}{a_s} \omega r \sin\theta\right)^2$$

$$\Rightarrow \quad \boxed{H_{fs} = \frac{f_s L_s}{2 g d_s} \times \left(\frac{D}{d_s}\right)^4 (\omega r \sin\theta)^2}$$

Pressure head at the beginning of stroke

$$H_{ts} = H_{atm} - H_{as} - H_{fs} - H_s$$

At the beginning, $\theta = 0°$

$$\therefore \quad H_{as} = \frac{6}{9.81} \times \left(\frac{120}{90}\right)^2 \times \left(\frac{2\pi \times 72}{60}\right)^2 \times 90 \times 10^{-3} \times \cos 0°$$

$$\Rightarrow \quad H_{as} = 5.56 \text{ m}$$

Also, $$H_{fs} = \frac{0.022 \times 6}{2 \times 9.81 \times 90 \times 10^{-3}} \times \left(\frac{120}{90}\right)^4 \times \left(\frac{2\pi \times 72}{60} \times 90 \times 10^{-3} \times \sin 0°\right)^2$$

$\Rightarrow$ $H_{fs} = 0$

In terms of water, H_{atm} = 10.3 m of water

$\therefore$ H_{ts} = 10.3 – 5.56 – 0 – 2.5 = 2.24 m

Pressure head at the middle of stroke,

$\theta = 90°$

$\Rightarrow$ $\cos 90° = 0$

and $\sin 90° = 1$

$\therefore$ $H_{as} = 0$

$$H_{fs} = \frac{0.022 \times 6}{2 \times 9.81 \times 90 \times 10^{-3}} \times \left(\frac{120}{90}\right)^4 \times \left[\frac{2\pi \times 72}{60} \times 90 \times 10^{-3}\right]^2 = 0.1088$$

$\therefore$ H_{ts} = 10.3 – 0 – 0.1088 – 2.5 = 7.6912 m

Pressure head at the end of stroke

$\theta = 180°$

$\Rightarrow$ $\sin 180° = 0$

and $\cos 180° = -1$

$\therefore$ H_{as} = 5.56 × cos 180° = – 5.56 m

$H_{fs} = 0$

$\therefore$ H_{ts} = 10.3 – (– 5.56) – 0 – 2.5 = 13.36 m

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