DEPARTMENT: CIVIL ENGINEERING
SEMESTER: III
SUBJECT CODE / Name: CE8403 / Applied Hydraulic Engineering

UNIT 5-PUMPS

2 MARK QUESTIONS AND ANSWERS

1. How are fluid machines classified?

Fluid machines are classified into 2 categories depending upon the direction of transfer of energy:

1. Turbines
2. Pumps or compressors. .

2. What is centrifugal pump?

The hydraulic machines which convert mechanical energy in to pressure energy by means of centrifugal force is called centrifugal pump. It acts a reverse of inward radial flow turbine.

3. What are the main parts of centrifugal pump?

1. Suction pipe with foot valve and strainer
2. Impeller
3. Casing
4. Deliver y pipe

4. Write down the use of centrifugal pump?

1. Used in deep sump and basement
2. The high discharge capacity
3. It is driven by electric motors

5. Define multistage pump:

If centrifugal pump consists of two or more impellers the pump is called Multistage pump. To produce a high head impellers are connected in series .To produce high discharge impellers are connected in parallel.

6. What is Net Positive Suction Head (NPSH)?

NPSH is defined as the total head required making liquid flow through suction pipe to pipe impeller.

7. Define slip of a reciprocating pump and negative slip:

Slip is defined as the difference between theoretical discharges and actual discharge.

If actual discharge is greater than theoretical discharge negative value is found this negative value is called negative slip.

8. What do you know coefficient of discharge?

It is defined as the ratio of actual discharge b y theoretical discharge. It is denoted By Cd

9. What do you know Drop down curve?

The water surface has a convex profile upwards this curve is called drop down Curve.

10. What is separation of reciprocating pump?

If the pressure in the cylinder is below the vapour pressure , dissolved gasses will be liberated from the liquid and cavitations will takes place . The continuous flow of liquid will not ex it which means separation of liquid takes place. Th e pressure at which separation takes place is called separation pressure and head corresponding to the separation pressure is called separation pressure head.

11. What is an indicator diagram?

Indicator diagram is the graph between the pressure head and distance traveled b y the piston from inner dead center for one complete revolution.

12. What is Air vessel?

Air vessel is a closed chamber containing compressed air in the top portion and liquid at the bottom of the chamber . It is used to obtain a continuous supply of water at uniform rate to save a considerable amount of work and to run the pump at high speed with out separation

13. What is the purpose of an air vessel fitted in the pump?

1. To obtain a continuous supply of liquid at a uniform rate.
2. To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipes, and
3. To run the pump at a high speed with out separation.

14. What is the work saved by fitting a air vessel in a single acting, double acting pump?

Work saved by fitting air vessels in a single acting pump is 84.87%, In a double acting pump the work saved is 39.2%.

15. What is Discharge through a Reciprocating Pump in per sec?

For Single acting

Discharge (Q)=ALN/60

Where,

A=Area of the Cylinder

L=Length of Stroke in m.

N=Speed of Crank in RPM

For Double acting

Q=2ALN/60

16. 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

17.Define pump :

It is defined as the hydraulic machine which convert mechanical energy in to hydraulic energy

18.Define Multistage pump:

If centrifugal pump consists of two or more impellers the pump is called multistage pump. To produce a high head impellers are connected in series .To produce high discharge impellers are connected in parallel.

19.Define Manometric head:

Manometric head is the head against which a centrifugal pump has to work.

$$H_m = H_s + h_d + H_{fs} + H_{fd} + (vd^2/2g)$$

Where

H_m – manometric head
H_s - suction head
H_d – delivery head
H_{fs} – friction head loss in suction pipe
H_{fd} – friction head loss in delivery pipe

20.What is Net Positive Suction Head (NPSH) ?

NPSH is defined as the total head required to make liquid flow through suction pipe to pipe impeller.

21.Define slip of a reciprocating pump and negative slip:

Slip is defined as the difference between theoretical discharge and actual discharge.

If actual discharge is greater than theoretical discharge negative value is found this negative value is called negative slip.

22.What do you know coefficient of discharge?

It is defined as the ratio of actual discharge by theoretical discharge. It is denoted By C_d .

23.What is separation of reciprocating pump?

If the pressure in the cylinder is below the vapour pressure , dissolved gasses will be liberated from the liquid and cavitations will takes place . The continuous flow of liquid will not exit which means separation of liquid takes place. The pressure at which separation takes place is called separation pressure and head corresponding to the separation pressure is called separation pressure head.

24.What is an indicator diagram?

Indicator diagram is the graph between the pressure head and distance traveled by the piston from inner dead center for one complete revolution.

25.What is Air vessel?

Air vessel is a closed chamber containing compressed air in the top portion and liquid at the bottom of the chamber . It is used to obtain a continuous supply of water at uniform rate to save a considerable amount of work and to run the pump at high speed with out separation.

26.Write the Manometric efficiency of the pump?

Manometric efficiency = $(gHm)/(V_{w2}U_2)$

Where

Hm –manometric head

27.Write the expression for over all efficiency ?

over all efficiency = $(\vartheta g\ QHm)/(1000 \times P)$

Where

Hm – manometric head P – power

28.What is the minimum speed for starting the centrifugal pump?

$N=(120\ \eta_{man} V_{w2}\ D_)/(\pi(D_2^2-D_1^2)$ Where

η_{man} – manometric efficiency
V Whirl at out let of the turbine

D_2 - diameter of impeller at out let

29. Write down the use of centrifugal pump?

1.Used in deep sump and basement
2.The high discharge capacity
3.It is driven by electric motors
4.What is centrifugal pump?

The hydraulic machines which convert mechanical energy in to pressure energy by means of centrifugal force is called centrifugal pump. It acts a reverse of inward radial flow turbine.

30.How are fluid machines classified?

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To obtain a continuous supply of liquid at a uniform rate. 2.To save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipes, and 3.To run the pump at a high speed with out separation.

32. What is the work saved by fitting a air vessel in a single acting ,double acting pump?

Work saved by fitting air vessels in a single acting pump is 84.87%,

In a double acting pump the work saved is 39.2%.

33.What is Discharge through a Reciprocating Pump in Per sec ?

For Single acting

Discharge (Q)=ALN/60
Where
A=Area of the Cylinder in m^2
L=Length of Stroke in m.
N=Speed of Crank in RPM

For Double acting

Q=2ALN/60

34. What is the Work done by Reciprocating Pump Per sec.?

Work done = $\rho gALN(h_S+h_D)/60$ (for single acting)

For Double acting:

Work done= $2\rho gALN(h_S+h_D)/60$

Where

ρ=Density of Water in kg/m^3 A=Area of the Cylinder in m^2 L=Length of Stroke in m N=Speed in rpm
h_S,h_D=Suction and Delivery head in m

35. What is the Pressure head due to acceleration in the Suction & Delivery Pipe ?

$$h_F=4fl(A/a*\omega r\sin\theta)^2/2gd$$

where

f=Co-efficient of friction.
A = Area of piston in m^2.
a = Areaof pipe in m^2.

ω = Angular speed

r = Radius of crank

36. 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.

37. What is the Work done by the Pump per sec due to acceleration and friction in the suction and delivery Pipes ?

For single acting

W= ρgALN(hs+hd+0.67hfs+0.67hfd)/60

For Double acting

W=2ρgALN(hs+hd+0.67hfs+0.67hfd)/60 Where

hfs, hfd =loss of head due to acceleration in the suction and delivery Pipe.

38. What is the Mean Velocity of Single acting reciprocating pump ?

v=Aω r/3.14a

Where

ω =Angular velocity in rad/sec

r =Radius of the crank in m
A and a =Area of cylinder and Pipe in m^2

39.Pump:

A pump is device which converts mechanical energy into hydraulic energy.

40.Reciprocating pump:

It operates on the principal of actual displacement of liquid by a piston or plunger, which reciprocates in a closely fitting cylinder.

41.Indicator diagram:

Indicator diagram is nothing but a graph plotted between the pressure head in the cylinder and the distance traveled by the piston from inner dead center for one complete revolution of the crank.

42.Suction head:

It is the vertical height of the centre line of the pump shaft above the liquid surface in the sump from which the liquid is being raised.

43.Manometric head. :

It is the head against which a centrifugal pump works.

44.Mechanical efficiency. :

It is defined as the ratio of the power actually delivered by the impeller to the power supplied to the shaft.

45.Overall efficiency. :

It is the ratio of power output of the pump to the power input to the pump.

46.Speed ratio:

It is the ratio of peripheral speed at outlet to the theoretical velocity of jet corresponding to manometric head.

47.Flow ratio:

It is the ratio of the velocity of flow at exit to the theoretical velocity of jet corresponding to manometric head.

48.Indicator diagram:

Indicator diagram is nothing but a graph plotted between the pressure head in the cylinder and the distance traveled by the piston from inner dead center for one complete revolution of the crank.

16 MARK QUESTIONS AND ANSWERS

1. **A centrifugal pump delivers salt water against a head of 15 m at a speed of 100 rpm. The vanes are curved backward at 30º with the periphery. Obtain the discharge for an impeller diameter of 30 cm and outlet width of 5 cm at a manometric efficiency of 90%.**

(AUC Apr/May 2010)

Given Data:

H = 15 m

N = 100 rpm

D_2 = 0.3 m = 30 cm

B = 0.05 m= 5 cm

D_{max} = 90%

$\phi = 30^0$

Solution:

$$S_{max} = \frac{g \times H}{V \times w_2 \times u_2}$$

$$0.9 = \frac{9.81 \times 15}{V \times w_2 \times u_2}$$

$$V \times w_2 \times u_2 = 163.50$$

$$\tan\theta = \frac{VF_2}{u_2 - V \times w_2}$$

$$\tan 30^0 = \frac{VF_2}{u_2 - V \times w_2}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.3 \times 100}{60} = 1.57\ m/\sec$$

Substitute in equation 1

$$V_w = \frac{163.50}{1.57} = 104.14\ m/\sec$$

$$tan\ 30^0 = \frac{VF_2}{1.57 - 104.14}$$

$$VF_2 = 59.22\ m/\sec$$

$$Q = \pi \times D_2 \times B_2 \times V \times F_2$$

$$= \pi \times 0.3 \times 0.05 \times 59.22$$

$$= 2.79\ m^3/\sec$$

2.For a hydraulic machine installed between A and B, the following data is available:

	At A	At B
Diameter	**20cm**	**30cm**
Elevation	**105m**	**100m**
Pressure	**100 kPa**	**200 kPa**

The direction of flow is from A to B and the discharge is 200 litres per second. Is the machine a pump or a turbine? (AUC Apr/May 2010)

Solution:

At A:

Applying Bernoulli's theorem

$$H_A = \frac{P}{\rho g} + \frac{V^2}{2g} + Z$$

$$Q = 200 \times 10^{-3}\ m^3/\sec$$

$$V = \frac{Q}{A} = \frac{200 \times 10^{-3}}{\frac{\pi}{4} \times 0.2^2} = 6.37\ m/\sec$$

$$H_A = \frac{100\times10^3}{1000\times9.81} + \frac{6.37^2}{2\times9.81} + 105$$

$$= 10.19 + 2.06 + 105$$

$$H_A = 117.26\ m$$

At B:

Applying Bernoulli's theorem

$$H_B = \frac{P}{\rho g} + \frac{V^2}{2g} + Z$$

$$Q = 200\times10^{-3}\ m^3/\sec$$

$$V = \frac{Q}{A} = \frac{200\times10^{-3}}{\frac{\pi}{4}\times0.3^2} = 2.83\ m/\sec$$

$$H_A = \frac{100\times10^3}{1000\times9.81} + \frac{2.83^2}{2\times9.81} + 100$$

$$= 10.19 + 0.408 + 100$$

$$H_A = 110.60\ m$$

Where $V_A < V_B$ and $H_A < H_B$

hence the machine is a turbine, not a pump

3. A single acting reciprocating pump having a cylinder diameter of 150 mm and stroke of 300 mm is used to raise the water through a height of 20 m. Its crank rotates at 60 rpm. Find the theoretical power required to run the pump and the theoretical discharge. If actual discharge is 5 lit/s find the percentage of slip. If delivery pipe is 100 mm in diameter and is 15 m long, find the acceleration head at the beginning of the stroke.

(AUC Nov/Dec 2010)

Given Data:

L = 0.3 m

N = 60 rpm

D = 0.15 m

B = 0.05 m= 5 cm

2r = 0.3 m ; r = 0.15 m

$Q_{act} = 5 \times 10^{-3}$

$d_d = 0.1$ m

$\ell_d = 0.1$ m

Solution:

To Find : 1. To Determine the Theoretical power:

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

$$= \frac{\frac{\pi}{4} \times 0.15^2 \times 0.3 \times 60}{60}$$

$$= 5.30 \times 10^{-3} \ m^3/\text{sec}$$

To Find : 2. To Determine the Theoretical Discharge:

$$P_{th} = \frac{\rho \times g \times ALN}{60} \times (L_s + h_d)$$

$$= \frac{1000 \times 9.81 \times \frac{\pi}{4} \times 0.15^2 \times 0.3 \times 60}{60} \times 20$$

$$= 1040 \ watts = 1.040 \ k.watts$$

To Find : 3 To Determine the Percentage of Slip:

$$\% \ of \ slip = \left(1 - \frac{Q_a}{Q_t}\right) \times 100$$

$$= \left(1 - \frac{5 \times 10^{-3}}{5.3 \times 10^{-3}}\right) \times 100$$

$$= 5.66 \ \%$$

To Find : 4. To Determine the Acceleration Head:

$$\text{Pressure Head} = \frac{\ell_d}{gd} \times \frac{Ad}{ad} \times w^2 \times r \cos\theta$$

$$w = \frac{2\pi n}{60} = \frac{2\pi \times 60}{60} = 6.28$$

$$\text{Pressure Head} = \frac{15}{9.81} \times \frac{0.0176}{0.0078} \times (6.28)^2 \times 0.15 \cos\theta$$

$$= 1.52 \times 2.256 \times 5.91 \cos\theta$$

$$= 20.28 \cos\theta$$

Pressure head at the beginning $\theta = 0^0$, *then we can get*

$$= 20.28 \cos\theta$$

$$= 20.28 \times 1.0$$

$$P_{Head} = 20.28\ m$$

4.The impeller of a centrifugal pump having external and internal diameters 500 mm and 250 mm respectively, width at outlet 50 mm and running at 1200rpm. Works against a head of 48 m. The velocity of flow through the impeller is constant and equal to 3 m/s. The vanes are set back at an angle of 40º at outlet. Determine

(i) Inlet Vane angle

(ii) Work –done by the impeller and Manometric efficiency.

(AUC Apr/May 2011)

Given Data:

D_2 = 500 mm = 0.5 m

D_1 = 250 mm = 0.25 m

B = 50 mm = 5 cm

N = 1200 rpm

H = 48 m

Solution:

To Find : 1. To Determine the inlet vane angle:

$$V_1 = VF_1 = VF_2 = 3 m/\sec$$

$$\phi = 40^0$$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.25 \times 1200}{60} = 15.70\ m/\sec$$

$$\tan\theta = \frac{V_1}{u_1} = \frac{3}{15.7}$$

$$\theta = 10^0 49'$$

$$u_2 = \frac{\pi D_2 N}{60}$$

$$= \frac{\pi \times 0.5 \times 1200}{60}$$

$$= 31.42\ m/\sec$$

$$\tan\theta = \frac{VF_2}{u_2 - Vw_2}$$

$$\tan 40^0 = \frac{3}{31.42 - Vw_2}$$

$$Vw_2 = 27.84\ m/\sec$$

$$\tan\beta = \frac{VF_2}{Vw_2} = \frac{3}{27.84}$$

$$\beta = 6^0\,9'$$

To Find : 2. To Determine the Work done:

$$work\ \ done = \frac{V \times w_2 \times u_2}{g}$$

$$= \frac{27.84 \times 31.42}{9.81}$$

$$= 89.17\ Nm$$

To Find : 3. To Determine the manometric efficiency:

$$D_{\max} = \frac{g \times H_m}{V \times w_2 \times u_2} \times 100$$

$$= \frac{9.81 \times 48}{27.84 \times 31.42} \times 100$$

$$= 53.83\ \%$$

5. A three throw pump has cylinders of 250 mm diameter and stroke of 500 mm each. The pump is required to deliver 0.1 m3/sec at a head of 100 m. Friction losses are estimated to be m in the suction pipe and 19 m in delivery pipe. Velocity of water in delivery pipe is m/s, overall efficiency is 85% and the slip is 3% Determine

(i) Speed of the pump and

(ii) Power required for running the pump. (AUC Apr/May 2011)

Given Data:

D = 250 mm = 0.25 m

L = 500 mm = 0.5 m

Head = 100 m

Q_a = 0.1 m ^{3}/sec = 5 cm

V_d = 1 m/sec

ŋ = 85 % , % of Slip = 3.0 %

Solution:

To Find : 1. To Determine the inlet vane angle:

$$Q_t = \frac{3 \times ALN}{60}$$

$$A = \frac{\pi}{4} \times D^2$$

$$= \frac{\pi}{4} \times 0.25^2 \quad = 0.049\ m^2$$

We can get

$$Q_t = \frac{3 \times ALN}{60}$$

$$= \frac{3 \times 0.049 \times 0.5 \times N}{60}$$

$$Q_t = \frac{3 \times ALN}{60}$$

$$= 0.0012\ N$$

<u>% of the Slip</u>

$$\%\ \text{of the Slip} = \frac{Q_t - Q_c}{0.0012N} \times 100$$

$$0.03 = \frac{0.0012N - 0.1}{0.0012N} \times 100$$

$$36 \times 10^{-6} N = 120 \times 10^{-3} N - 10$$

$$N = 85.91\ rpm$$

$$\eta_0 = \frac{water\ \ power}{Shaft\ \ power}$$

$$water\ \ power = \frac{\rho \times g \times Q \times H}{1000} \quad in\ kN$$

$$H = (h_s + h_d) + hf_d + hf_s + \frac{V^2}{d}$$

$$= 100 + 1.0\ 19.0 + \frac{1^2}{2 \times 9.81}$$

$$= 120.05\ m$$

$$water\ \ power = \frac{1000 \times 9.81 \times 0.1 \times 120.05}{1000}$$

$$= 117.76\ kN$$

$$Shaft\ \ power = \frac{water\ \ power}{\eta_0}$$

$$= \frac{117.76}{0.85}$$

$$= 138.55\ kN$$

6. The impeller of a centrifugal pump has an external diameter of 450 mm and internal diameter of 200 mm. The speed of the pump is 1440 rpm. Assuming a constant radial flow through the impeller at 2.5 m/s and that the vanes at exit are set back at an angle of 25º, Determine:

(1) The inlet vane angle

(2) The angle, the absolute velocity of water at exit makes with the tangent and

(3) The work done per unit weight. (AUC Apr/May 2012)

<u>Given data</u>

D_2 = 450 mm = 0.45 m

D_1 = 200 mm = 0.20 m

N = 1440 rpm

VF_1 = VF_2 m/sec

$$\phi = 25^0$$

Solution:

To Find : 1. To Determine the inlet vane angle:

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.20 \times 1440}{60} = 15.07\ m/\sec$$

$VF_1 = VF_2$ m/sec

$$\tan\theta = \frac{V_1}{u_1} = \frac{3}{15.07}$$

$$\theta = 9^0 25'$$

$$u_2 = \frac{\pi D_2 N}{60}$$

$$= \frac{\pi \times 0.45 \times 1440}{60}$$

$$= 33.929\ m/\sec$$

$$\tan\theta = \frac{VF_2}{u_2 - Vw_2}$$

$$\tan 25^0 = \frac{2.5}{33.929 - Vw_2}$$

$$Vw_2 = 28.560 m/\sec$$

$$\tan\beta = \frac{VF_2}{Vw_2} = \frac{2.5}{28.560}$$

$$\beta = 5^0$$

To Find : 2. To Determine the Work done per unit weight:

$$work\ \ done = \frac{Vw_2 \times u_2}{g}$$

$$= \frac{28.520 \times 33.929}{9.81}$$

$$= 98.78\ \ Nm$$

Problem : 7 A centrifugal pump delivers water against a net head of 14.5 meters and a design speed of 1000 rpm. The vanes are curved back to an angle of 30° to the periphery. The impeller diameter is 30 cm and outlet width is 5 cm. Determine the discharge of the pump if $\eta_{man} = 95\%$

Solution:

$H_m = 14.5$ m. (net head); N = 1000 rpm.

Vane angle at outlet $\beta = 30°$; $D_2 = 30$ cm ; $B_2 = 0.05$ m = 5 cm : $\eta_{man} = 95\% = 0.95$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.30 \times 1000}{60} = \mathbf{15.70\ m/s}$$

$$\eta_{man} = \frac{g H_m}{V_{w_2} \times u_2} = \frac{9.8 \times 14.5}{V_{w_2} \times 15.70} = 0.95$$

$$\therefore V_{w_2} = \mathbf{9.54\ m/s}$$

in outlet velocity Δ

$$\tan \phi \frac{V_{f_2}}{(u_2 - V_{w_2})} ;\ \tan 30 = \frac{V_{f_2}}{15.70 - 9.54} = \frac{V_{f_2}}{6.16}$$

$$\therefore V_{f_2} = 6.16 \times \tan 30 = 3.556\ m/s$$

$$\therefore \text{ Dricharge } Q = \pi D_2 B_2 V_{f_2}$$

$$= \pi \times 0.30 \times 0.05 \times 3.556$$

$$= 0.1675\ m^3/s.$$

$$\mathbf{Q = 167.5\ lps.}$$

Problem: 8 The diameters of an impeller of a centrifugal pump at inlet and outlet area 25 cm & 50 cm respectively. Determine to be minimum starting speed of the pump if it works against a head of 50 m.

Solution:

Given:

$$H_m = 50 \text{ m} ; \; D_1 = 25 \text{ cm} = 0.25 \text{ m} ; D_2 = 50 \text{ cm} = 0.5 \text{ m}$$

Min. starting speed $= N.r.p.m$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.25 \times N}{60} = 0.0131 \text{ N (m/s)}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.5 \times N}{60} = 0.0262 \text{ N (m/s)}$$

$$\frac{u_2^2}{2g} - \frac{u_1^2}{2g} = H_m$$

$$\frac{0.0262^2 N^2}{2g} - \frac{0.0131^2 N^2}{2g} = 50 \text{ m.}$$

$$(0.0262^2 - 0.0131^2) N^2 = 2 \times 9.81 \times 50$$

$$(0.0131 \times 0.0393) N^2 = 981$$

$$\therefore N^2 = \frac{981}{0.0131 \times 0.0393} = 1905483.3$$

$\therefore$ **N = 1380 r.p.m Answer**

Problem: 10 A centrifugal pump with 1.2 m outer diameter of impeller and inner diameter of impeller being 0.6 m. runs at 200 r.p.m and pumps 1880 lps with an average life of 6 m. Angle of vanes at exit with the tangent to the impeller is 26° and the radial velocity of flow is 2.5 m/s. Determine the manometric efficiency and the least speed to start pumping.

Solution:

Given:

Diameter of impeller at inlet $= 0.6$ m

at outlet $= 1.2$ m

Speed $= 200$ r.p.m

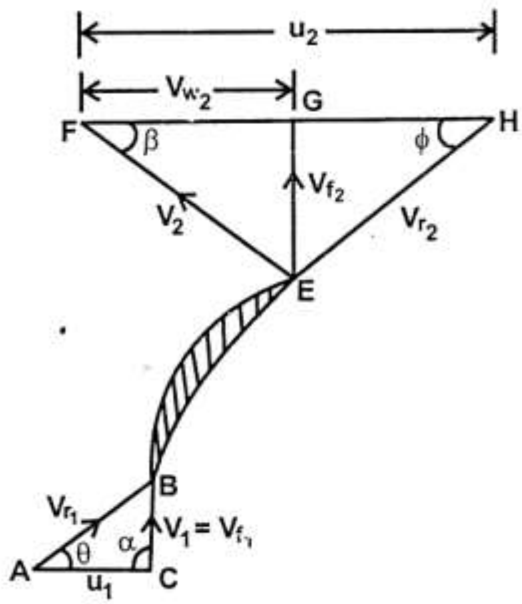
Discharge: 1880 lps $= 1.88 \text{ m}^3/\text{s}$.

$H_m = 6$ m.

$\phi = 26°$

$V_{f_2} = 2.5$ m/s.

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 1.2 \times 200}{60} = 12.56 \text{ m/s}$$



In triangle EGH, $\tan\phi = \frac{V_{f_2}}{(u_2 - V_{w_2})} = \frac{EG}{GH} = \frac{EG}{FH - FG}$

$$\therefore \tan 26° = \frac{2.5}{\left(u_2 - V_{w_2}\right)}$$

$$\therefore u_2 - V_{w_2} = \frac{2.5}{\tan 26°} = 5.13.$$

$$\therefore V_{w_2} = u_2 - 5.13 = 12.56 - 5.13 = 7.43 \text{ m/s}$$

$$\eta_{man} = \frac{g H_m}{V_{w_2} \times u_2} = \frac{9.81 \times 6.0}{7.43 \times 12.56} = 0.63 = \mathbf{63\%}$$

Least speed to start pump is given by

$$\frac{u_2^2}{2g} - \frac{u_1^2}{2g} = H_m \text{ and } u_2 = w\, r_2 \text{ and } u_1 = w\, r_1$$

$$\therefore \frac{\left(\omega\, r_2\right)^2}{2g} - \frac{(\omega\, r_1)^2}{2g} = H_m$$

$$\therefore \frac{\omega^2}{2g}\left(r_2^2 - r_1^2\right) = H_m \,. \quad \therefore \frac{\omega^2}{2 \times 9.81}\left(0.6^2 - 0.3^2\right) = 6.0$$

$$\therefore \omega^2 = \frac{6.0 \times 2 \times 9.81}{(0.6^2 - 0.3^2)} = 436$$

$$\therefore \omega = \sqrt{436} = 20.88 = \frac{2\,\pi\, N}{60}$$

$$\therefore N = \frac{60 \times 20.88}{2 \times \pi} \approx \mathbf{200\ r.p.m}$$

Answer (1) $\eta_{man} = 63\%$ (2) $N = 200$ r.p.m.

Problem: 11 A three stage centrifugal pump has impeller 40 cm in dia and 2 cm wide at outlet. The vanes are curved back at the outlet at 45° and reduce the circumferencial area by 10%. The manometric efficiency is 90% and the overall efficiency is 80%. Determine the head generated by the pump when running at 1000 rpm. delivering 50 litres per second. What should be the shaft power?

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Solution:

Stages: $n = 3$; $D_2 = 40$ cm $= 0.40$ m

$B_2 = 2$ cm $= 0.02$ m.

Vane angle $\phi = 45°$

Area at outlet $= 0.9 \times \pi\, D_2 \times B_2$

$$= 0.9 \times \pi \times 0.4 \times 0.02$$

$$= 0.02262 \text{ m}^2$$

$$\eta_{man} = 90\% = 0.90$$

$$\eta_0 = 80\% = 0.80$$

$$N = 1000 \text{ rpm}$$

$$Q = 50 \ = \text{lines/s} = 0.05 \text{ m}^3/\text{s}$$

$$V_{f_2} = \frac{Q}{\text{area of flow}} = \frac{0.05}{0.02262} = 2.21 \text{ m/s}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.4 \times 1000}{60} = 20.94 \text{ m/s}$$

$$\tan \phi = \frac{V_{f_2}}{u_2 - V_{w_2}} = \frac{2.21}{20.94 - V_{w_2}} = \tan 45 = 1$$

$$\therefore 2.21 = 20.94 - V_{w_2}$$

$$\therefore V_{w_2} = 20.94 - 2.21 = 18.73 \text{ m/s}$$

$$\eta_{man} = \frac{gH_m}{V_{w_2} u_2}$$

$$0.90 = \frac{9.81 \times H_m}{18.73 \times 20.94}$$

$$\therefore H_m = 35.98 \text{ m.}$$

Total head generated $= n\, H_m = 3 \times 35.98 = \mathbf{107.94\ m}$

Power output $= \dfrac{\text{wt. lifted} \times \text{ht. lifted}}{1000}$ (work done)

$$= \frac{1000 \times 9.87 \times 0.05 \times 107.94}{1000} = \frac{eg\,Q\,H}{1000} = 52.94 \text{ kW.}$$

$$\eta_0 = \frac{52.94}{S.P}$$

$$\therefore S.P = \frac{52.94}{\eta_0} = \frac{52.94}{0.80} = \mathbf{66.175\ kW}$$

Problem: 12 A four-stage centrifugal pump has from identical impellers, keyed to the same shaft. The shaft is running at 400 rpm. and the total manometric lead developed by the multi stage pump is 40 m. The discharge through the pump is 0.3 m^3/s. The vanes of each impeller are having out let angle of 45°. If the width and dia. of each impeller at outlet is 5 cm and 60 cm respectively, find the manometric efficiency.

Solution: $n = 4;\ N = 400$ rpm

Total manometric head $= 40$ m.

$$H_m \text{ for each stage } = \frac{40}{4} = 10 \text{ m}$$

$$Q = 0.3\ m^3/S;\ \phi = 45°\ ;\ B_2 = 5 \text{ cm} = 0.05 \text{ m};\ D_2 = 60 \text{ cm} = 0.6 \text{ m}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.6 \times 400}{60}\ 12.56 \text{ m/s.}$$

$$V_{f_2} = \frac{\text{Discharge}}{\text{area of flow}} = \frac{0.30}{\pi D_2 B_2} = \frac{0.30}{\pi \times 0.6 \times 0.05} = 3.183 \text{ m/s.}$$

From outlet velocity triangle

$$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}}$$

$$1 = \frac{3.183}{12.56 - V_{w_2}}$$

$$\therefore 12.56 - V_{w_2} = 3.183$$

$$V_{w_2} = 12.56 - 3.183 = 9.377 \text{ m/s.}$$

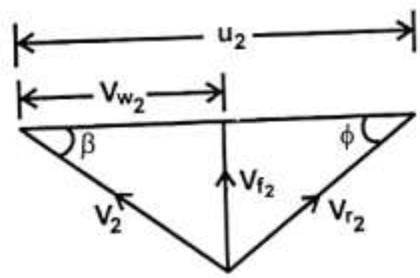


Fig. 4.6

$$\eta_{man} = \frac{g H_m}{V_{w_2} u_2} = \frac{9.81 \times 10.0}{9.377 \times 12.56} = 0.8229 = 82.29\%$$

Problem:13 A double acting reciprocating pump, running at 400 rpm discharges 10.0 m^3/min. of water. The pump has a stroke of 400 mm. The dia. of piston is 200 mm. The delivery and suction head are 20 m & 5 m respectively. Find the slip of the pump and power required to drive the pump.

Solution:

$$N = 400 \text{ rpm},\ Q_{ac} = 1\ m^3/\text{min.} = \frac{10}{60} = 0.1666\ m^3/s.$$

$$L = 400 \text{ mm} = 0.40 \text{ m}\ ;\ D = 200 \text{ mm} = 0.20 \text{ m}$$

$$A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \times 0.2^2 = 0.031416 \text{ m}^2$$

$$h_s = 5 \text{ m} ; h_d = 20 \text{ m}.$$

$$Q_{th} = \frac{2 \text{ ALN}}{60} = \frac{2 \times 0.031416 \times 0.4 \times 400}{60}$$

$$= 0.1675 \text{ m}^3/\text{s}.$$

$$\text{Slip} = Q_{th} - Q_{ac} = 0.1675 - 0.1666 = 0.0009 \text{ m}^3/\text{s}.$$

$$\text{Power required } P = \frac{2 \gamma \text{ALN} (h_s + h_d)}{60000} = \frac{2 \times 1000 \times 9.81 \times 0.031416 \times 0.4 \times 40}{60000} (5 + 20)$$

$$= 4.109 \text{ kW}.$$

Problem : 14 A single acting reciprocating pump is used to lift water running at 40 rpm where the barometric pressure $= 90000 \text{ N/m}^2$ and vapour pressure 12000 N/m^2 and pressure required to force the suction valve open $= 3000 \text{ N/m}^2$. The pump has following particulars. Length of stroke $= 30$ cm. Dia. of cylinder $= 12$ cm. Diameter of suction pipe $= 10$ cm. Length of suction pipe $= 10$ m. Length of connecting rod $= 65$ cm.

Solution:

$$n = \frac{\text{Ratio of length of connecting rod}}{\text{Length of crank}} = \frac{65}{15}. \quad \because \text{ Length of crank } K = R = \frac{L}{2} = \frac{30}{2}.$$

$$\therefore \Delta P \left(1 + \frac{1}{n} \right) = \left(1 + \frac{15}{65} \right) \rho L \omega^2 R \frac{D^2}{d^2}$$

$$= \left(1 + \frac{15}{65} \right) 1000 \times 10 \times \left(\frac{2 \pi 40}{60} \right)^2 \times \frac{15}{100} \times \left(\frac{12}{10} \right)^2$$

$$= \frac{80}{65} \times \mathbf{37747 \text{ N/m}^2}$$

$$= 46477.8 \text{ N/m}^2$$

$$H_{s\,max} = \frac{p_a - p_v - p_{sv} - \Delta p \left(1 + \frac{1}{n} \right)}{\rho g}$$

$$= \frac{90000 - 12000 - 3000 - 46477.8}{1000 \times 9.81}$$

$$\therefore H_{s\,max} = \mathbf{2.907 \text{ m}}$$

Problem: 15 A double acting reciprocating pump has a stroke of 25 cm and a piston diameter of 12.5 cm. The centre of the pump is 4 m above this level of water in the sump and 30 m below delivery water level. The length of suctions and delivery pipes are 6 m and 35 m respectively and their diameters are both 6 cm. Friction factor for the pipes f = 0.04. If the pump is working at 30 rpm, find the pressure head in meters of water on the piston at

(i) the beginning of suction stroke

(ii) the middle of suction stroke and

(iii) the end of suction stroke

If the mechanical efficiency is 75% what is the power required to drive the pump? Take atmospheric pressure as 10.3 m of water.

Solution:

Given data:

$N = 30$ rpm, $\eta = 75\% = 0.75$; $f = 0.04$

$d_s = d_d = 6$ cm ; $L_s = 6$m ; $L_d = 35$ m, $H_s = 4$ m ; $H_d = 30$ m. Stroke $= 2R = 25$ cm and D = piston dia = 12.5 cm.

I. Suction side:

(i) at beginning of suction stroke, i.e., $\theta = 180°$

$$\text{Inertia head } = \frac{\Delta p}{\rho g} = \frac{L_s}{g}\omega^2 R \left(\frac{D}{d_s}\right)^2$$

$$= \frac{6}{9.81} \times \left(\frac{2\pi \times 30}{60}\right)^2 \times 0.125 \times \left(\frac{0.125}{0.06}\right)^2$$

= 3.28 m of water below atmospheric pressure

Fri n head being zero, the pressure head on piston

$$= H + \frac{\Delta P}{\rho g} = -4 - 3.28$$

= – 7.28 m of water i.e. 7.25 m of water below atmospheric pressure.

(ii) Pressure head at middle of suction stroke i.e. $\theta = 270°$

Inertia head $= 0$

$$\text{Friction head } H_{LS\,(max)} = \frac{f L_s}{2\,gd}\left(\frac{\omega R D^2}{d^2}\right)^2$$

$$= \frac{0.04 \times 6}{2 \times 9.81 \times 0.06} \left[\frac{2\,\pi\, 30}{60} \times 0.125 \times \left(\frac{0.125}{0.06} \right)^2 \right]^2$$

$$= 0.6 \text{ m of water}$$

$\therefore$ Pressure head on piston at middle of suction stroke

$$- - 4 - 0.6 = - 4.6 \text{ m of water below atmospheric pressure.}$$

(iii) Pressure head at the end of suction stroke i.e. $\theta = 360°$

Inertia head $\frac{\Delta p \max}{\rho g} = + 3.28$ m of water [Similar to $\theta = 180°$]

Friction head $= 0$.

$\therefore$ Pressure at end of suction stroke $= - 4 + 3.28 = 0.72$ m of water below atmospheric.

$$\therefore Q = \frac{2\,\pi\, D^2}{4} \cdot \frac{2\,R\,N}{60} = \frac{2 \times \pi\,(0.125)^2}{4} \times \frac{0.25 \times 30}{60}$$

$$= 3.06 \text{ lit/sec. or } 0.00306 \text{ m}^3/\text{s}.$$

II. Considering the delivery side

$$\frac{\Delta P \max}{\rho g} = \frac{L_d}{g} \omega^2 R \left(\frac{D}{d} \right)^2 = \frac{35}{9.81} \left(\frac{2\,\pi \times 30}{6} \right)^2 \times \frac{0.125}{60} \left(\frac{0.125}{0.06} \right)^2$$

$$= 19.14 \text{ m of water}$$

Friction head at mid-stroke

$$\left(H_{Ld} \right)_{max} = \frac{L_d}{L_s} \left(H_{Ls} \right)_{max} = \frac{35}{6} \times 0.6 = 3\ 5 \text{ m of water.}$$

Max head against which pump has to work is the longer the two

(i) $H_s + \left(H_{Ls} \right)_{max} + H_d + \left(H_{Ld} \right)_{max} = 4 + 0.6 + 30 + 3.5 = 38.1$ m

(ii) $H_s \left(\frac{\Delta sp}{\rho g} \right)_{max} + H_d + \left(\frac{\Delta pd_d}{\rho g} \right)_{max} = 4 + 3.28 + 30 + 19.14$

$$= 56.42 \text{ m}$$

$\therefore H = 56.42$ m

Power delivered by pump $= \rho\, g\, QH = 9.81 \times 1000 \times 3.06 \times 10^3 \times 56.42$ Nm/s

$= 1.69$ kW

Power required to run the pump $= \frac{1.69}{\eta_m} = \frac{1.69}{0.75} = \mathbf{2.25\ kW}$

Problem : 16 The plunger diameter of a single acting reciprocating pump is 20 cm and its stroke is 40 cm. The pump runs at 50 rpm and lifts water through a height 30 m. Find the theoretical discharge and percentage slip if the actual discharge is 10 litres/sec. Find the theoretical power required to run the pump.

One delivery pipe 25 m long has 10 cm diameter. Determine the acceleration head at the beginning of delivery strike. If an air vessel is fitted close to the cylinder in the delivery side, determine the head in the cylinder necessary to over come friction in the delivery pipe. The friction factor in the Darcy-Weisbach equation is 0.025.

Solution:

Data Given:

$2R = 40$ cm ; $D = 10$ cm ; $N = 50$ rpm. $H = H_s + H_D = 30$ m.

Theoretical Discharge $Q_{th} = \frac{\pi D^2}{4} \times \frac{2\,R\,N}{60}$

$$Q_{th} = \frac{\pi\, 0.2^2}{4} \times 0.4 \times \frac{50}{60}\ \text{m}^3/\text{s}$$

$$= 0.010476\ \text{m}^3/\text{s}$$

$$= 10.476\ \text{lps.}$$

Actual Discharge $Q_A = 10.0$ lps

$$\therefore \%\ \text{of slip} = \left(\frac{10.476 - 10}{10.476} \right) \times 100$$

$$= \mathbf{4.54\%}$$

Theoretical power required $= \rho\, g\, Q\, H$

$$= 1000 \times 9.81 \times 0.010476 \times 30$$

$$= 9.81 \times 104.76 \times 3$$

$$= 3083 \text{ W}$$

$$= 3.08 \text{ kW}.$$

Acceleration head at the beginning of delivery stroke

$$= \frac{L}{g}\,\omega^2\,R\left(\frac{D}{d}\right)^2$$

$$= \frac{25}{9.81}\left(\frac{2\,\pi \times 50}{60}\right)^2 \times 0.2 \times \left(\frac{20}{10}\right)^2$$

$$= \mathbf{10.68\ m}$$

With air vessel fitted, the velocity in the delivery pipe

$$V_d = \frac{4Q}{\pi\, d^2} = \frac{4 \times 10 \times 10^{-3}}{\pi \times 0.12} = \mathbf{1.273\ m/s}$$

Friction head required to overcome friction

$$= f\,\frac{L\,V_d^2}{2\,g\,d} = \frac{0.025 \times 25 \times 1.273^2}{2 \times 9.81 \times 0.1}$$

$$= \mathbf{0.516\ m}$$

Problem : 17 A single cylinder double acting reciprocating pump of Diameter 300 mm and stroke length 400 mm runs at 40 rpm discharging 35 lps. of water under a total head of 20 m. What will be the volumetric efficiency, work done per sec. and power required for a overall efficiency of 75% what will be the mechanical efficiency of the pump.

Solution:

Using equation (4.11)

$$Q_{Th} = 2\left(\frac{\pi\, D^2}{4} \cdot \frac{2\,R\,N}{60}\right)$$

$$= 2\left[\frac{\pi \times 0.3^2}{4} \cdot \frac{2 \times 0.2 \times 40}{60}\right]$$

$$= 0.0377142 \text{ m}^3/\text{s} = 37.7 \text{ lps}$$

Volumetric efficiency $= \frac{Q_{ac}}{Q_{th}} = \frac{35}{37.7} = 0.9284$ or **92.84%**

Mechanical efficiency $= \frac{\text{overall efficiency}}{\text{Volumetric efficiency}} = \frac{75}{92.84} = 0.8078 = 80.78\%$

Work done/sec. $= \frac{\rho g Q H}{1000} \text{ kW} = \frac{9810 \times 20 \times 0.0377}{1000}$

$$= \mathbf{7.397 \text{ kW}}$$

Power required $= \frac{\text{Work done/sec.}}{\eta_0} = \frac{7.397}{0.75} = \mathbf{9.863 \text{ kW.}}$

Problem : 18 A single acting reciprocating pump runs at 500 rpm delivers 0.1 m^3/s of water. The dia of piston is 200 mm dia & length 400 mm. Determine: 1. The theoretical discharge of pump, 2. Coefficient of discharge, 3. Slip and 4. % of slip.

Solution:

$$N = 500 \text{ rpm} \;\; Q_{act} = 0.1 \text{ m}^3/\text{s};\; D = 200 \text{ mm} = 0.20 \text{ m}$$

Stroke: $L = 400 \text{ mm} = 0.40 \text{ m}\,;\; A = \frac{\pi}{4} D^2 = \frac{\pi}{4} \times 0.2^2 = 0.031416 \text{ m}^2$

1. $Q_{th} = \frac{ALN}{60} = \frac{0.031416 \times 0.4 \times 500}{60} = \mathbf{0.1047 \text{ m}^3/\text{s.}}$

2. $C_d = \frac{Q_{ac}}{Q_{th}} = \frac{0.1}{0.1047} = \mathbf{0.955}$

3. Slip $= Q_{th} - Q_{ac} = 0.1047 - 0.1 = \mathbf{0.0047 \text{ m}^3/\text{sec.}}$

4. % of slip $= \left(\frac{Q_{th} - Q_{ac}}{Q_{th}}\right)100 = \left(\frac{0.1047 - 0.1}{0.1047}\right) \times 100 = \mathbf{4.489\%}$

Say 4.5 %

19.What is meant by Positive displacement Pumps. Explain the various types of positive displacement pump's with all the details

Positive-displacement pumps are another category of pumps. Types of positive-displacement pumps are reciprocating, metering, and rotary pumps. Positive-displacement pumps operate by forcing a fixed volume of fluid from the inlet pressure section of the pump into the discharge zone of the pump. These pumps generally tend to be larger than equal-capacity dynamic pumps. Positive-displacement pumps frequently are used in hydraulic systems at pressures ranging up to 5000 psi. A principal advantage of hydraulic power is the high power density (power per unit weight) that can be achieved. They also provide a fixed displacement per revolution and, within mechanical limitations, infinite pressure to move fluids.

Positive displacement means that, when the pump piston or rotor moves, fluid moves and displaces the fluid ahead of it. Because of its operation, a positive displacement pump can build up a very high discharge pressure and, should a valve in the discharge system be closed for any reason, serious damage may result - the cylinder head, the casing or other downstream equipment may rupture or the driver may stall and burn out.

A Positive Displacement pump must therefore be fitted with a safety relief system on the discharge side.

Types of positive displacement pump

- ROTARY PUMPS
- RECIPROCATING (PISTON) PUMPS
- GEAR PUM

1.Rotary Pumps

In Rotary pumps, movement of liquid is achieved by mechanical displacement of liquid produced by rotation of a sealed arrangement of intermeshing rotating parts within the pump casing.

2.The gear pump

Construction and Operation:

In this pump, intermeshing gears or rotors rotate in opposite directions, just like the gears in a vehicle or a watch mechanism. The pump rotors are housed in the casing or stator with a very small clearance between them and the casing. (The fluid being pumped will lubricate this small clearance and help prevent friction and therefore wear of the rotors and casing).

In this type of pump, only one of the rotors is driven. The intermeshing gears rotate the other rotor. As the rotors rotate, the liquid or gas, (this type of machine can also be used as a compressor), enters from the suction line and fills the spaces between the teeth of the gears and becomes trapped forming small 'Slugs' of fluid between the teeth.

The slugs are then carried round by the rotation of the teeth to the discharge side of the pump.

At this point, the gears mesh together and, as they do so, the fluid is displaced from each cavity by the intermeshing teeth.

Since the fluid cannot pass the points of near contact of the intermeshed teeth nor between the teeth and casing, it can only pass into the discharge line.

As the rotation continues, the teeth at the suction end are opened up again and the same amount of fluid will fill the spaces and the process repeated. The liquid at the discharge end is constantly being displaced (moved forward).

Thus gear pumps compel or force a fixed volume of fluid to be displaced for each revolution of the rotors giving the 'Positive Displacement' action of the pump.

Gear pumps are generally operated at high speed and thus give a fairly pulse-free discharge flow and pressure. Where these pumps are operated at slower speeds, as in pumping viscous liquids, the output tends to pulsate due to the meshing of the teeth.

Any gas or air drawn into the pump with the liquid, will be carried through with the liquid and will not cause cavitation. This action of the pump means that it's a 'Self Priming' pump. The discharge pressure may however, fluctuate.

The output from this type of pump is directly proportional to the speed of operation. If the speed is doubled, the output will be doubled and the pressure will have very little effect. (At higher pressures, due to the fine clearances between the teeth and between the casing and the rotors, a small leakage back to the suction side will occur resulting in a very small drop in actual flow

rate. The higher the discharge pressure, the more likely that internal leakage will occur).

Rotary pumps are widely used for viscous liquids and are self-lubricating by the fluid being pumped. This means that an external source of lubrication cannot be used as it would contaminate the fluid being pumped. However, if a rotary pump is used for dirty liquids or slurries, solid particles can get between the small clearances and cause wear of the teeth and casing. This will result in loss of efficiency and expensive repair or replacement of the pump.

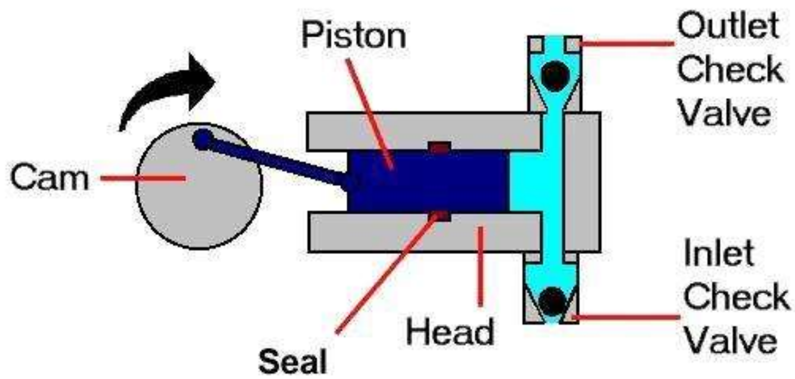
3.Reciprocating Pumps

In a reciprocating pump, a volume of liquid is drawn into the cylinder through the suction valve on the intake stroke and is discharged under positive pressure through the outlet valves on the discharge stroke. The discharge from a reciprocating pump is pulsating and changes changes only when the speed of the pump is changed. This is because the intake is always a constant volume. Often an air chamber is connected on the discharge side of the pump to provide a more

even flow by evening out the pressure surges. Reciprocating pumps are often used for sludge and slurry.

One construction style of a reciprocating pump is the direct-acting steam pump. These consist of a steam cylinder end in line with a liquid cylinder end, with a straight rod conection between th steam piston and the pump piston or plunger. These pistons are double acting which means that each side pumps on every stroke.

Another construction style is the power pump which convert rotary motion to low speed reciprocating motion using a speed reducing gear. The power pump can be either single or double-acting. A single-acting design discharges liquid only on one side of the piston or plunger. Only one suction and one discharge stroke per revolution of the crankshaft can occur. The double-acting design takes suction and discharges on both sides of the piston resulting in two suctions and discharges per crankshaft revolution. Power pumps are generally very efficient and can develop high pressures. These pumps do however tend to be expensive.



The most simple reciprocating pump is the 'Bicycle Pump', which everyone at some time or other will have used to re-inflate their bike tyres. The name 'Bicycle PUMP' is not really the correct term because it causes compression.

It is essentially a hand operated compressor and consists of a metal or plastic tube called a 'Cylinder' inside of which a hand-operated rod or 'Piston' is pushed back and forth. On the piston end, a special leather or rubber cup - shaped attachment is fixed.

When the piston is pushed forward, (this is called a 'Stroke'), the cup flexes against the cylinder walls giving a seal to prevent air passing to the other side. As the pump handle is pushed, air pressure builds

up ahead of the cup and is forced (discharged) into the tyre through the tyre valve which also prevents air escaping when the pump is disconnected or when the piston is pulled back.

When the pump handle is pulled back, (called the 'Suction' stroke), the cup relaxes and the backward motion causes air to pass between it and the cylinder wall to replace the air pushed into the tyre. This reciprocating action is repeated until the tyre is at the required pressure. Because the air is expelled from the pump during the forward stroke only, the pump is known as a 'Single Acting Reciprocating Pump'.

20.Explain the working Principle of Single Acting Reciprocating Pumps and double acting reciprocating pump with all the details

Single Acting Reciprocating Pumps

In industry, reciprocating pumps are of many sizes and designs. Their operation is similar to the bicycle pump described above.

An industrial reciprocating pump is constructed of metal and has the following main parts :

1. The cylinder

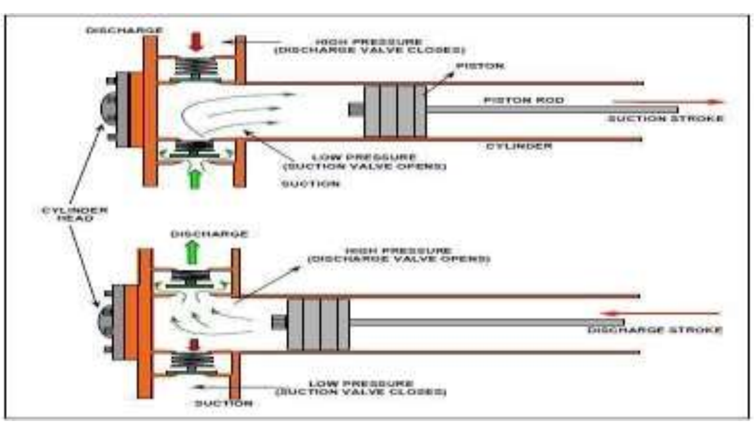
This is a metal tube-shaped casing (or body), which is generally fitted with a metal lining called a 'cylinder liner '. The liner is replaceable when it becomes worn and inefficient. The cylinder is also fitted with suction and discharge ports which contain special spring loaded valves to allow liquid to flow in one direction only - similar to check valves.

2. The piston

The piston consists of a metal drive rod connected to the piston head which is located inside the cylinder. The piston head is fitted with piston rings to give a seal against the cylinder lining and minimize internal leakage. The other end of the drive rod extends to the outside of the cylinder and is connected to the driver. high pressure steam which was fed to a drive cylinder by a system of valves in a steam chest). Modern industries generally use high power electric motors, linkages and gearing to convert rotating motion into a reciprocating action.

Double Acting Reciprocating Pumps

This type of pump operates in exactly the same way as the single acting with respect to its action. The difference is, that the cylinder has inlet and outlet ports at each end of the cylinder. As the piston moves forward, liquid is being drawn into the cylinder at the back end while, at the front end, liquid is being discharged. When the piston direction is reversed, the sequence is reversed.



With a double acting pump, the output pulsation is much less than the single acting.

In theory, a reciprocating pump will always deliver the same volume for each stroke regardless of discharge pressure. But, as discharge pressure is increased, there is more likelihood of internal leakage between the piston rings and the cylinder liner, or leaking internal valves, causing a decrease in output. A measure of this is known as the ' Volumetric Efficiency ' of the pump.
The amount of liquid which leaks internally is known as the ' Slip ' and, if the pump is in good condition, the slip should be below 1.0%. If slip is above 5.0%, the pump needs to be overhauled. However, at operating pressures, the amount of slip is relatively constant as long as wear is not rapid. The output therefore can still be classed as constant. This type of pump is useful for delivery of fixed quantities of liquid as used in metering or dosing operations.

The speed of a reciprocating pump is generally measured as ' Strokes per Minute '. This is the number of times the piston moves back and forth in one minute. Speed can also be measured as ' R.P.M.' of the drive motor.

As the cylinder(s) are of constant dimensions, the volume of liquid moved for each stroke, (discounting leakage described above), is the same and therefore the output per minute, hour or day ..etc can be calculated.

This type of pump operates in exactly the same way as the single acting with respect to its action. The difference is, that the cylinder has inlet and outlet ports at EACH END OF THE CYLINDER. As the piston moves forward, liquid is being drawn into the cylinder at the back end while, at the front end, liquid is being discharged. When the piston direction is reversed, the sequence is reversed.

With a double acting pump, the output pulsation is much less than the single acting. In theory, a reciprocating pump will always deliver the same volume for each stroke regardless of discharge pressure. But, as discharge pressure is increased, there is more likelihood of internal leakage between the piston rings and the cylinder liner, or leaking internal valves, causing a decrease in output. A measure of this is known as the ' Volumetric Efficiency ' of the pump. The amount of liquid which leaks internally is known as the ' Slip ' and, if the pump is in good condition, the slip should be below 1.0%. If slip is above 5.0%, the pump needs to be overhauled. However, at operating pressures, the amount of slip is relatively constant as long as wear is not rapid. The output therefore can still be classed as constant. This type of pump is useful for delivery of fixed quantities of liquid as used in metering or dosing operations.

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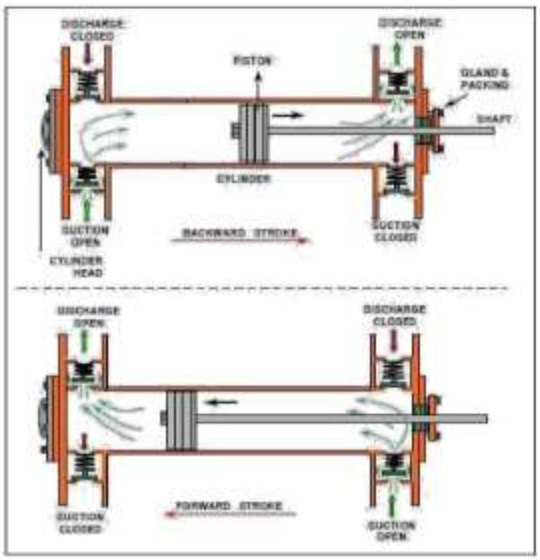


21.Briefly Discuss About Metering Pumps and Variable Displacement Vane Pumps .Give all in detail

<u>Metering Pumps</u>

Metering pumps provide precision control of very low flow rates. Flow rates are generally less than 1/2 gallon per minute. They are usually used to control additives to the main flow stream. They are also called proportioning orcontrolled-volume pumps. Metering pumps are available in either a diaphragm or packed plunger style, and are designed for clean service and dirty liquid can easily clog the valves and nozzle connections.

<u>Variable Displacement Vane Pumps</u>

One of the major advantages of the vane pump is that the design readily lends itself to become a variable displacement pump, rather than a fixed displacement pump such as a spur-gear (X-X) or a gerotor (I-X) pump. The centerline distance from the rotor to the eccentric ring is used to determine the pump's displacement. By allowing the eccentric ring to pivot or translate relative to the rotor, the displacement can be varied. It is even possible for a vane pump to pump in reverse if the eccentric ring moves far enough. However, performance cannot be optimized to pump in both directions. This can make for a very interesting hydraulic control oil pump.

Variable displacement vane pumps are used as an energy savings device, and have been used in many applications, including automotive transmissions, for over 30 years.

22.Explain in deatil about Mono Pumps and also the Diaphragm pump with neat Skecth

Mono Pumps

Browse through the Moyno technical bulletins to see how the rotor turns inside the casing. This is called a "progressing cavity". This pump handles solids beautifully. It is said that they can pump strawberries with little damage to each berry.

Diaphragm pump

The diaphragm pump is an offshoot of a plunger pump. Because of the risk that contamination could travel between the plunger and the cylinder, the diaphragm is safer for microbial processing. This applet is crude but shows how a reciprocating piston (plunger) pump works. The flywheel that moves the plunger can attach the arm to the plunger at various points to change the amplitude of the stroke and thus the pumping rate. The pumping rate can also be changed with a different rotational speed, but variable speed motors or mechanical means of changing rpm are expensive.

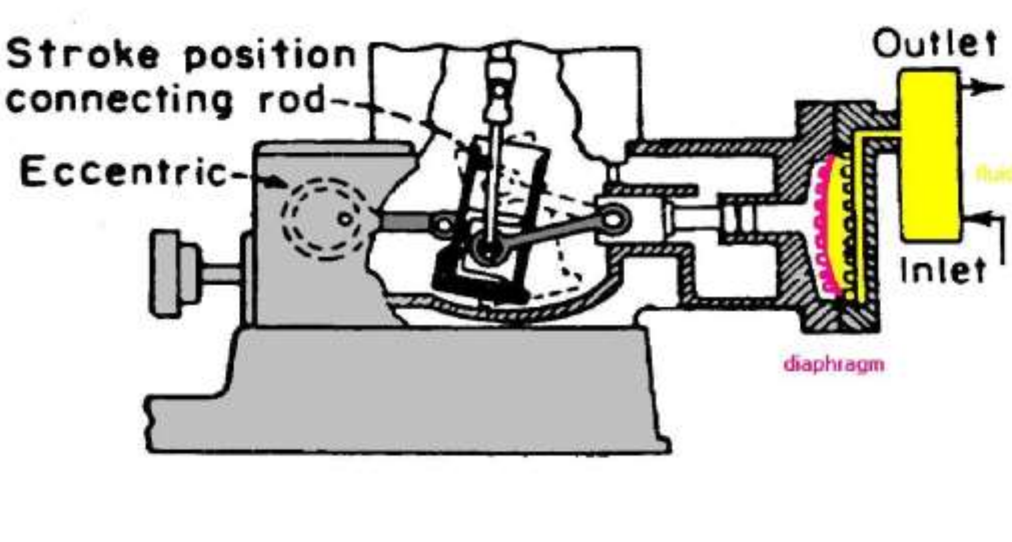


Fig. 4.6 diaphragm pump

A single acting pump with One cylinder is called a ' Single-acting Simplex ' pump. A double acting pump with One cylinder is called a ' Double-acting Simplex '.

23.Write Short notes on multi-cylinder pumps

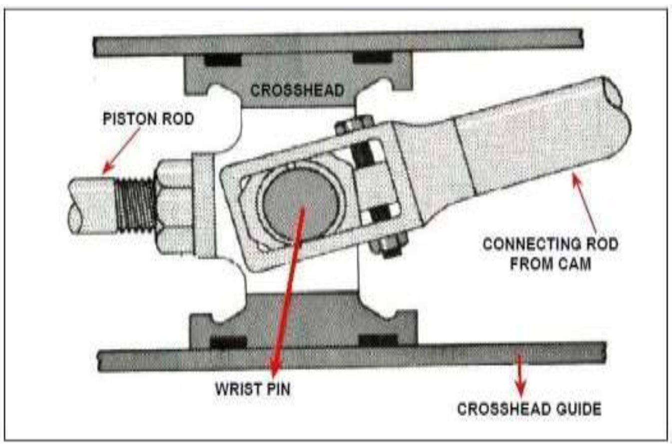
Where more than one cylinder is being driven by one driver, the arrangement is named according to the type and number of cylinders.

1. A Single-acting Duplex pump has TWO single acting cylinders.
2. A Double-acting Duplex pump has TWO double acting cylinders.
3. A Single-acting Triplex pump has THREE single acting cylinders.
4. A ' Double-acting Triplex ' pump has THREE double acting cylinders.

The more double-acting cylinders in a pump arrangement, driven by a single motor, the smoother and pulsation-free, is the output.

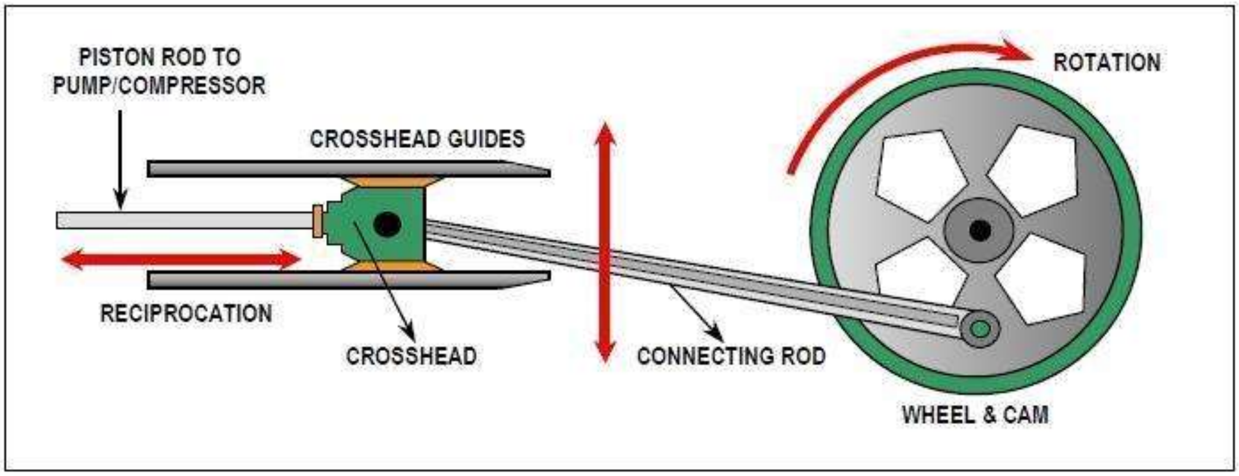
24. Explain the of converting rotation into reciprocation

The electric motor drives a fly-wheel or cam-shaft which is connected eccentrically to a connecting rod. The other end of the connecting rod is coupled to a 'Cross-head Gear' and 'Slide Assembly'. (This arrangement is the basis of the operation of the old Steam Engine drive cylinders and pistons).



As the motor rotates the fly-wheel or cam, the eccentrically mounted connecting rod rotates with it. This causes the rod to move up and down and backwards and forwards. The up and down motion cannot be transmitted to the pump shaft - it would not work. We do however, need the back and forth movement. The connecting rod goes to the cross-head gear which consists of a pivot inserted into the slide assembly. The pivot removes the up and down movement of the rod but allows the pump shaft to move back and forth.

The diagrams will explain the principle much more easily than words.



25.What is meant by PD Pumps. Explain and comparing 4 Types of PD Pumps with all the details

Selection of a positive displacement (PD) rotary pump is not always an easy choice. There are four common types of PD pumps available: internal gear, external gear, timed lobe, and vane. Most PD pumps can be adapted to handle a wide range of applications, but some types are better suited than others for a given set of circumstances.

The first consideration in any application is pumping conditions. Usually the need for a PD pump is already determined, such as a requirement for a given amount of flow regardless of differential pressure, viscosity too high for a centrifugal pump, need for high differential pressure, or other factors.

Inlet conditions, required flow rate, differential pressure, temperature, particle size in the liquid, abrasive characteristics, and corrosiveness of the liquid must be determined before a pump selection is made.

A pump needs proper suction conditions to work well. PD pumps are self-priming, and it is often assumed that suction conditions are not important. But they are. Each PD pump has a minimum inlet pressure requirement to fill individual pump cavities. If these cavities are not completely filled, total pump flow is diminished. Pump manufacturers supply information on minimum inlet conditions required. If high lift or high vacuum inlet conditions exist, special attention must be paid to the suction side of the pump.

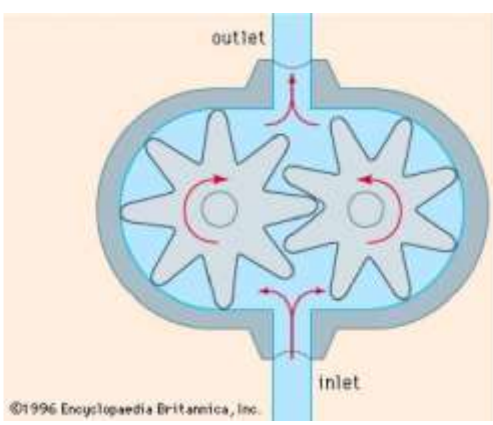
Rotary Pumps

By definition, positive-displacement (PD) pumps displace a known quantity of liquid with each revolution of the pumping elements. This is done by trapping liquid between the pumping elements and a stationary casing.

Pumping element designs include gears, lobes, rotary pistons, vanes, and screws.

PD pumps are found in a wide range of applications -- chemical-processing; liquid delivery; marine; biotechnology; pharmaceutical; as well as food, dairy, and beverage processing. Their versatility and popularity is due in part to their relatively compact design, high-viscosity performance, continuous flow regardless of differential pressure, and ability to handle high differential pressure.

A rotary pump traps fluid in its closed casing and discharges a smooth flow. They can handle almost any liquid that does not contain hard and abrasive solids, including viscous liquids. They are also simple in design and efficient in handling flow conditions that are usually considered to low for economic application of centrifuges. Types of rotary pumps include cam-and-piston, internal-gear, lobular, screw, and vane pumps. Gear pumps are found in home heating systems in
which the burners are fired by oil. Rotary pumps find wide use for viscous liquids. When pumping highly viscous fluids, rotary pumps must be operated at reduced speeds because at higher speeds the liquid cannot flow into the casing fast enough to fill it. Unlike a centrifugal pump, the rotary design will deliver a capacity that is not greatly affected by pressure variations on either the suction or discharge ends. In services where large changes in pressure are anticipated, the rotary design should be considered.



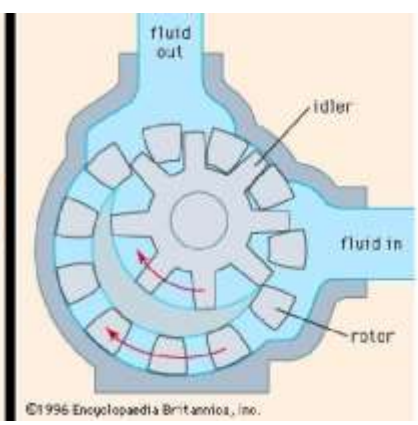


Fig 4.9 External gear Pump **Fig 4. 10Internal gear Pump**

Advantages of Rotary Pumps

They can deliver liquid to high pressures.

Self - priming.

Give a relatively smooth output, (especially at high speed).

Positive Acting.

Can pump viscous liquids.

Disadvantages of Rotary Pumps

More expensive than centrifugal pumps.

Should not be used for fluids containing suspended solids.

Excessive wear if not pumping viscous material.

Must NEVER be used with the discharge closed.

rotary vane pump is a positive-displacement pump that consists of vanes mounted to a rotor that rotates inside of a cavity. In some cases these vanes can be variable length and/or tensioned to maintain contact with the walls as the pump rotates

Types

The simplest vane pump is a circular rotor rotating inside of a larger circular cavity. The centers of these two circles are offset, causing eccentricity. Vanes are allowed to slide into and out of the rotor and seal on all edges, creating vane chambers that do the pumping work. On the intake side of the pump, the vane chambers are increasing in volume. These increasing volume vane chambers are filled with fluid forced in by the inlet pressure. Often this inlet pressure is nothing more than pressure from the atmosphere. On the discharge side of the pump, the vane chambers are decreasing in volume, forcing fluid out of the pump. The action of the vane drives out the same volume of fluid with each rotation. Multistage rotary vane vacuum pumps can attain pressures as low as 10^{-3} mbar (0.1 Pa).

Uses

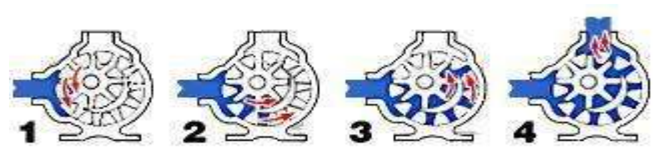
Common uses of vane pumps include high pressure hydraulic pumps and automotive uses including, supercharging, power steering and automatic transmission pumps. Pumps for mid-range pressures include applications such as carbonators for fountain soft drink dispensers and espresso coffee machines. They are also often used as vacuum pumps for providing braking assistance (through a braking booster) in large trucks, and in most light aircraft to drive gyroscopic flight instruments, the attitude indicator and heading indicator. Furthermore, vane pumps can be used in low-pressure gas applications such as secondary air injection for auto exhaust emission control, and in vacuum applications including evacuating refrigerant lines in air conditioners, and laboratory freeze dryers, extensively in semiconductor low pressure chemical vapor deposition systems, and vacuum experiments in physics. In this application the pumped gas and the oil are mixed within the pump, but must be separated externally. Therefore the inlet and the outlet have a large chamber – maybe with swirl – where the oil drops fall out of the gas. The inlet has a venetian blind cooled by the room air (the pump is usually 40 K hotter) to condense cracked pumping oil and water, and let it drop back into the inlet. It eventually exits through the outlet.

Internal Gear Pump Overview

In addition to their wide viscosity range, the pump has a wide temperature range as well, handling liquids up to 750°F / 400°C. This is due to the single point of end clearance (the distance between the ends of the rotor gear teeth and the head of the pump). This clearance is adjustable to accommodate high temperature, maximize efficiency for handling high viscosity liquids, and to accommodate for wear.

The internal gear pump is non-pulsing, self-priming, and can run dry for short periods. They're also bi-rotational, meaning that the same pump can be used to load and unload vessels. Because internal gear pumps have only two moving parts, they are reliable, simple to operate, and easy to maintain.

How Internal Gear Pumps Work



1. Liquid enters the suction port between the rotor (large exterior gear) and idler (small interior gear) teeth. The arrows indicate the direction of the pump and liquid.

2. Liquid travels through the pump between the teeth of the "gear-within-a-

3. The pump head is now nearly flooded, just prior to forcing the liquid out of the discharge

port. Intermeshing gears of the idler and rotor form locked pockets for the liquid which assures volume control.

4. Rotor and idler teeth mesh completely to form a seal equidistant from the discharge and suction ports. This seal forces the liquid out of the discharge port.

- Only one stuffing box
- Non-pulsating discharge Excellent for high-viscosity liquids
- Constant and even discharge regardless of pressure conditions
- Operates well in either direction Can be made to operate with one direction of flow with either rotation Low NPSH required
- Single adjustable end clearance Easy to maintain
- Flexible design offers application customization • Medium pressure limitations
- One bearing runs in the product pumped Overhung load on shaft bearing

Applications

Common internal gear pump applications include, but are not limited to:

- All varieties of fuel oil and lube oil
- Resins and Polymers
- Alcohols and solvents
- Asphalt, Bitumen, and Tar
- Polyurethane foam (Isocyanate and polyol)
- Food products such as corn syrup, chocolate, and peanut butter
- Paint, inks, and pigments
- Soaps and surfactants
  Glycol

Materials of Construction / Configuration Options

- Externals (head, casing, bracket) - Cast iron, ductile iron, steel, stainless steel, Alloy 20, and higher alloys.
- Internals (rotor, idler) - Cast iron, ductile iron, steel, stainless steel, Alloy 20, and higher alloys.

- Bushing - Carbon graphite, bronze, silicon carbide, tungsten carbide, ceramic, colomony, and other specials materials as needed.
- Shaft Seal - Lip seals, component mechanical seals, industry-standard cartridge mechanical seals, gas barrier seals, magnetically-driven pumps.
- Packing - Impregnated packing, if seal not required.

External Gear Pump Overview

External gear pumps are a popular pumping principle and are often used as lubrication pumps in machine tools, in fluid power transfer units, and as oil pumps in engines.

External gear pumps can come in single or double (two sets of gears) pump configurations with spur (shown), helical, and herringbone gears. Helical and herringbone gears typically offer a smoother flow than spur gears, although all gear types are relatively smooth. Large-capacity external gear pumps typically use helical or herringbone gears. Small external gear pumps usually operate at 1750 or 3450 rpm and larger models operate at speeds up to 640 rpm. External gear pumps have close tolerances and shaft support on both sides of the gears. This allows them to run to pressures beyond 3,000 PSI / 200 BAR, making them well suited for use in hydraulics. With four bearings in the liquid and tight tolerances, they are not well suited to handling abrasive or extreme high temperature applications.

Tighter internal clearances provide for a more reliable measure of liquid passing through a pump and for greater flow control. Because of this, external gear pumps are popular for precise transfer and metering applications involving polymers, fuels, and chemical additives.

1. As the gears come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the gear teeth as they rotate.

2. Liquid travels around the interior of the casing in the pockets between the teeth and the casing -- it does not pass between the gears.

3. Finally, the meshing of the gears forces liquid through the outlet port under pressure.

Because the gears are supported on both sides, external gear pumps are quiet-running and are routinely used for high-pressure applications such as hydraulic applications. With no overhung bearing loads, the rotor shaft can't deflect and cause premature wear.

Advantages

- High speed
- High pressure
- No overhung bearing loads
- Relatively quiet operation
- Design accommodates wide variety of materials

Disadvantages

Four bushings in liquid area

No solids allowed

Fixed End Clearances

Applications

- Common external gear pump applications include, but are not limited to:
- Various fuel oils and lube oils
- Chemical additive and polymer metering
- Chemical mixing and blending (double pump)
- Industrial and mobile hydraulic applications (log splitters, lifts, etc.)
- Acids and caustic (stainless steel or composite construction)
- Low volume transfer or application

Lobe Pump Overview

Lobe pumps are used in a variety of industries including, pulp and paper, chemical, food, beverage, pharmaceutical, and biotechnology. They are popular in these diverse industries because they offer superb sanitary qualities, high efficiency, reliability, corrosion resistance, and good clean-in-place and sterilize-in-place (CIP/SIP) characteristics.

These pumps offer a variety of lobe options including single, bi-wing, tri-lobe (shown), and multi-lobe. Rotary lobe pumps are non-contacting and have large pumping chambers, allowing them to handle solids such as cherries or olives without damage. They are also used to handle slurries, pastes, and a wide variety of other liquids. If wetted, they offer self-priming performance. A gentle pumping action minimizes product degradation. They also offer reversible flows and can operate dry for long periods of time. Flow is relatively independent of changes in process pressure, so output is constant and continuous.

Rotary lobe pumps range from industrial designs to sanitary designs. The sanitary designs break down further depending on the service and specific sanitary requirements. These requirements include 3-A, EHEDG, and USDA. The manufacturer can tell you which certifications, if any, their rotary lobe pump meets.

Lobe Pumps

Lobe pumps are similar to external gear pumps in operation in that fluid flows around the interior of the casing.

1. As the lobes come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the lobes as they rotate.

2. Liquid travels around the interior of the casing in the pockets between the lobes and the casing -- it does not pass between the lobes.

3. Finally, the meshing of the lobes forces liquid through the outlet port under pressure.

Lobe pumps are frequently used in food applications because they handle solids without damaging the product. Particle size pumped can be much larger in lobe pumps than in other PD types. Since the lobes do not make contact, and clearances are not as close as in other PD pumps, this design handles low viscosity liquids with diminished performance. Loading characteristics are not as good as other designs, and suction ability is low. High-viscosity liquids require reduced speeds to achieve satisfactory performance. Reductions of 25% of rated speed and lower are common with high-viscosity liquid

4. As the lobes come out of mesh, they create expanding volume on the inlet side of the pump. Liquid flows into the cavity and is trapped by the lobes as they rotate.

5. Liquid travels around the interior of the casing in the pockets between the lobes and the casing -- it does not pass between the lobes.

6. Finally, the meshing of the lobes forces liquid through the outlet port under pressure.

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Advantages

-Pass medium solids

-No metal-to-metal contact

Disadvantages

- Superior CIP/SIP capabilities
- Long term dry run (with lubrication to seals)
- Non-pulsating discharge

Vane Pump Overview

While vane pumps can handle oderate viscosity liquids, they excel at handling low viscosity liquids such as LP gas (propane), ammonia, solvents, alcohol, fuel oils, gasoline, and refrigerants. Vane pumps have no internal metal-to-metal contact and self-compensate for wear, enabling them to maintain peak performance on these non-lubricating liquids.

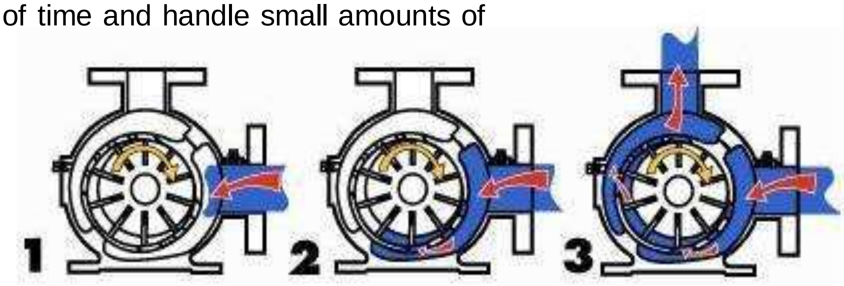
Vane pumps are available in a number of vane configurations including sliding vane (left),

flexible vane, swinging vane, rolling vane, and external vane. Vane pumps are noted for their dry priming, ease of maintenance, and good suction characteristics over the life of the pump. Moreover, vanes can usually handle fluid temperatures from -32°C /

25°F to 260°C / 500°F and differential pressures to 15 BAR / 200 PSI (higher for hydraulic vane pumps).

Each type of vane pump offers unique advantages. For example, external vane pumps can handle large solids.

Flexible vane pumps, on the other hand, can only handle small solids but create good vacuum. Sliding vane pumps can run dry for short periods of time and handle small amounts of vapor.



Vane Pumps

Despite the different configurations, most vane pumps operate under the same general principle described below.

1. A slotted rotor is eccentrically supported in a cycloidal cam. The rotor is located close to the wall of the cam so a crescent-shaped cavity is formed. The rotor is sealed into the cam by two side plates. Vanes or blades fit within the slots of the impeller. As the rotor rotates (yellow arrow) and fluid enters the pump, centrifugal force, hydraulic pressure, and/or pushrods push the vanes to the walls of the housing. The tight seal among the vanes, rotor, cam, and side plate is the key to the good suction characteristics common to the vane pumping principle.

2. The housing and cam force fluid into the pumping chamber through holes in the cam (small red arrow on the bottom of the pump). Fluid enters the pockets created by the vanes, rotor, cam
.

Problem 26

The following details refer to a centrifugal pump. Outer diameter : 30 cm. Eye diameter : 15 cm. Blade angle at inlet : 30°. Blade angle at outlet : 25°. Speed 1450 rpm. The flow velocity remains constant. The whirl at inlet is zero. Determine the work done per kg. If the manometric efficiency is 82%, determine the working head. If width at outlet is 2 cm, determine the power ηo = 76%.

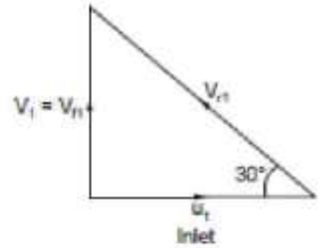
$$u_1 = \frac{\pi \times 0.3 \times 1450}{60} = 22.78 \text{ m/s}$$

$$u_2 = 11.39 \text{ m/s.}$$

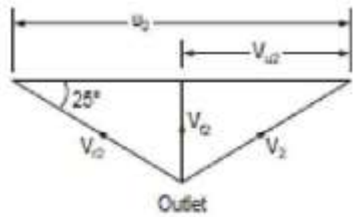
From inlet velocity diagram.

$$V_{f1} = u_1 \tan \beta_1$$

$$= 11.39 \times \tan 30 = 6.58 \text{ m/s}$$



From the outlet velocity diagram,



$$V_{u2} = u_1 - \frac{V_{f2}}{\tan\beta_2} = 22.78 - \frac{6.58}{\tan 25} = 8.69 \text{ m/s}$$

Work done per kg $= u_2 V_{u2} = 22.78 \times 8.69$

$= 197.7$ **Nm/kg/s**

$$\eta_m = 0.82 = \frac{gH}{197.7}$$

$\therefore$ **H = 16.52 m**

$$\text{Flow rate} = \pi \times 0.3 \times 0.02 \times 6.58 = 0.124 \text{ m}^3\text{/s}$$

$$\text{Power} = \frac{0.124 \times 10^3 \times 9.81 \times 16.52}{0.76 \times 10^3} = 26.45 \text{ kW.}$$

Problem 27

A homologus model of a centrifugal pump runs at 600 rpm against a head of 8 m, the power required being 5 kW. If the prototype 5 times the model size is to develop a head of 40 m determine its speed, discharge and power. The overall efficiency of the model is 0.8 while that of the prototype is 0.85.

(1) $Q \propto D2\ H^{1/2}$ (as $Q = AVf$, $A \propto Db$, $b \propto D$, $Vf \propto u \propto H$)

(2) $u \propto DN \propto \sqrt{H} \quad \therefore \quad \frac{ND}{\sqrt{H}} = \text{const.}$

$$Q_m = \frac{P_m \times \eta_m}{\rho g H_m} = \frac{5 \times 10^3 \times 0.8}{10^3 \times 9.81 \times 8} = 0.05097 \text{ m}^3\text{/s}$$

From (1) $$Q_p = Q_m \cdot \frac{D_p^{\,2}}{D_m^{\,2}} \cdot \frac{H_p^{\,1/2}}{H_m^{\,1/2}}$$

$$= 0.05097 \times 5^2 . \left(\frac{40}{8}\right)^{1/2} = 2.8492 \text{ m}^3\text{/s}$$

From (2) $$N_p = N_m \cdot \left(\frac{H_p}{H_m}\right)^{1/2} . \frac{D_m}{D_p} = 600 \,.\, 5^{1/2} . \frac{1}{5} = 268.32 \text{ rpm}$$

$$\text{Power} = \frac{2.8492 \times 9.81 \times 40 \times 10^3}{0.85 \times 10^3} = 1315.3 \text{ kW.}$$

Problem 2: The diameter and width of a contrifugal pump impeller are 50 cm and 2.5 cm. The pump runs at 1200 rpm. The suction head is 6 m and the delivery head is 40 m. The frictional drop in suction is 2 m and in the delivery 8 m. The blade angle at out let is 30°. The manometric efficiency is 80% and the overall efficiency is 75%. Determine the power required to drive the pump. Also calculate the pressures at the suction and delivery side of the pump.

Inlet swirl is assumed as zero.

Total head against the pump is

40 + 6 + 2 + 8 = 56 m.

u2 = π × 0.5 × 1200/60 = 31.42 m/s

$$\eta_m = \frac{g\,H}{u_2\,V_{u2}} = 0.8$$

$$\therefore \quad \frac{9.81 \times 56}{3142 \times V_{u2}} = 0.8,\ \text{solving } V_{u2} = 21.86 \text{ m/s}$$

$$\tan\beta_2 = \frac{V_{f2}}{u_2 - V_{u2}}$$

$$\therefore \quad V_{f2} = \tan 30\,(31.42 - 21.86) = 5.52 \text{ m/s}$$

$$\text{Flow rate} \quad = \pi D_2 b_2 V_{f2} = \pi \times 0.5 \times 0.15 \times 5.52$$

$$= 0.13006 \text{ m}^3\text{/s}$$

$$\therefore \quad \text{Power} = \frac{0.13006 \times 10^3 \times 9.81 \times 56}{0.75 \times 10^3} = 95.3 \text{ kW}$$

Considering the water level and the suction level as 1 and 2

$$\frac{P_1}{\gamma} + 0 + 0 = \frac{P_2}{\gamma} + Z + \frac{V_2^2}{2g} + \text{losses}$$

$$10 = \frac{P_2}{\gamma} + 6 + \frac{5.52^2}{2 \times 9.81} + 2,\ \text{solving,}$$

$$\frac{\mathbf{P_2}}{\gamma} = \mathbf{0.447 \text{ m absolute (vacuum)}}$$

Consider suction side and delivery side, as 2 and 3

$$\frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \frac{u_2 V_{u2}}{g} = \frac{P_3}{\gamma} + \frac{V_3^2}{2g}$$

$$V_3 = \sqrt{2186^2 + 5.52^2} = 22.55 \text{ m/s}$$

$$\frac{P_3}{\gamma} = 0.447 + \frac{5.52^2}{2 \times 9.81} + \frac{3142 \times 2186}{9.81} - \frac{22.55^2}{2 \times 9.81} = \mathbf{40.1 \text{ m absolute}}$$

Problem 29

.4 It is proposed to design a homologous model for a centrifugal pump. The prototype pump is to run at 600 rpm and develop 30 m head the flow rate being 1 m3/s. The model of 1/4 scale is to run at 1450 rpm. Determine the head developed discharge and power required for the model. Overall efficiency = 80%.

In this case the speeds and diameter ratios are specified.

$$Q = AVf\ ,\ A = \pi\ Db,\ b \propto D,\ \therefore A \propto D^2$$

$$P_p = \frac{30 \times 1 \times 10^3 \times 9.81}{0.8 \times 1000} = 367.9 \text{ kW}$$

Using (1) $\quad Q_m = Q_p\left(\frac{D_m}{D_p}\right)^3 \cdot \frac{N_m}{N_p} = 1 \times \left(\frac{1}{4}\right)^3 \times \frac{1450}{600} = 0.03776 \text{ m}^3\text{/s}$

Using (4) $\quad H_m = H_p\left(\frac{D_m}{D_p}\right)^2 \cdot \left(\frac{N_m}{N_p}\right)^2 = 30 \times \left(\frac{1}{4}\right)^2 \cdot \left(\frac{1450}{600}\right)^2 = 10.95 \text{ m}$

Using (3) $\quad P_m = P_p\frac{Q_m}{Q_p} \cdot \frac{H_m}{H_p} = 367.9 \times \frac{0.03776}{1} \cdot \frac{10.95}{30} = 5.07 \text{ kW}$

Check : $\quad P_m = \frac{0.03776 \times 10^3 \times 9.81 \times 10.95}{0.8} = 5.07 \text{ kW}$

Problem 30

A single acting reciprocating water pump of 180 mm bore and 240 mm stroke operates at 40 rpm. Determine the discharge if the slip is 8%. What is the value of coefficient of discharge. If the suction and delivery heads are 6 m and 20 m respectively determine the theoretical power. If the overall efficiency was 80%, what is the power requirement.

$$\text{Theoretical discharge} = \frac{A\,L\,N}{60}$$

$$= \frac{\pi \times 0.18^2}{4} \times 0.24 \times \frac{40}{60} = 4.0775 \times 10^{-3}\ \text{m}^3/\text{s}$$

$$= 4.0715\ \text{l/s} = 4.0715\ \text{kg/s}$$

$$\text{Slip} = 8\%$$

$$\therefore \quad \text{Actual flow} = 4.0715 \times \frac{92}{100} = 3.746\ \text{l/s or kg/s}$$

$$\text{Coefficient of discharge} = \frac{3.746}{4.0715} = 0.92$$

$$\text{Theoretical power} = mgH = 3.746 \times 9.81 \times 26$$

$$= 955.45\ \text{W}$$

$$\text{Actual Power} = 955.45/0.8$$

$$= \mathbf{1194.3\ W\ or\ 1.1943\ kW}$$

If it is a double acting pump, in case the piston rod diameter is neglected, the flow and power will be double this value. The slip and coefficient discharge and efficiency remaining the same.

Problem 31

It is desired to have a discharge of water of 10 l/min using a reciprocating pump running at 42 rpm. The bore to stroke ratio is to be 1 : 1.5. It is expected that the slip will be 12%. Determine the bore and stroke for (a) single acting pump, and (b) double acting pump.If the total head is 30 m and the overall efficiency is 82%, determine the power required in bothcases.

Single acting pump :

$$\text{Theoretical discharge} = \frac{A\,L\,N}{60}\ \text{m}^3/\text{s}$$

$$\text{Actual discharge} = (1 - \text{slip})\,\frac{A\,L\,N}{60}\ \text{m}^3/\text{s}$$

$$\text{Actual per minute} = (1 - \text{slip}) \times A\,L\,N$$

$$A = \frac{\pi D^2}{4}, \qquad L = 1.5\,D,\ (1 - 0.12)\,\frac{\pi D^2}{4} \times 1.5\,D \times 42 = 0.01$$

$$\text{Solving} \qquad D^3 = \frac{0.01 \times 4}{0.88 \times \pi \times 1.5 \times 42}$$

Solving, **D = 62.7 mm and Stroke = 94 mm**

$$\text{Power} = \frac{mgh}{\eta} = \frac{10 \times 9.81 \times 30}{0.82 \times 60} = 60\ \text{W}$$

Double acting : (Neglecting piston rod diameter)

$$0.01 = (1-0.12)\left(\frac{2\pi D^2}{4}\times 15D\times 42\right)$$

Solving: D = 48.6 mm, L = 97.2 mm

The advantage of double acting pump is compactness and lower weight as can be seen form the values.

The power required will be double that of the single acting pump P = 120 W.

Problem 32

In a single acting reciprocating pump the bore and stroke are 90 and 160 mm. The static head requirements are 4 m suction and 15 m delivery. If the pressure at the end of delivery is atmospheric determine operating speed. The diameter of the delivery pipe is 90 mm and the length of the delivery pipe is 22 m. Determine the acceleration head at θ = 30 from the start of delivery.

In this case, the acceleration head equals the static delivery head.

$\therefore$ $$15 = \frac{22}{9.81}\times\frac{0.09^2}{0.09^2}.\omega^2\times 0.08$$

Solving, $\omega = 9.1437$

$$N = \frac{\omega\times 60}{2\pi} = \frac{9.1437\times 60}{2\times\pi}$$

$$= \mathbf{87.32\ rpm}$$

At the position 30° from start of delivery,

$$h_a = \frac{l}{g}.\frac{A}{a}.\omega^2 r\cos\theta$$

$$= \frac{22}{9.81}\times\frac{0.09^2}{0.09^2}.9.1437^2\times 0.08\times\cos 30$$

$$= \mathbf{12.99\ m.}$$

Problem 33

A reciprocating pump handling water with a bore of 115 mm and stroke of 210 mm runs at 35 rpm. The delivery pipe is of 90 mm diameter and 25 m long. An air vessel of sufficient volume is added at a distance of 2 m from the pump. Determine the acceleration head with and without the air vessel.

Without air vessel:

$$h_a = \frac{l}{g} \cdot \frac{A}{a} \cdot \omega^2 r$$

$$= \frac{25}{9.81} \times \frac{0.115^2}{0.09^2} \times \left(\frac{2\pi \times 35}{60}\right)^2 \times 0.105 = 5.869 \text{ m}$$

With air vessel l reduces to 2 m.

$$\therefore \qquad h' = \frac{5.869 \times 2}{25} = 0.47 \text{ m}$$

Problem 34

In a reciprocating pump delivering water the bore is 14 cm and the stroke is 21 cm. The suction lift is 4 m and delivery head is 12 m. The suction and delivery pipe are both 10 cm diameter, length of pipes are 9 m suction and 24 m delivery. Friction factor is 0.015.Determine the theoretical power required. Slip is 8 percent. The pump speed is 36 rpm.

Volume delivered assuming single acting

$$= A\,L\,N/60 = \frac{\pi \times 0.14^2}{4} \times 0.21 \times \frac{36}{60}$$

$$= 1.9396 \times 10^{-3} \text{ m}^3\text{/s or } 1.9396 \text{ kg/s}$$

Slip is 8%

$\therefore$ Actual mass delivered = 1.9396 × 0.92 = 1.784 kg/s

Total static head = 4 + 12 = 16 m head

Friction head in the delivery pipe:

Maximum velocity, $v = \frac{A}{a}\omega r = \frac{0.14^2}{0.1^2} \times \frac{2\pi \times 36}{60} \times 0.105 = 0.7758$ m/s

$$h_{fd} = \frac{flv^2}{2gd} = \frac{0.015 \times 24}{2 \times 9.81 \times 0.1} \cdot [0.7758]^2 = 0.11 \text{ m}$$

Average is, $2/3\ h_{fd} = 0.07363$ m

Friction head in the suction pipe ;

Velocity is the same as diameters are equal

$$h_{fs} = \frac{0.015 \times 9}{2 \times 9.81 \times 0.1} \times [0.7758]^2 = 0.0414 \text{ m}$$

Average = $2/3\ h_{fs} = 0.0414 \times 2/3 = 0.02761$ m

Total head = 16 + 0.07363 + 0.02761 = 16.10124 m

Theoretical Power = 1.784 × 9.81 × 16.1024 = 282 W.

Without air vessel:

$$h_{as} = \frac{l_s}{g} \cdot \frac{A}{a_s} \cdot \omega^2 r = \frac{12}{9.81} \times \frac{0.1^2}{0.09^2} \cdot \left(\frac{2\pi \times 40}{60}\right)^2 \times 0.075$$

$$= 1.987 \text{ m}$$

Absolute pressure = 10.3 – 3.5 – 1.987 = **4.812.** Safe against separation

With air vessel :

$$h_a' = 1.987 \times 1.5/12 = 0.248 \text{ m}$$

Absolute pressure = 10.3 – 35 – 0.248 = **6.55 m**

The pump can be run at a higher speed.

IMPORTANT QUESTIONS

PART A

1. What is meant by Pump?
2. What is meant by Priming?
3. Differentiate between the single acting pump and double acting pump
4. What are the functions of air vessels?
5. Define slip, percentage slip and negative slip of a reciprocating pump
6. Define Manometric efficiency
7. Define Mechanical efficiency.
8. Define overall efficiency.
9. Define speed ratio, flow ratio.
10. Mention main components of Reciprocating pump.
11. What is indicator diagram?
12. What is meant by Cavitations?

*****ALL THE BEST *****