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R. C. Patel College of Engineering & Polytechnic, Shirpur

QUESTION BANK OF CHAPTER – 5
CENTRIFUGAL AND RECIPROCATING PUMPS

Program Name: Diploma in Mechanical Engineering | Program Code: ME

Name of Subject & Code : Fluid Mechanics and Machinery (313309) | Semester : THIRD

Instructions: (1) Illustrate your answers with neat sketches wherever necessary.

Q.1.	Two marks questions.	Previous Exam	CO PO Mapping
1.	List the four basic components of reciprocating pump.	S25-1.c	CO5- TLO5.1 -R
2.	Compare single acting and double acting reciprocating pump on the basis of nature and quantity of discharge.	W24-1.f	CO5- TLO5.3 -R
3.	Define NPSH.	W24-1.g	CO5- TLO5.2 -R
4.	State the need of priming in centrifugal pump.	W25-1.f	CO5- TLO5.1 -R
Q.2.	Four marks questions.	Previous Exam	CO PO Mapping
1.	State any four faults in centrifugal pump and their remedies.	W24-4.d S25-5.b	CO5- TLO5.4 -R
2.	Explain with neat sketch construction, working and applications of multistage pump	W24-6.b W25-4.d	CO5- TLO5.1 -A
3.	A centrifugal pump having outer diameter equal to two times the inner diameter and running at 900 rpm works against a total head of 60 m. Velocity of flow through impeller is constant and equal to 3 m/s. The vanes are set back at an angle at 40° at outlet. If diameter of impeller is 600 mm and width at outlet is 60 mm. Calculate - i) Discharge ii) Vane angle at inlet iii) W.D. by impeller on water per second. iv) Manometric efficiency. v) Power required to drive the pump if overall efficiency is 70%.	W24-6.c	CO5- TLO5.3 -A
4.	Draw neat sketch and state uses, advantages of Air vessel in reciprocating pump.	W24-4.c W25-1.g	CO5- TLO5.3 -U
5.	Explain the working of double acting reciprocating pump with neat sketch.	S25-4.c W25-4.c	CO5- TLO5.1 -A
6.	A centrifugal pump has the following characteristics : Outer dia. of impeller = 800 mm, Width of impeller vanes at outlet = 100 mm, Angle of impeller vanes at outlet = 40°. The impeller runs at 550 rpm and delivers 0.98 m3/s water under an effective head of 35 m. A 500 kW motor is used to drive the pump. Determine the manometric, mechanical and overall efficiencies of the pump. Assume water enters the impeller	S25-6.c	CO5- TLO5.3 -A

	vanes radially at inlet.		
7.	A centrifugal pump has an impeller of 500 mm external diameter and 250 mm internal diameter, runs at 1000 rpm. The vanes are set back at an angle of 30° to outer rim. If the radial velocity of water through impeller is maintained constant at 2 m/s. Find :- i) Angle of inlet ii) Velocity of water at outlet. iii) Workdone when velocity at inlet circumference of the wheel is half the velocity of outer circumference of the wheel.	W25-4.e	CO5- TLO5.3 -A
8.	A single acting reciprocating pump running at 50 rpm delivers 0.00736 m3/s of water. The diameter of piston is 200 mm and stroke length is 300 mm, the suction and delivery heads are 3.5 m and 11.5 m respectively. Determine (i) Theoretical discharge (ii) Slip (iii) Power required to run the pump.		CO5- TLO5.3 -A
9.	Describe an indicator diagram of a reciprocating pump. Sketch the theoretical indicator diagram for a single-acting reciprocating pump not fitted with an air vessel. Also explain clearly the effect of acceleration and friction on both suction and delivery strokes.	S25-6.b W25-6.c	CO5- TLO5.3 –U
10.	Define the following terms with respect to centrifugal pump. i) Total head ii) Manometric head		CO5- TLO5.2 -R
11.	Explain the working of centrifugal pump with neat sketch.		CO5- TLO5.1 -A
	* * *Best of Luck* * *		

for [signature] 8/6/2026

Mr. J. N. Chaudhari
Subject Teacher

Mr. A. D. Patil
HOD(ME)

Dr. N. G. Haswani
Principal

* Fluid Mechanics & Machinery *

Chapter 5 : Centrifugal & Reciprocating Pumps.

5.1 - Centrifugal pumps : water lifting devices used in ancient India (IKS), classification, construction & working principle of centrifugal pump, Types of casing & impellers, Priming methods, Static head, Manometric head, NPSH, workdone, manometric efficiency, overall efficiency, Numerical on above parameters. Performance characteristics of centrifugal pump. Troubleshooting, construction, working & appln of multistage Pump.

* Water Lifting Devices used in ancient India (IKS):

1. Shaduf (Dhenkli) -

   Lever based system with a bucket & counterweight to lift water.

2. Rahat (Persian wheel) -

   Rotating wheel with buckets, driven by animals, for continuous water lifting.

3. Charas / Mot :-

   Leather bags pulled by animal to draw water from well.

4. Araghatta -

   Improved wheel system using gears for better efficiency.

- Features -
  - operated by human or animal power
  - simple mechanical principles are used.
  - low cost & ecofriendly.

* Classification of Centrifugal Pumps *

A) Based on dirn of flow :

- Radial flow pump - water flows $\perp^{er}$ to shaft
- Axial flow pump - water flows $\parallel^{el}$ to shaft.
- Mixed flow pump - Combination of both.

B) Based on No. of Stages :

- Single stage pump - one impeller
- Multi-stage pump - Multi impellers (high head)

C) Based on Impeller type :

- Closed impeller - High efficiency
- Open impeller - for dirty water
- Semi-open impeller - Moderate use

D) Based on casing type :

- Volute Pump
- Diffuser pump

E) Based on Head :

- Low head pump
- Medium head pump
- High head pump.

* Construction & Working of Centrifugal Pump *

Construction -

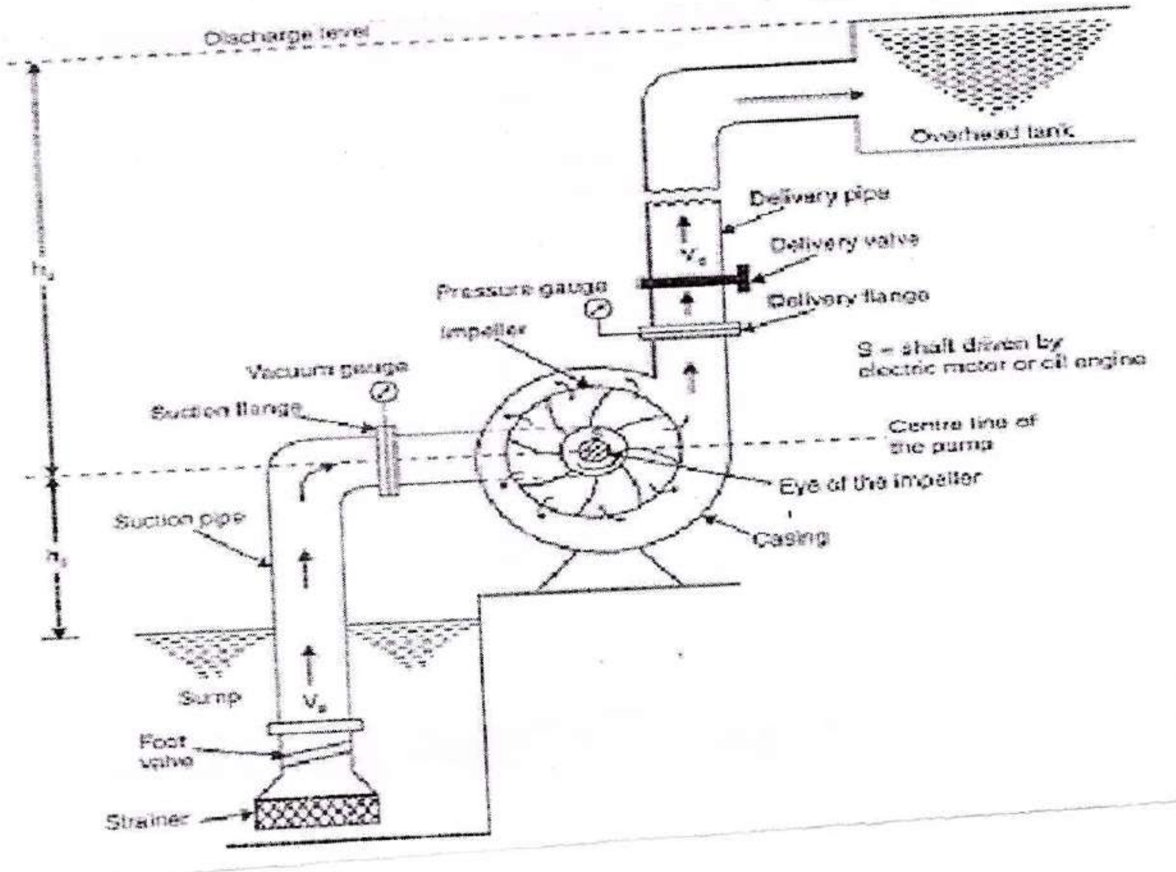
1. Impeller -
   - Rotating parts with vanes
   - Transfers energy to water.

2. Casing (Volute / Diffuser)
- Encloses impeller
- Converts velocity energy → pressure energy.

3. Suction Pipe
- connects water source to pump.
- Has foot valve & strainer (prevents backflow & debris)

4. Delivery Pipe
- Carries water to req^d height.

5. Shaft & Bearings
- Transmit power from motor to impeller.

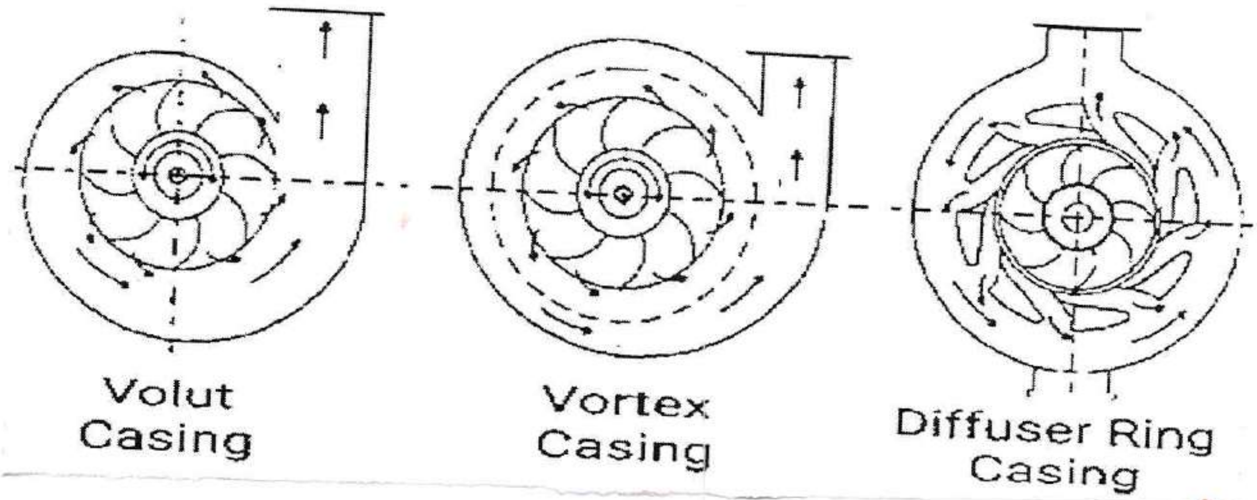


Working :

1. Priming - pump is filled with water (no air inside)
2. Impeller Rotation - Impeller rotates due to motor.
3. Centrifugal Action - water is thrown outward from center (eye) to periphery.
4. Pressure increase - velocity energy converts into pressure energy in casing.

5. Continuous flow -
- Low pressure at center - draws more water
- High pressure at outlet - delivers water

* Types of Casings *



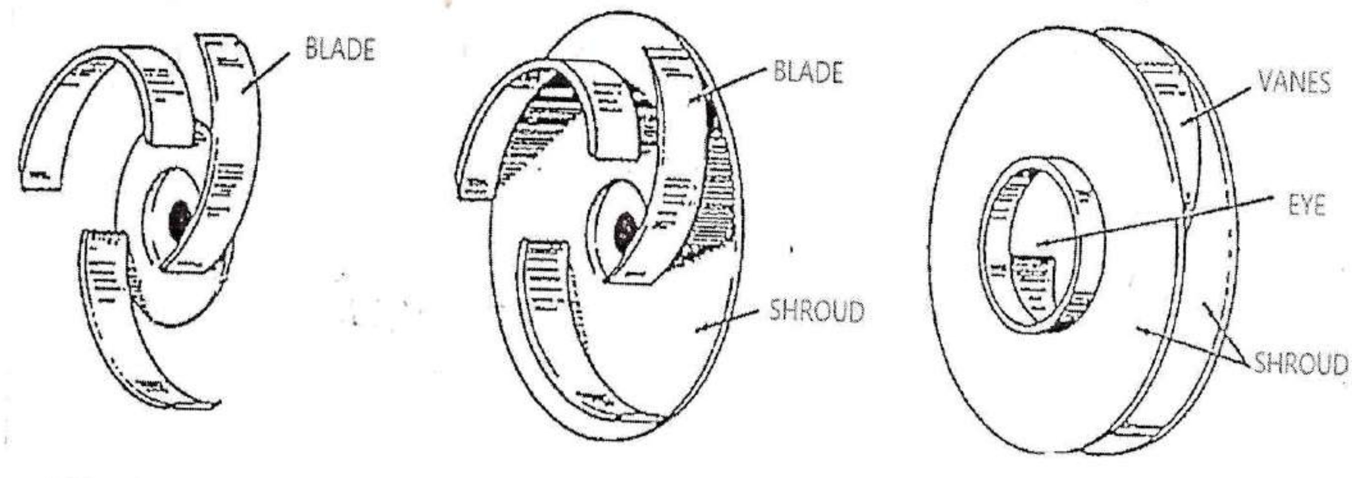
1. Volute Casing :-
   - Spiral shaped passage surroundin the impeller.
   - Area of flow passage gradually increases from cutwater to outlet.
   - As water leaves the impeller, it enters the volute.
   - Increasing area → velocity decreases → pressure increases.
   - Used in domestic water appl^n, irregation pumps, general industrial use.

2. Vortex Casing :-
   - Similar to volute but includes a circular chamber (vortex space) bet^n impeller & casing.
   - water first forms a vortex in chamber.
   - Then flows into volute.
   - Reduces sudden shock when water exits impeller.
   - Used in pumps where smooth flow is needed.

3. Diffuser casing :-
   - Provided with guide vanes (diffuser blades) surroundings impeller.
   - Passages gradually expand.

- water from impeller passes through guide vanes.
- velocity decreases gradually.
- Pressure increases efficiently.
- Used in high head pumps, powerplants & boiler feed pumps.

* Types of Impeller *



OPEN IMPELLER — SEMI OPEN IMPELLER — CLOSE IMPELLER

A) Based on Construction :

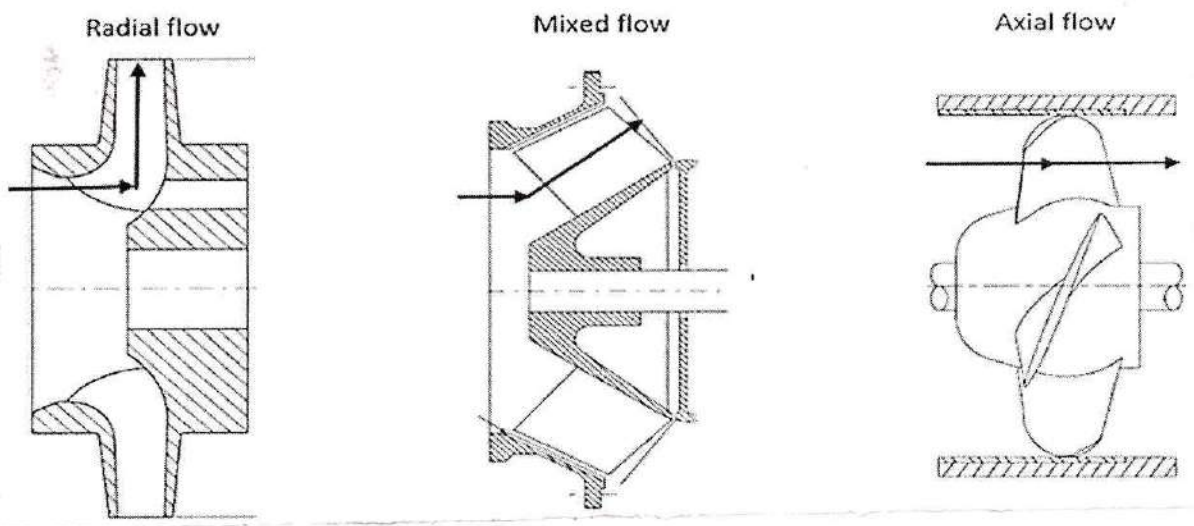
1. Closed Impeller (Shrouded Impeller) :
   - Vanes closed betn two side plates (front & back shrouds)
   - Narrow passage for fluid flow.
   - water flows smoothly through enclosed channels.
   - Leakage losses are minimal.
   - Highest efficiency ($\approx 80-90\%$)
   - Used for clean water supply, boiler feed pumps.

2. Open Impeller :
   - Vanes are not covered by side plates
   - Mounted directly on shaft.
   - fluid flows freely over vanes.
   - Larger clearance allows passage of solids.
   - Can handle dirty, slurry, sewage water.
   - Lowest efficiency ($\approx 50-70\%$)

3. Semi-open Impeller (Semi-closed Impeller):
- Vanes covered on one side only
- Other side open
- combines features of open & closed impellers.
- Moderate efficiency
- Handles slightly dirty fluid.
- Used in wastewater systems, irrigation with suspended particles.

B) Based on Direction of flow:

1. Radial flow impeller
   - water flows ⊥er to shaft
   - Produces high head, low discharge
   - Most commonly used.



2. Axial flow impeller
   - water flows parallel to shaft
   - produces low head, high discharge
   - Works like a propeller.

3. Mixed flow impeller
   - water flows partly radial + partly axial
   - Moderate head & discharge.

c) Based on Vane shape:

1. Backward Curved Vane.
2. Forward Curved Vane.

* Priming of Centrifugal Pump *

It is the process of removing air from the pump & suction pipe & filling them with water before starting.

Need of Priming :
- Centrifugal pump cannot pump air
- Air blocks suction - no water delivery.

◦ Methods of Priming :

1. Manual Priming
   - Pump is filled manually with water
   - Simple but time consuming.
2. Priming Using Vacuum Pump
   - Air is removed using vacuum pump
   - Suitable for large installation.
3. Self Priming Pump
   - Automatically removes air
   - No external priming needed.
4. Priming with foot valve
   - foot valve prevents backflow
   - Keeps pump always filled.

* Static Head (H_s) :

It is the vertical height difference betn source & delivery point.

Types -

◦ Suction head (h_s) - Height of pump above water surface.

◦ Delivery head (h_d) - Height water is delivered.

$$\boxed{H_s = h_s + h_d}$$

* Manometric Head (H_m):

It is the actual head against which the pump works.

$$H_m = H_{static} + \text{Losses}$$

$$H_{mano} = (h_s + h_d) + (h_{fs} + h_{fd}) + \frac{V_d^2}{2g}$$

h_s = suction head , h_{fs} = frictional loss in suction pipe

h_d = delivery head h_{fd} = frictional loss in delivery pipe

V_d = velocity of liquid in the delivery pipe.

* Net Positive Suction Head (NPSH):

It is the minimum pressure req^d at suction to avoid cavitation,

$$\boxed{H_{sv} = (H_a - H_s) - H_v}$$

Where, $H_a = \frac{P_a}{\rho g}$ & $H_s = h_s + h_{fs} + \frac{V_s^2}{2g}$

$H_v = \frac{P_v}{\rho g}$

* Workdone of Centrifugal Pump :-

$$\text{Workdone} = \frac{W}{g} . (V_{w_1} . u_1) \quad --- \quad (\text{since } V_w = 0)$$

* Efficiencies :-

1. Manometric efficiency (η_{mano}) -

It is the ratio of manometric head developed by the pump to theoretical head imparted by impeller.

$$\boxed{\eta_{mano} = \frac{H_m . g}{V_{w_1} . u_1}}$$

2. Volumetric efficiency (η_{vol}):

It is the ratio of water discharged from pump to water discharged through impeller,

or

It is the ratio of actual discharge to theoretical discharge.

$$\boxed{\eta_{vol} = \frac{Q}{Q+q}}$$

Where, Q = Actual discharge at pump outlet /sec
q = leakage of liquid from impeller /sec

3. Mechanical efficiency (η_{mech}):

It is the ratio of power available at the impeller to the power supplied at the pump shaft.

$$\boxed{\eta_{mech} = \frac{\rho . Q . V_{w_1} . u_1}{S.P.}} \quad \text{or} \quad \eta_{mech} = \frac{P_{impeller}}{P_{shaft}}$$

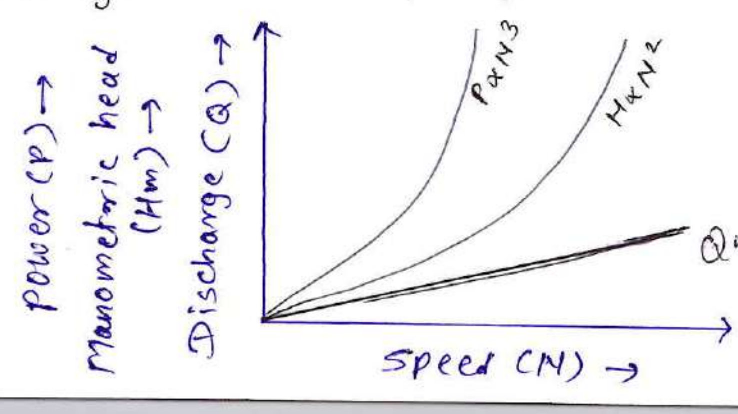
4. Overall efficiency (η_{over}):

It is the ratio of output hydraulic power to input shaft power,

$$\boxed{\eta_{over} = \frac{\rho . g . Q . H_m}{S.P}} \quad \text{or} \quad \boxed{\eta_0 = \eta_m * \eta_{vol} \times \eta_{mech}}$$

* Performance Characteristic Curves *

1. Main characteristic curves (Manometric head, power discharge w.r.t. speed) -



Relations: $Q \propto N$

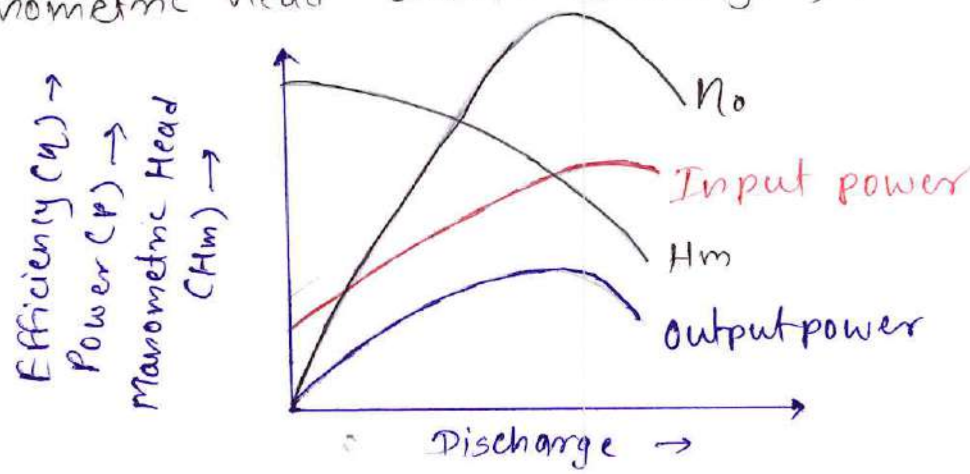
$H_m \propto N^2$

$P \propto N^3$

Explanation:

- Discharge increases linearly with speed.
- Head (H_m) increases with square of speed.
- Power (P) increases with cube of speed.

2. Operating Characteristic Curves (Efficiency, Power, Manometric head w.r.t. discharge):



a) Head Vs Discharge -.
- Head decreases as discharge increases.
- At zero discharge → max^m head (Shut off head)

b) Efficiency Vs Discharge -
- Efficiency increases → reaches max^m (BEP) → then decreases.
- BEP : Best Efficiency Point.

c) Power Vs Discharge -
- Power increases continuously with discharge.

* Troubleshooting of Centrifugal Pump *

1. Pump not delivering water

→ Causes -
- No priming
- Air leakage
- Blocked suction

Remedy -
- Proper priming
- Check pipe joints.

2. Low discharge

→ Causes -
- low speed
- Impeller damage
- Leakage

Remedy -
- Increase speed
- Repair impeller.

3. Cavitation

→ causes -
- Low NPSH
- High suction lift

Remedy -
- Reduce suction height
- Increase NPSH

4. Excessive vibration / Noise

→ Causes -
- Misalignment
- Bearing failure

Remedy -
- Proper alignment
- Replace bearings.

5. Overheating

→ Causes -
- Dry running
- friction

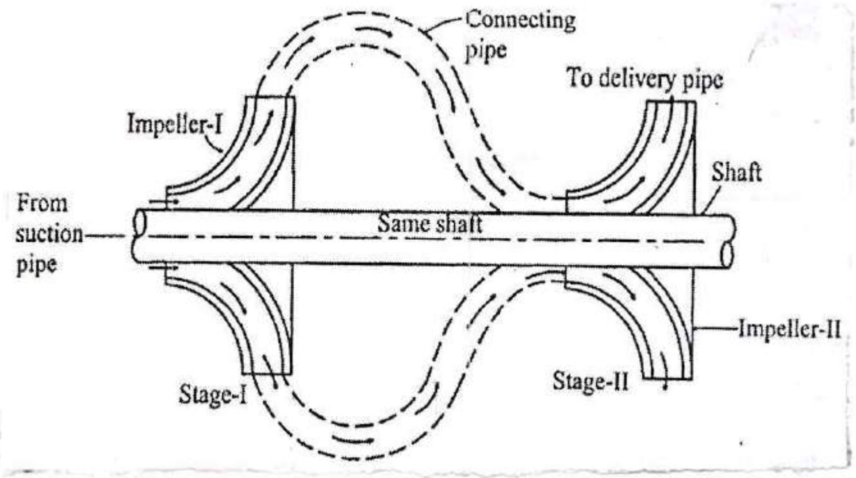
Remedy
- Ensure water flow
- lubrication.

* Construction, Working & appln of Multistage Pump *

Multistage Pump -
It has two or more impellers mounted on same or diff. shafts to increase head or discharge.

Types of multistage Pump -

1. Pumps in series (for high head) -
water flows from one impeller to next in sequence & each stage increases the pressure (head).



Construction -

- Multiple impellers mounted on the same shaft
- Outlet of one stage → inlet of next stage.
- Diffuser (guide vanes) used betn stages.

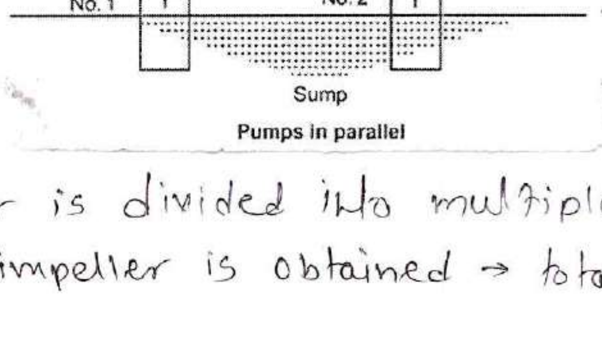
Working -

- Water enters 1st impeller - pressure increases,
- Passes through diffuser → velocity ↓, pressure ↑
- Enters next impeller → further increase in pressure
- Process repeats → final high head obtained.

Application -

- Boiler feed pumps, High-rise buildings.

2. Pumps in Parallel (for High discharge) -



Pumps in parallel

Water is divided into multiple paths, & discharge from each impeller is obtained → total discharge increases.

Construction -

- Two or more impellers (or pumps)
- Connected to common suction & delivery pipes.

Working -

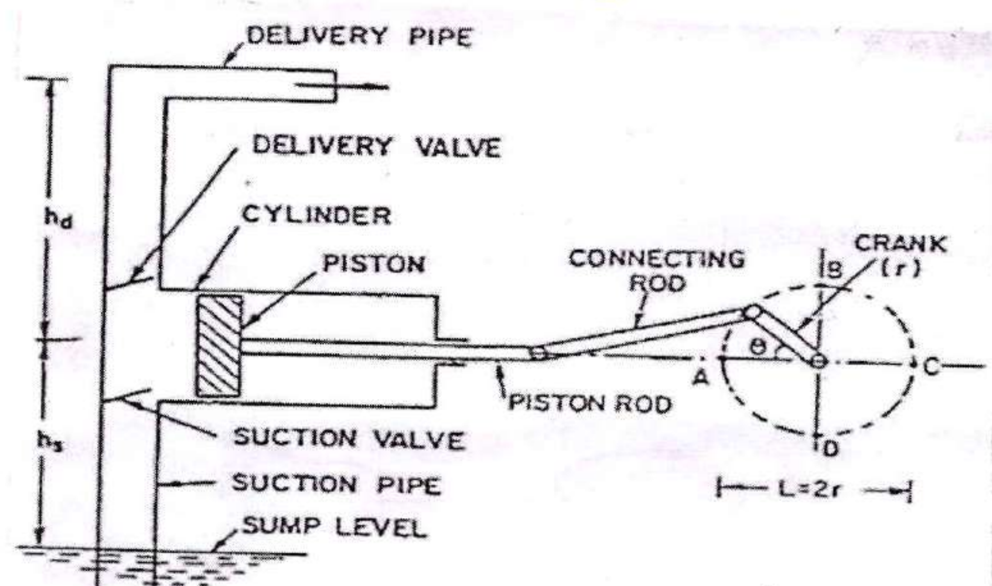
- Water enters system, splits into multiple impellers.
- Each impeller delivers water.
- Combined flow → high discharge

Application -

- Irrigation system, water supply schemes
- Flood control Pumping,

5.2 Reciprocating Pump: Construction, working principle & appl^n of single & double acting reciprocating pump, slip, Negative slip. Cavitation & Seperation. Use of air vessels, Indicator diagram with effect of acceleration head & frictional head & Pump selection criteria based on head & discharge (No numerical on reciprocating pump).

* ~~R~~Single Acting Reciprocating Pump *



Construction -

- Cylinder - contains piston
- Piston / Plunger - reciprocates inside cylinder
- Crank & connecting rod - convert rotary motion to reciprocating motion.

- suction valve → allows water entry
- Delivery valve → allows water exit
- suction pipe & delivery pipe.

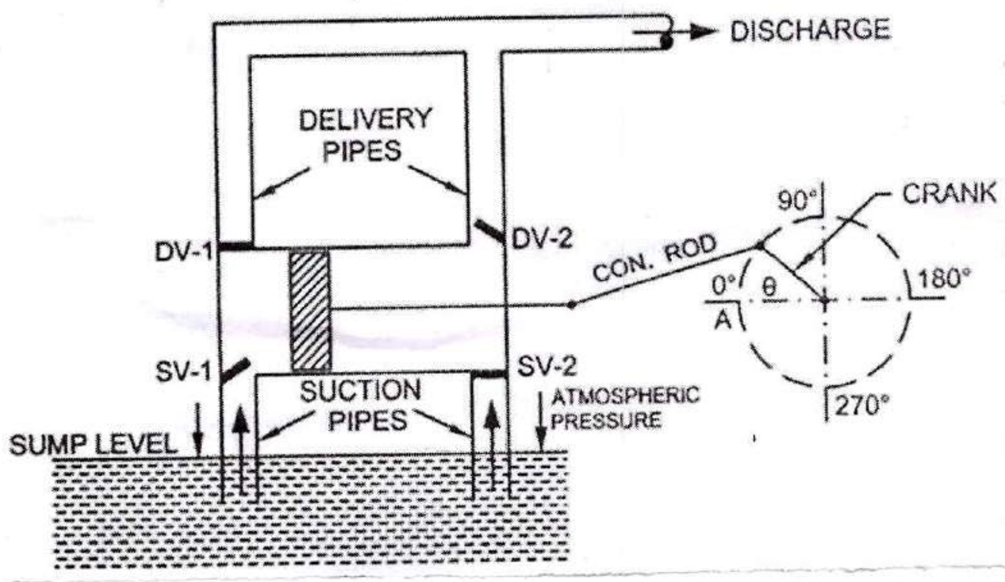
Working Principle -
Based on positive displacement

A) Suction stroke
- piston moves away from cylinder head.
- Pressure inside cylinder ↓
- Suction valve opens, water enters.

B) Delivery stroke
- Piston moves towards cylinder head.
- Pressure inside cylinder ↑
- Delivery valve opens, water is pushed out.

Application -
- Hand Pumps
- Small irrigation systems
- Domestic water supply.

* Double Acting Reciprocating Pump *



Construction -
Similar to single-acting pump but;
- Both sides of piston are used
- Two suction valves & two delivery valves.

Working Principle -
water is delivered during both strokes

A) Forward stroke
- One side → delivery
- Other side → suction

B) Return stroke
- Actions reverse
- Continuous pumping occurs.

Applications -
- Boiler feed pumps
- High - pressure systems
- Oil & Chemical industries.

* Slip :

It is the diff. betⁿ theoritical discharge & actual discharge of a pump.

$$\boxed{Slip = Q_{theoritical} - Q_{actual}}$$

$$\boxed{\%\ of\ slip = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100}$$

Reason for slip :
- Leakage through valves
- Imperfect sealing of piston
- Delay in valve opening / closing.

* Negative Slip :

When actual discharge exceeds theoritical discharge.

$$Q_{act} > Q_{th}$$

Why it happens ?
- At high speed
- Due to inertia of water in suction pipe
- Water continues flowing even during suction stroke.

It occurs when delivery pipe is short & suction pipe is long.

* Cavitation :

Formation & sudden collapse of vapour bubbles when pressure falls below vapour pressure.

Effect -
- Noise & Vibration
- Damage (pitting)
- Reduced efficiency

Prevention -
- Reduced suction lift
- Increase pressure at inlet
- Proper design of suction lift.

* Seperation :

When pressure in cylinder falls below vapour pressure. liquid Seperates forming cavities.

It occurs at high speed & high suction lift.

Effects -

- Flow disturbance
- Loss of efficiency
- possible damage.

* Air Vessel *

A closed Chamber containing compressed air, fitted near suction & delivery pipes.

Functions -

- Make flow uniform (reduces pulsation)
- Saves energy
- Allows pump to run at higher speed
- Reduces accl^n head.

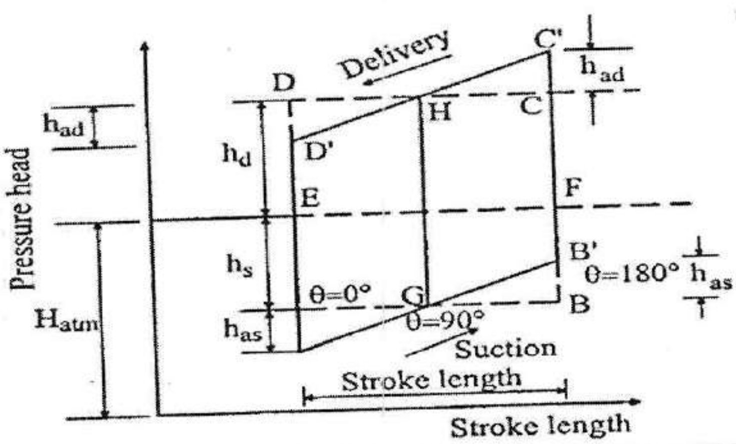
Working -

- During high flow → water enters vessel & compresses air
- During low flow → compressed air pushes water out

Result → smooth discharge, & fitted on suction & delivery sides.

* Indicator diagram with effect of accl^n head & frictional head *

1. Effect of accleration head :

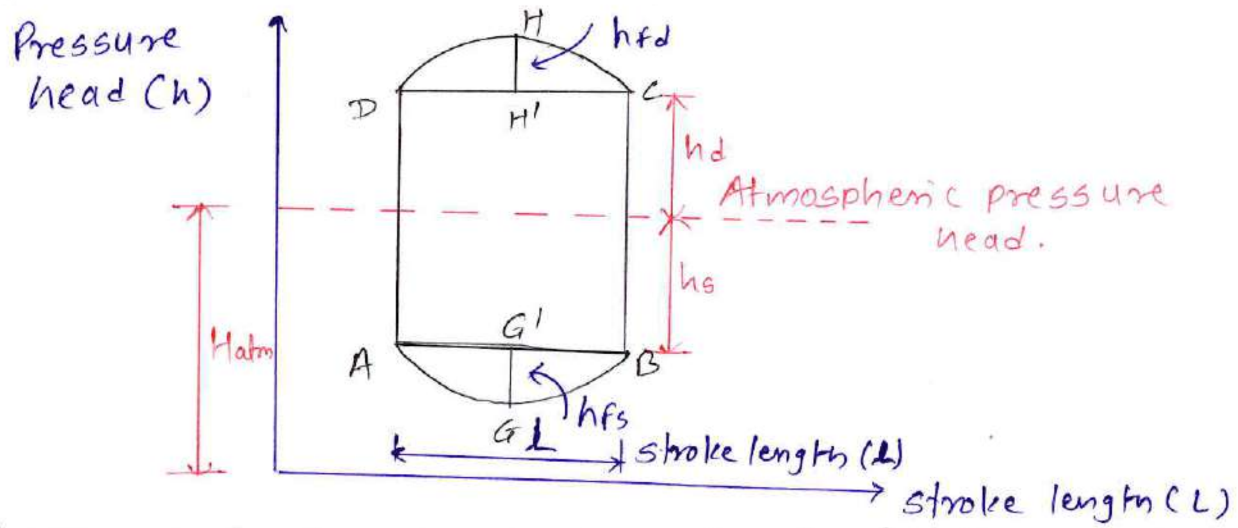


Acclⁿ head → Extra pressure reqᵈ to accelerate water in suction & delivery pipes.

Effect on diagram -

- Pressure is not constant
- Suction & delivery lines become curved (parabolic)
- At :
  - start of stroke → pressure minᵐ
  - Mid stroke → pressure normal
  - End of stroke → pressure maxᵐ

2. Effect of frictional head :

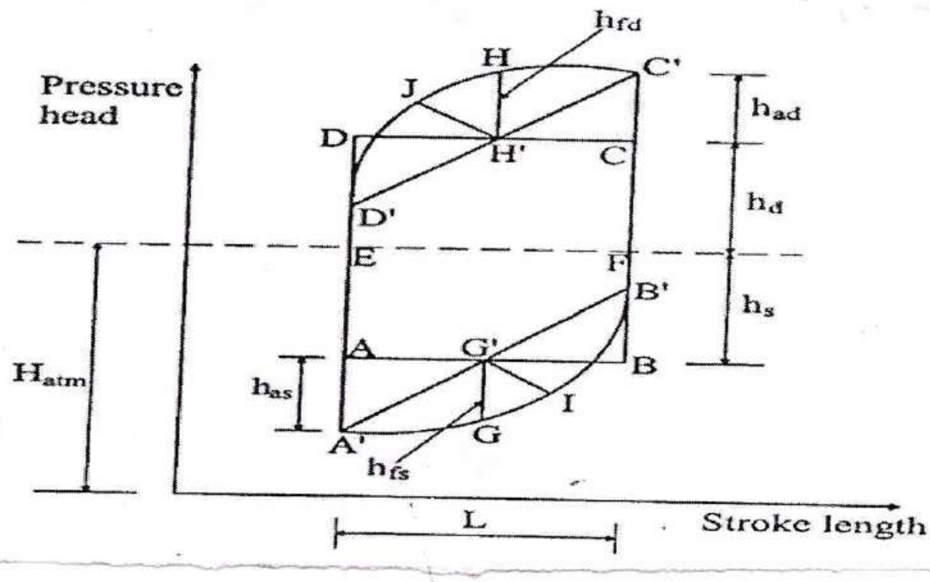


Frictional head → head loss due to friction in pipes.

Effect on diagram -

- Pressure gradually decreases due to losses.
- Suction & delivery lines become inclined (sloping).

3. Combined Effect (Actual Indicator diagram) :-



When both are present :
- Lines are curved + slanted
- Diagram becomes distorted.

Practical observation -
- lowest press. at start of suction → may cause separation
- Highest pressure at end of delivery.

* Pump Selection Criteria based on Head & Discharge *

1. Pump selection based on head :

   a) Low head (upto 15-20 m) → Centrifugal Pump,
      - High flow rate, simple construction.
      - smooth & continuous discharge.

      appln - irrigation, water supply, Drainage system.

   b) Medium head (20-100 m) → Multistage Centrifugal pump.
      - multiple impellers increase pressure.
      - suitable for moderate press. requirement.

      appln - Building water supply, industrial system,

   c) High head (>100 m) → Reciprocating Pump
      - Generates very high Pressure
      - Accurate discharge.

      appln - Boiler feed, hydraulic system, oil & gas industry.

2. Selection based on Discharge :

   a) High discharge → Centrifugal Pump
      - Can handle large volume, continuous flow.
      - low maintenance.

   b) low discharge → Reciprocating Pump
      - Precise flow control
      - suitable for small quantities.

* Numericals on Centrifugal Pump *

1. A centrifugal pump having outer diam. equal to two times the inner diam & running at 900 rpm works against a total head of 60 m. Velocity of flow through impeller is constant & equal to 3 m/s. The vanes are set back at an angle of 40° at outlet. If diam. of impeller is 600 mm & width at outlet is 60 mm. Calculate i) Discharge ii) Vane angle at inlet iii) W.D. by impeller on water per sec. iv) manometric efficiency v) Power reqd to drive the pump if overall eff. is 70%. (W-24)

→ Given data:

Outer diam. $D_2 = 600\ mm = 0.6\ m$

Inner diam, $D_1 = \frac{D_2}{2} = 0.3\ m$

Speed $N = 900\ rpm$

Head $H = 60\ m$

Flow velocity $V_f = 3\ m/s$ (const.)

Outlet vane angle, $\beta_2 = 40°$

Width at outlet, $b_2 = 60\ mm = 0.06\ m$

Overall efficiency, $\eta_o = 70\% = 0.7$

Velocity at outlet (Tangential):

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.6 \times 900}{60} = 28.27\ m/s$$

Whirl velocity at outlet V_{w2}:

$$V_{w2} = u_2 - \frac{V_f}{\tan\beta_2} = 28.27 - \frac{3}{\tan 40°} = 24.69\ m/s$$

Discharge (Q):

$$Q = \pi D_2 b_2 V_f = \pi \times 0.6 \times 0.06 \times 3 = 0.339\ m^3/s$$

$$\boxed{Q = 0.339\ m^3/s}$$

Now find inlet velocity & Vane angle β_1

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.3 \times 900}{60} = 14.14\ m/s$$

Assuming radial entry → $V_{w_1} = 0$

$\tan \beta_1 = \frac{V_f}{u_1} = \frac{3}{14.14} = 0.212$

∴ inlet vane angle ⇒ ∴ $\boxed{\beta_1 = 12^\circ}$

Workdone by impeller:

$W.D = \rho . Q . V_{w_2} . u_2 = 1000 \times 0.339 \times 24.69 \times 28.27$

$\boxed{W.D. = 236400 \text{ W}}$

Manometric efficiency :

$\eta_{mano} = \frac{g.H}{V_{w_2} . u_2} = \frac{9.81 \times 60}{24.69 \times 28.27} = 0.843 \times 100\%$

$\boxed{\eta_{mano} = 84.3\%}$

Power reqd :

$P = \frac{W.D}{\eta_o} = \frac{236.4}{0.7} = 337.7 \text{ kW}$

$\boxed{P = 337.7 \approx 338 \text{ kW}}$

2. A centrifugal pump has the following characteristics : outer diam. of impeller = 800 mm, width of impeller vanes at outlet = 100 mm. Angle of impeller vanes at outlet = 40°. The impeller runs at 550 rpm & delivers 0.98 m³/s water under an effective head of 35 m. A 500 kW motor is used to drive the pump. Determine the manometric, mechanical & overall efficiencies of pump. Assume water enters the impeller vanes radially at inlet. (S-25)

→ Given data :

Outer diam $D_2 = 0.8$ m

width at outlet $b_2 = 0.1$ m

outlet vane angle $\beta_2 = 40^\circ$

Speed $N = 550$ rpm

discharge $Q = 0.98 \text{ m}^3/\text{s}$

Head $H = 35$ m

input power $P_{in} = 500$ kW

Radial entry ⇒ $V_{w_1} = 0$

Pheripheral velocity at outlet,

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.8 \times 550}{60} = 23.04 \text{ m/s}$$

Flow vel. at outlet,

$$V_f = \frac{Q}{\pi D_2 b_2} = \frac{0.98}{\pi \times 0.8 \times 0.1} = 3.90 \text{ m/s}$$

Whirl vel. at outlet,

$$V_{w_2} = u_2 - \frac{V_f}{\tan \beta_2} = 23.04 - \frac{3.90}{\tan 40^\circ} = 18.39 \text{ m/s}$$

Workdone by impeller,

$$WD = \rho . Q . V_{w_2} . u_2 = 1000 \times 0.98 \times 18.39 \times 23.04$$

$$\boxed{WD = 414700 \text{ W}}$$

water power (output power),

$$P_{out} = \rho g Q H = 1000 \times 9.81 \times 0.98 \times 35$$

$$\boxed{P_{out} = 336600 \text{ W}}$$

Manometric efficiency,

$$\eta_{mano} = \frac{gH}{V_{w_2} . u_2} = \frac{9.81 \times 35}{18.39 \times 23.04} = 0.81 \times 100$$

$$\boxed{\eta_{mano} = 81\ \%}$$

Mechanical efficiency,

$$\eta_{mech} = \frac{\text{impeller power}}{\text{i/p power}} = \frac{414.7}{500} = 0.829 \times 100\ \%$$

$$\boxed{\eta_{mech} = 82.9\ \%}$$

Overall efficiency,

$$\eta_{over} = \frac{P_{out}}{P_{in}} = \frac{336.6}{500} = 0.673 \times 100\ \%$$

$$\boxed{\eta_o = 67.3\ \%}$$

3. A centrifugal pump has an impeller of 500 mm external diam. & 250 mm internal diam, runs at 1000 rpm. The vanes are set back at an angle of 30° to outer rim, If the radial velocity of water through impeller is maintained const. at 2m/s. Find:
i) Angle of inlet ii) velocity of water at outlet iii) workdone when velocity at inlet circumference of the wheel is half the velocity of outer circumference of the wheel. (W-25)

→ Given data:

Outer diam, $D_2 = 0.5$ m
inner diam, $D_1 = 0.25$ m
Speed $N = 1000$ rpm
outlet vane angle, $\beta_2 = 30°$
Flow (radial) velocity, $V_f = 2$ m/s
$u_1 = \frac{1}{2} \cdot u_2$

Peripheral velocities

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.5 \times 1000}{60} = 26.18 \text{ m/s}$$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.25 \times 1000}{60} = 13.09 \text{ m/s}$$

Inlet angle β_1,
for radial entry $V_{w_1} = 0$

$$\tan\beta_1 = \frac{V_{f_1}}{u_1} = \frac{2}{13.09} = 0.153$$

$$\therefore \boxed{\beta_1 = 8.7°}$$

Whirl velocity at outlet,

$$V_{w_2} = u_2 - \frac{V_f}{\tan\beta_2} = 26.18 - \frac{2}{\tan 30°} = 22.72 \text{ m/s}$$

Absolute velocity at outlet V_2,

$$V_2 = \sqrt{V_{w_2}^2 + V_f^2} = \sqrt{(22.72)^2 + 2^2}$$

$$\boxed{V_2 = 22.8 \text{ m/s}}$$

Workdone per kg of water.

$$WD = V_{w_2} \cdot u_2 = 22.72 \times 26.18$$

$$\boxed{WD = 594.8 \approx 595 \text{ J/kg}}$$

4. A single acting reciprocating pump running at 50 rpm delivers 0.00736 m^3/s of water. The diam. of piston is 200 mm & stroke length is 300 mm, the suction & delivery heads are 3.5 m & 11.5 m respectively. Determine
i) Theoretical discharge ii) slip iii) Power reqd to run the pump.

→ Given data :

Speed $N = 50$ rpm

Actual discharge, $Q_{act} = 0.00736 \ m^3/s$

piston diam $D = 0.2 m$

stroke length $L = 0.3 m$

Suction head $H_s = 3.5 m$

Delivery head $H_d = 11.5 m$

Total head $H = H_s + H_d = 3.5 + 11.5 = 15 m$

Area of piston,

$$A = \frac{\pi}{4} \cdot D^2 = \frac{\pi}{4} \cdot (0.2)^2 = 0.0314 \ m^2$$

Theoretical discharge,

for single acting pump, $Q_{th} = \frac{A \cdot L \cdot N}{60} = \frac{0.0314 \times 0.3 \times 50}{60}$

$$\boxed{Q_{th} = 0.00785 \ m^3/s}$$

Slip ;

$$\text{slip} = Q_{th} - Q_{act} = 0.00785 - 0.00736 = 0.00049 \ m^3/s$$

percentage slip =>

$$\% \text{slip} = \frac{0.00049}{0.00785} \times 100 = 6.24 \%$$

$$\boxed{\text{Percentage slip} = 6.24 \%}$$

Power reqd,

$$P = \rho \cdot g \cdot Q_{act} \cdot H$$

$$= 1000 \times 9.81 \times 0.00736 \times 15$$

$$\boxed{P = 1083 \text{ W}}$$