CENTRIFUGAL PUMPS

Nazaruddin Sinaga

Laboratorium Efisiensi dan Konservasi Energi

Universitas Diponegoro

INTRODUCTION

CONSTRUCTION

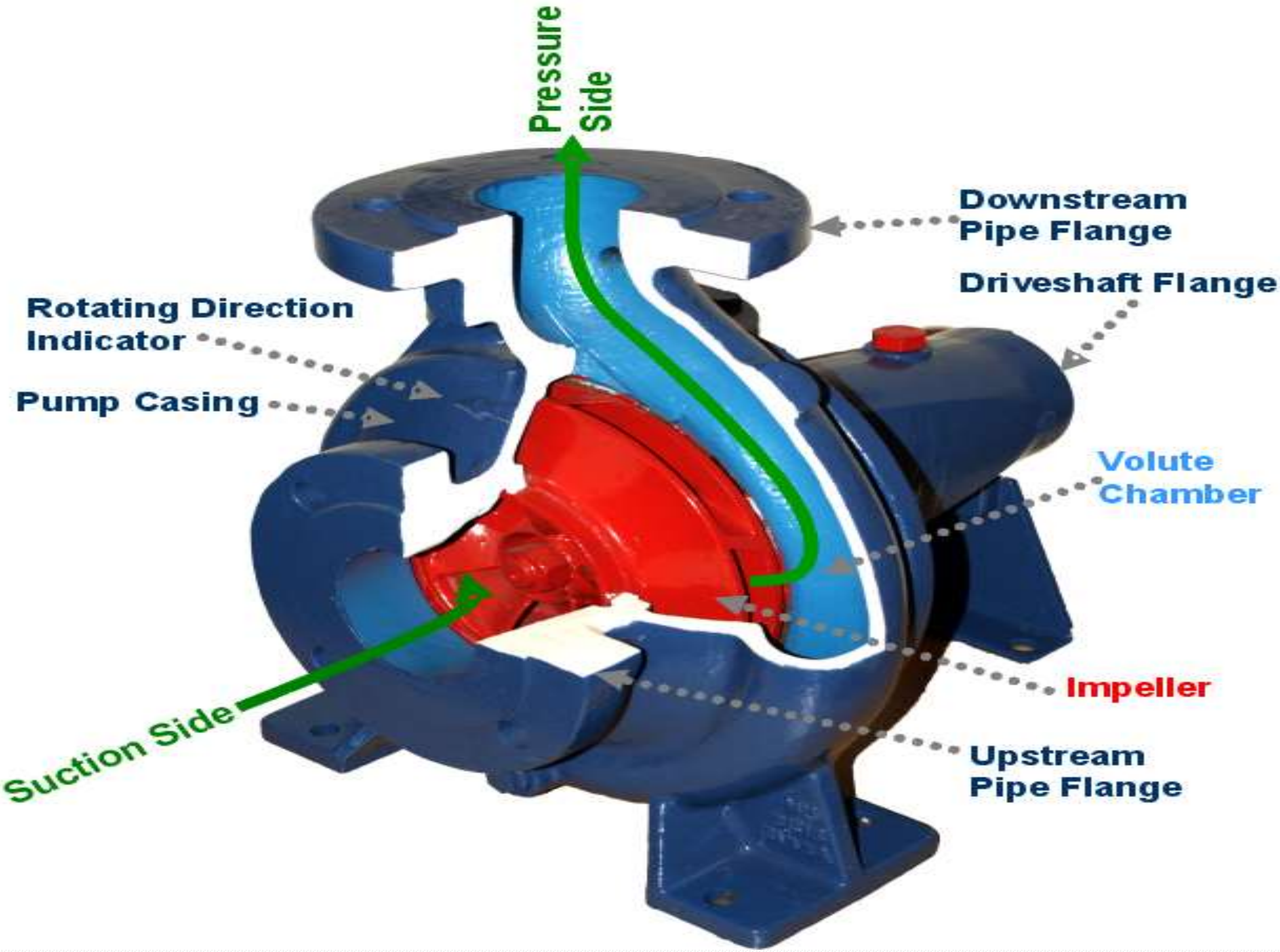
CLASSIFICATION

WORKING

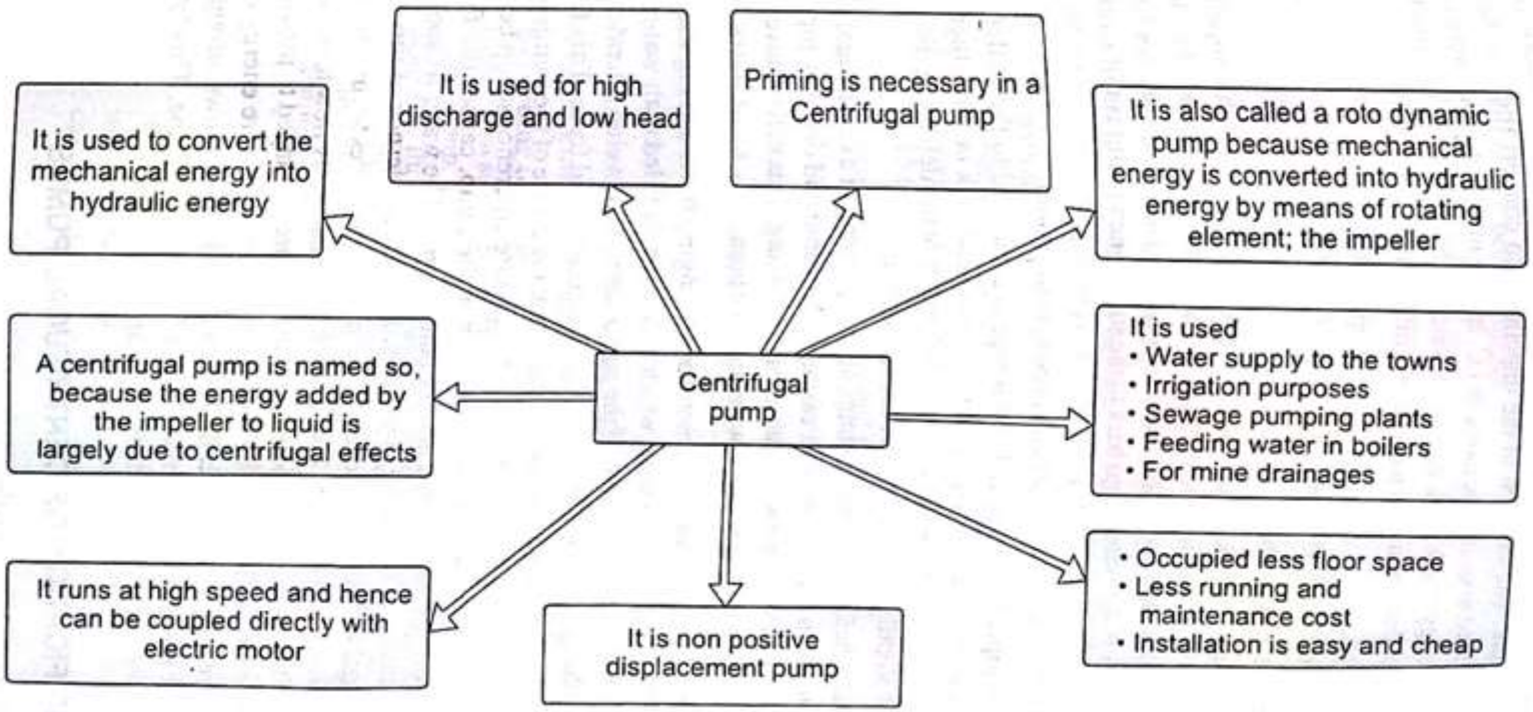
HEADS LOSSES & EFFICIENCIES

ADVANTAGE & DISADVANTAGE

APPLICATION


Pressure Side
Downstream Pipe Flange
Driveshaft Flange
Rotating Direction Indicator
Pump Casing
Volute Chamber
Impeller
Suction Side
Upstream Pipe Flange

INTRODUCTION



CONSTRUCTION

- Sump
- Strainer
- Foot valve
- Vanes
- Impeller
- Suction pipe
- Delivery pipe
- Casing
- Delivery valve

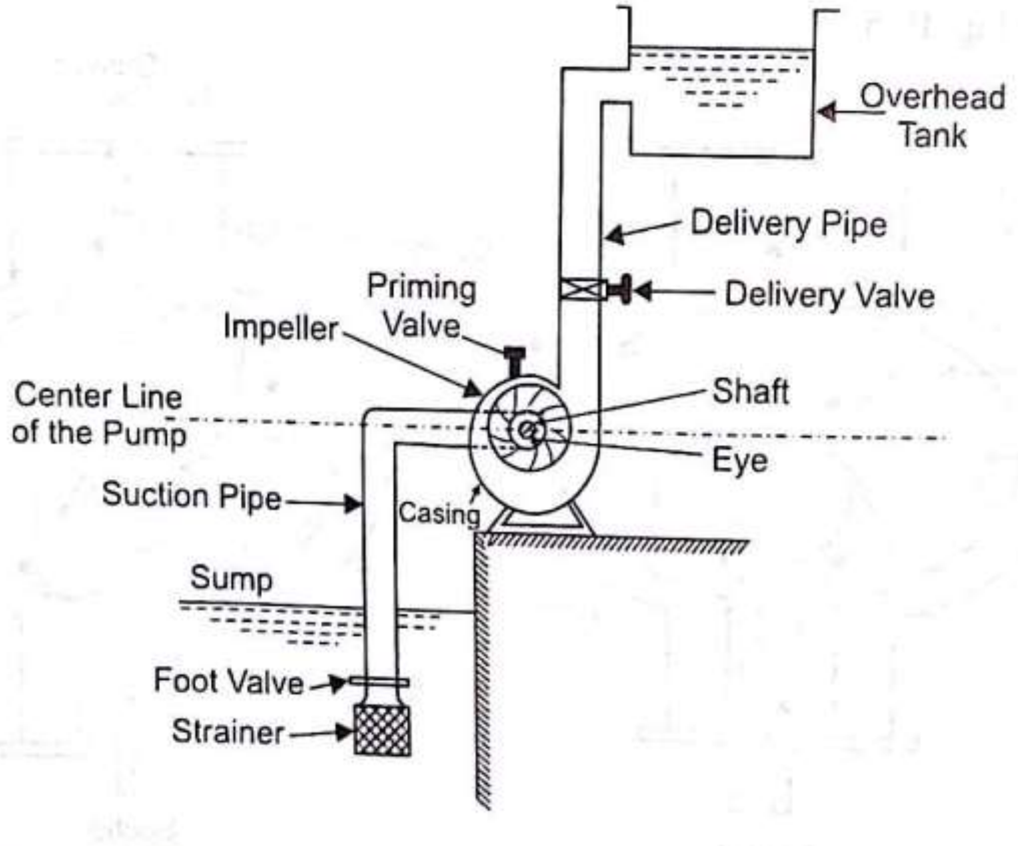


Fig. 10.7 Centrifugal pump

CLASSIFICATION

- According to working head
- According to casing
- According to number of entrances to the impeller
- According to types of impeller
- According to number of stages
- According to shape of the vanes
- According to disposition of shaft

➢ According to working head

- Low head centrifugal pump – working head developed by these pumps is up to 15m.
- Medium head centrifugal pump – working head developed by these system is 15m<H<45m.
- High head centrifugal pump – working head developed by these pumps is more than 45m.

According to casing

- **Volute Casing**
- In this casing, the impeller is surrounded by the spiral casing.
- The casing is such shaped that it's c/s area gradually increases from tongue to delivery pipe.
- Due to impact of the high velocity water leaving the impeller (shock losses), efficiency of conversion of K.E. into P.E. is very less.

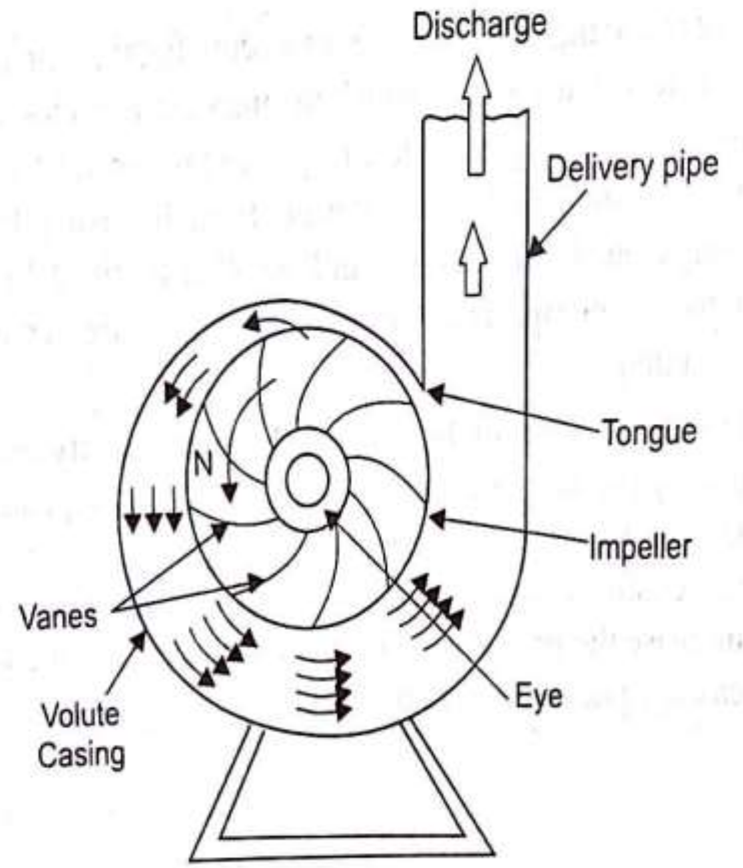


Fig. 10.10 Volute casing

- **Vortex Casing**
- In this casing, an annular space known as vortex or whirlpool chamber is provided b/w the impeller and volute casing.
- Liquid from the impeller flow with free vortex motion in vortex chamber where it's velocity is converted into pressure energy.
- It is more efficient than a volute casing.

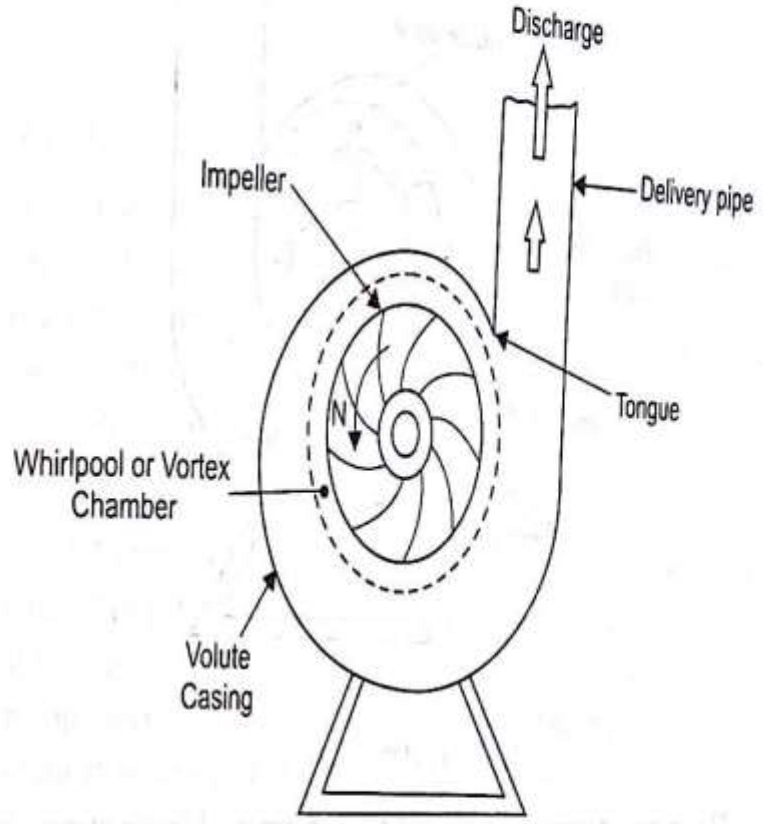


Fig. 10.11 Vortex casing

• Diffuser Casing

- In this casing , the guide vanes are arranged at the outlet of the impeller.
- The guide vanes are shaped to provide gradually enlarged passage for flow of liquid.
- The kinetic energy of the liquid coming out from the impeller is converted into the pressure energy during flow in guide vanes (increasing area).

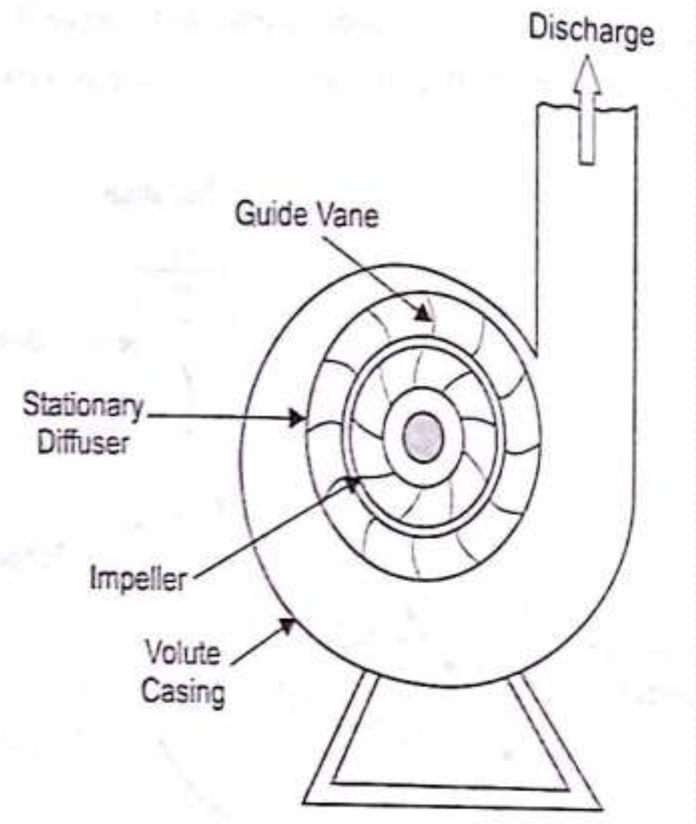


Fig. 10.12 Diffuser casing

➢ According to number of entrances to the impeller

- **Single suction pump**

Liquid enters from a suction pipe to impeller only from one side.

- **Double suction pump**

Liquid enters to both the sides of impeller.

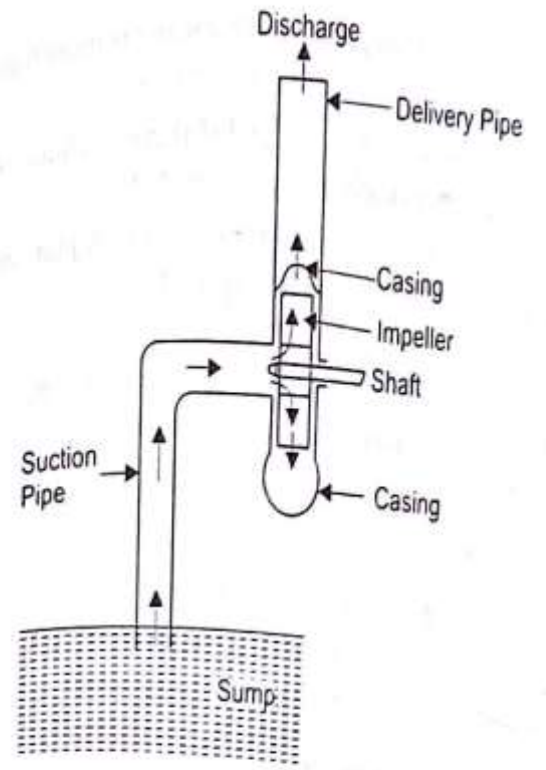


Fig. 10.13 Single suction pump

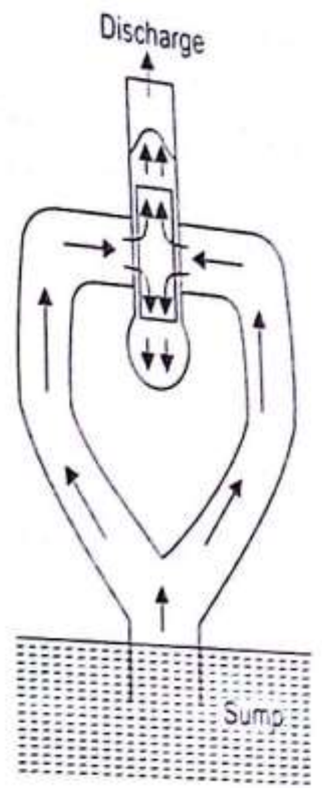
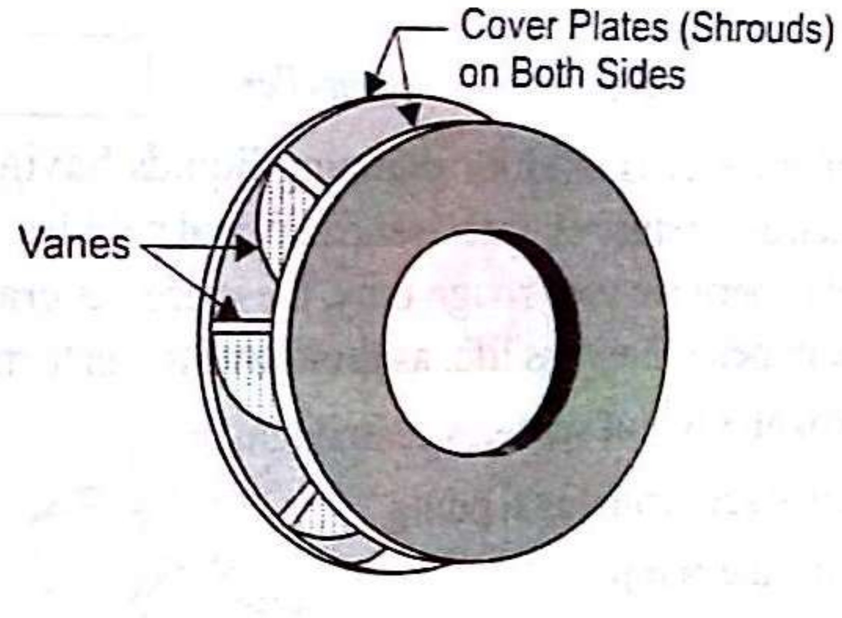


Fig. 10.14Double-Suction pump

➢ According to types of impeller

- **Closed impeller**

if the vanes of the impeller are covered with plates on both sides, it is called a closed impeller. It is made of cast iron, stainless steel, cast steel, gun metal.



Closed impeler.

- **Semi open impeller**

  if the vanes of the impeller are covered with plate on one side, it is called semi open impeller. It has less number of vanes, but it's height is more than that of closed impeller.

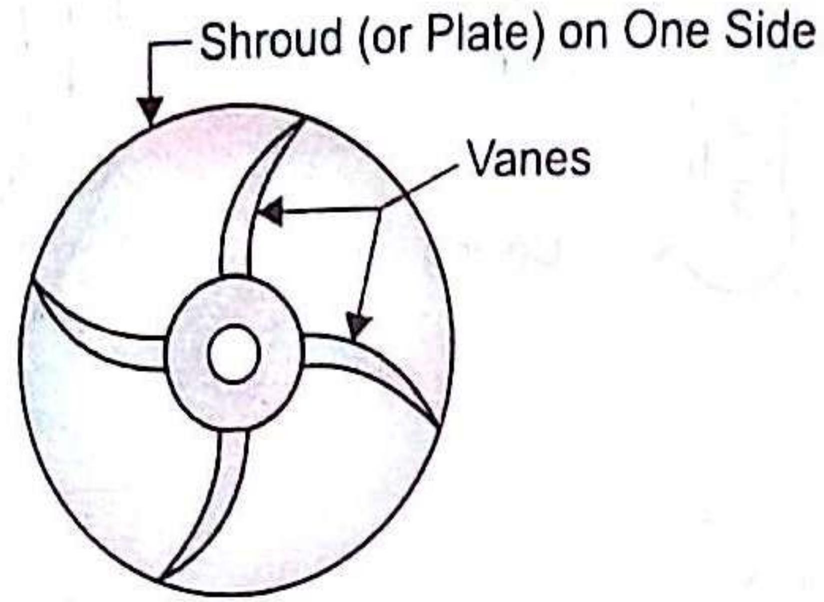


Fig. 10.16 Semi-open impeler

- **Open impeller**

If the vanes of the impeller are without covered plate, it is called open impeller. These are generally made of forged steel. It has less life, as they have to perform very rough task.

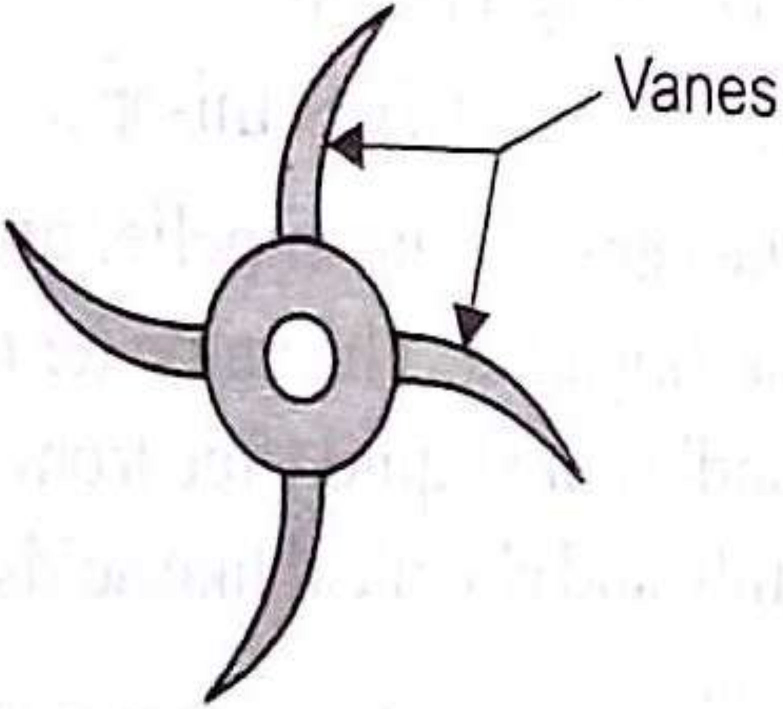
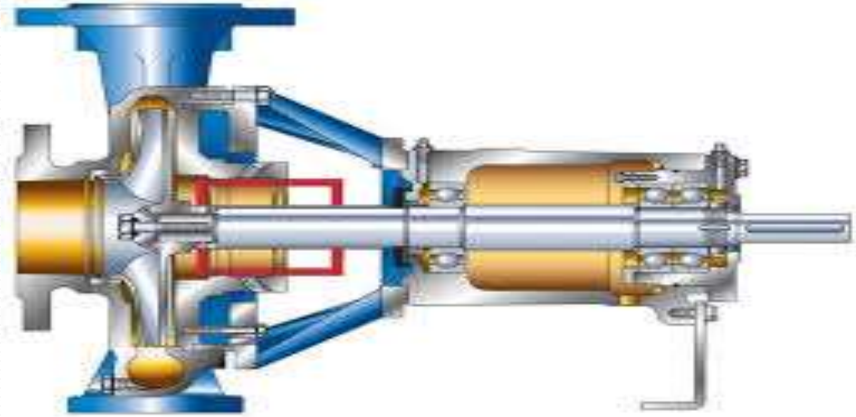


Fig. 10.17 Open impeller

➢ According to number of stage

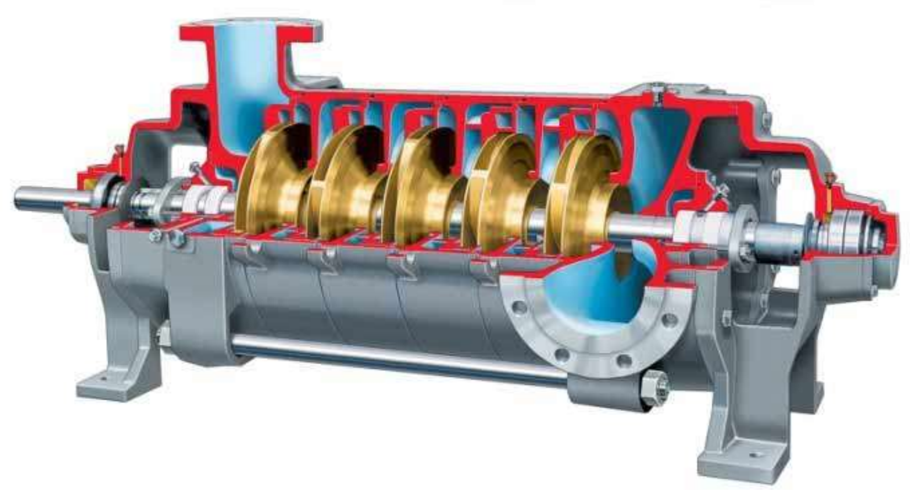
- **Single stage**

  In a single stage pump, only one impeller is used on the shaft.



- **Multi stage**

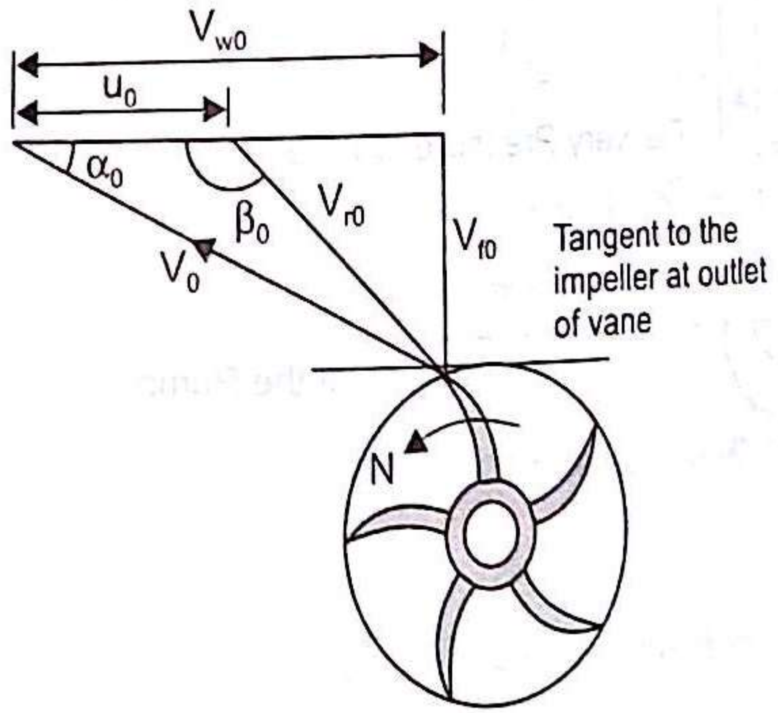
  In a multi stage pump, more than one impeller is used on the same shaft and enclosed in the same casing. It is used to raise high head.



➢ According to shape of the vanes

- **Curved forward vanes**

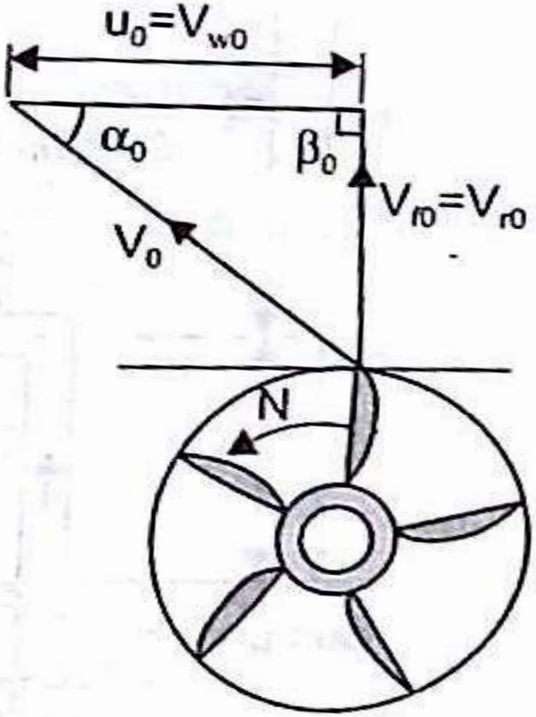
  The outlet tip of the vane is curved forward in the direction of rotation of the impeller. The impeller having such vanes is called slow speed impeller. This type of the impeller has low efficiency about 75%.



(a) Curved forward vanes, $\beta_o > 90°$, $u_o < V_{wo}$, slow speed impeller

- **Radial vanes**

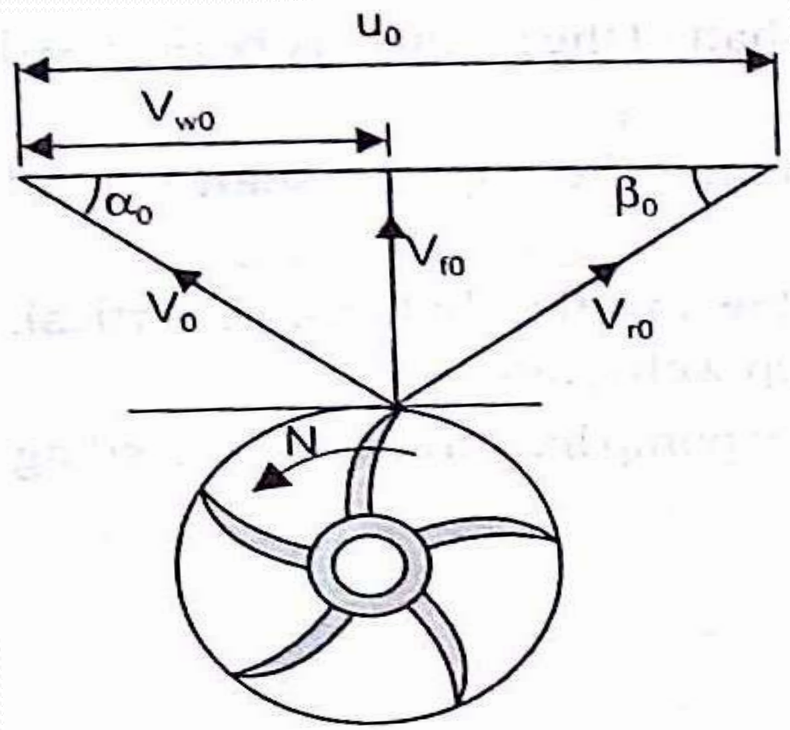
These vanes have outlet tips in radial direction. The impeller having such vanes is called medium speed impeller. The efficiency of this type of impeller varies from 80% to 85%.



(b) Radial vanes, $\beta_o = 90°$, $u_o = V_{wo}$, medium speed impeller

- **Curved backward vanes**

The outlet tip of the vane is curved backward in the direction of rotation of the impeller. The impeller having such vanes is called fast speed impeller. This type of impeller gives highest efficiency about 85% to 90%.



(c) Curved backward vanes, $\beta_o < 90°$, $u_o > V_{wo}$, high speed impeller

➢ According to disposition of the shaft

- **Horizontal pump**

In this type of pump, the impeller shaft is used horizontal.

- **Vertical pump**

In this type of pump, the impeller shaft is used vertical.

Priming

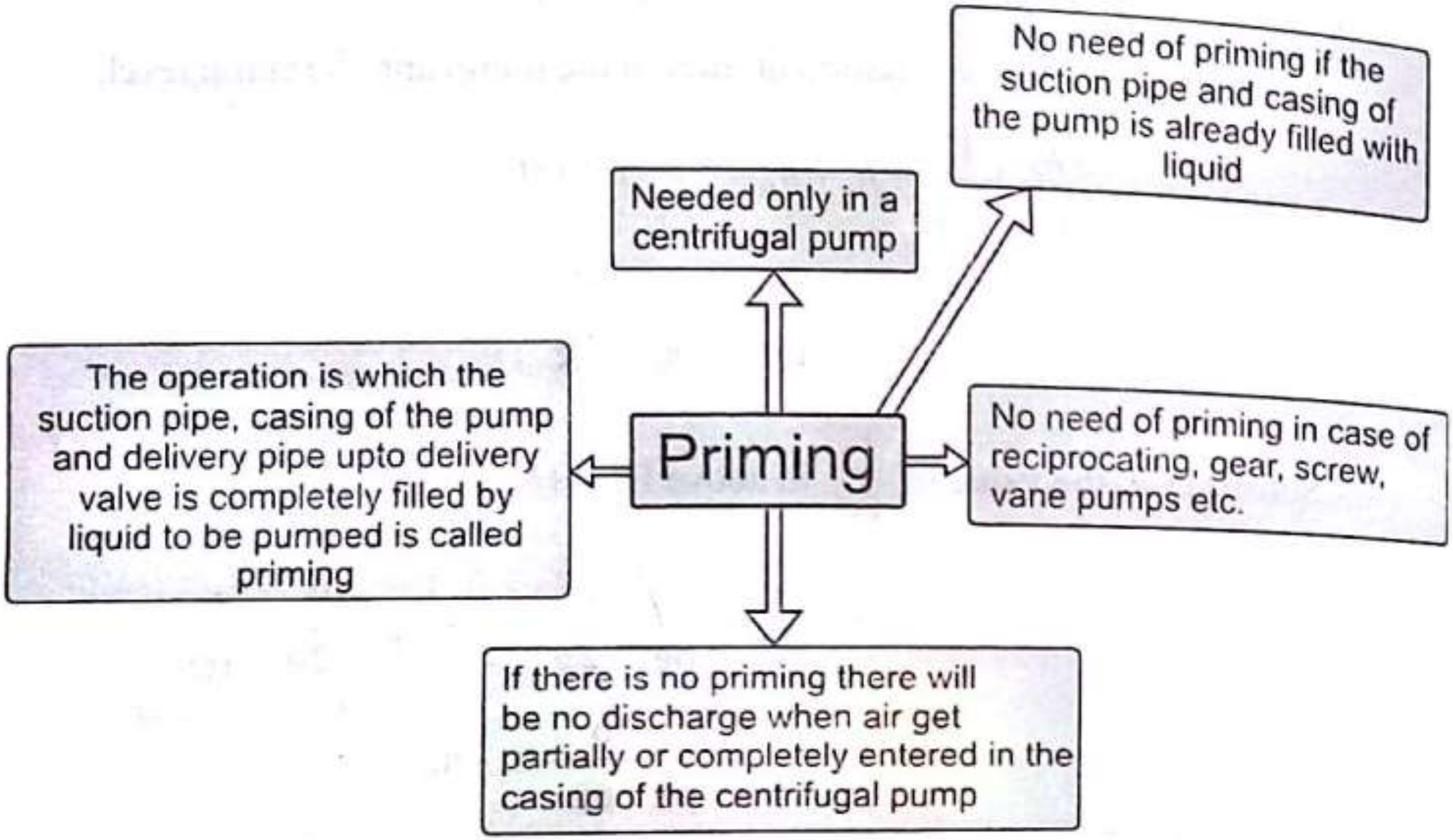


Fig. 10.20 Priming

Necessity of priming

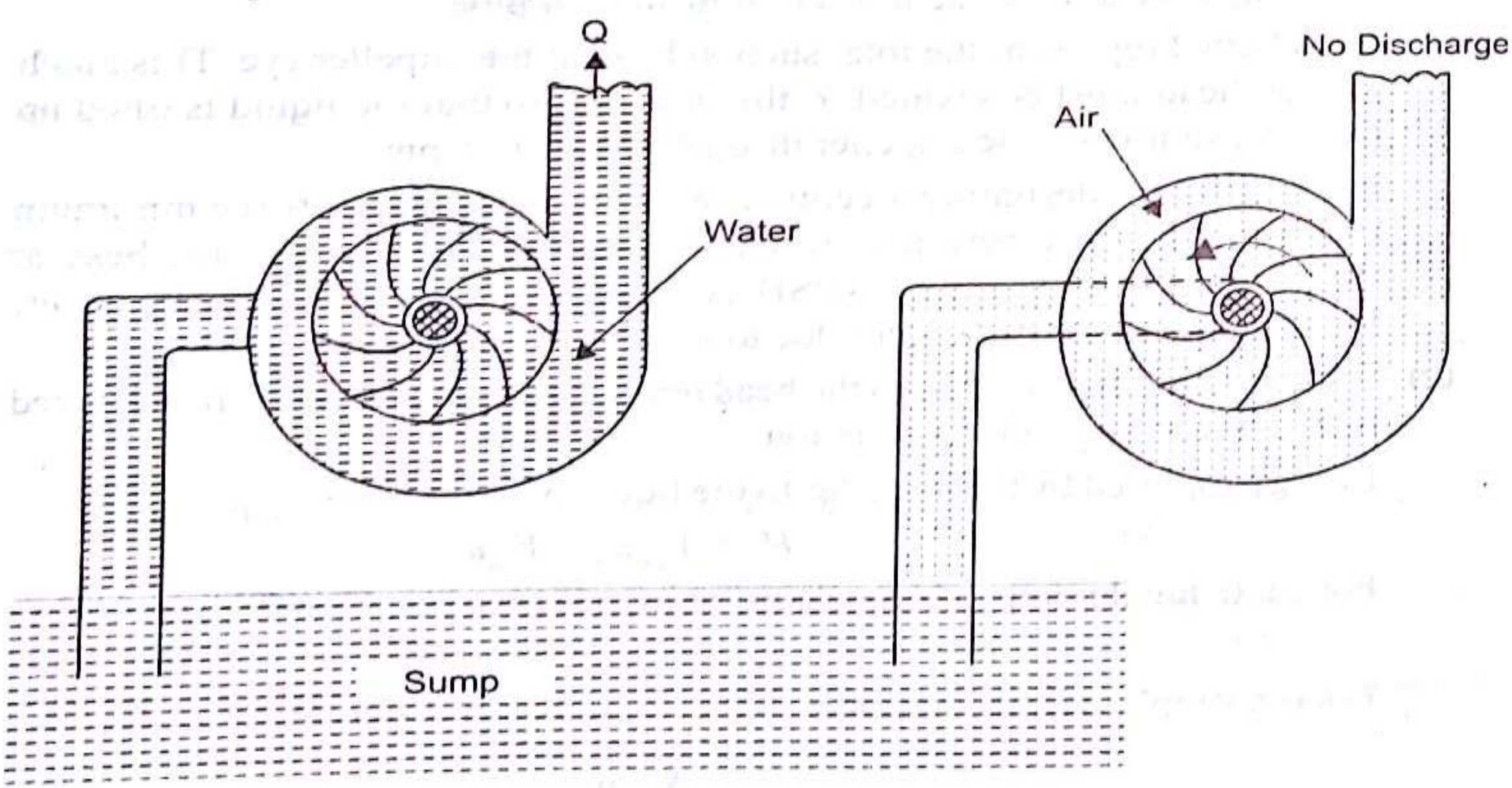
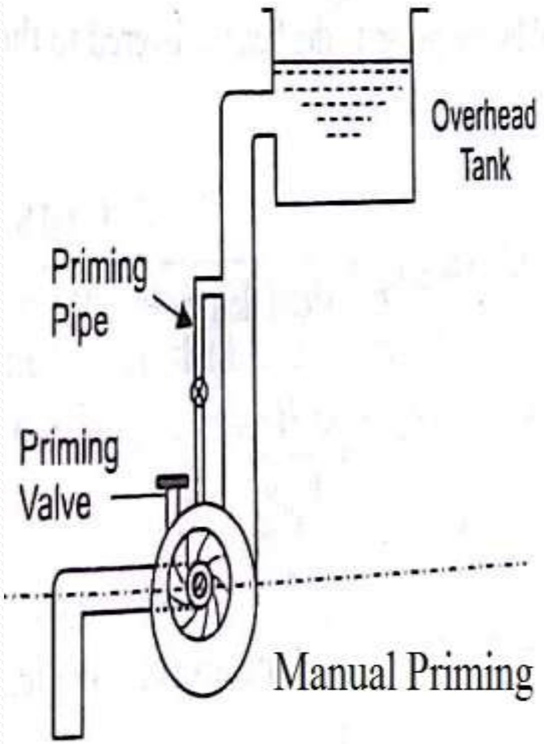


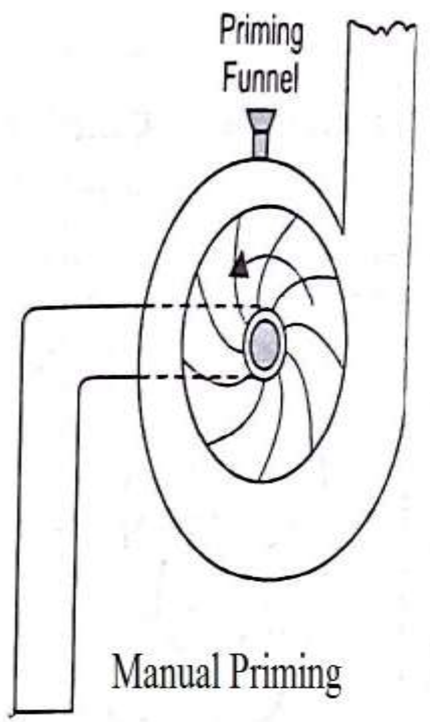
Fig. 10.21 No need of priming because of a impeller is run in water

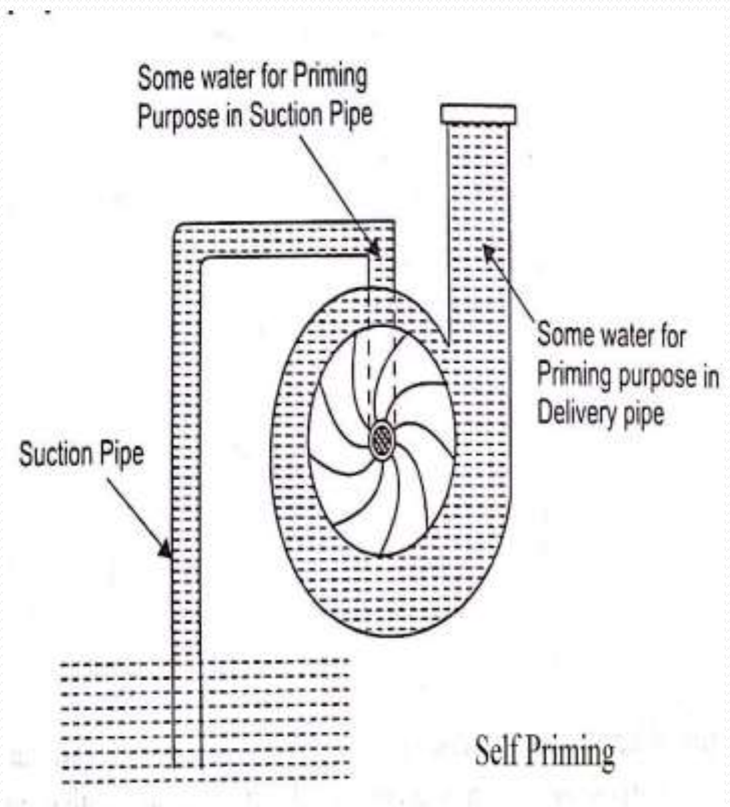
Fig. 10.22 Priming is necesary because of a impeller is run in air

Methods of Priming

Manual Priming **Self Priming**

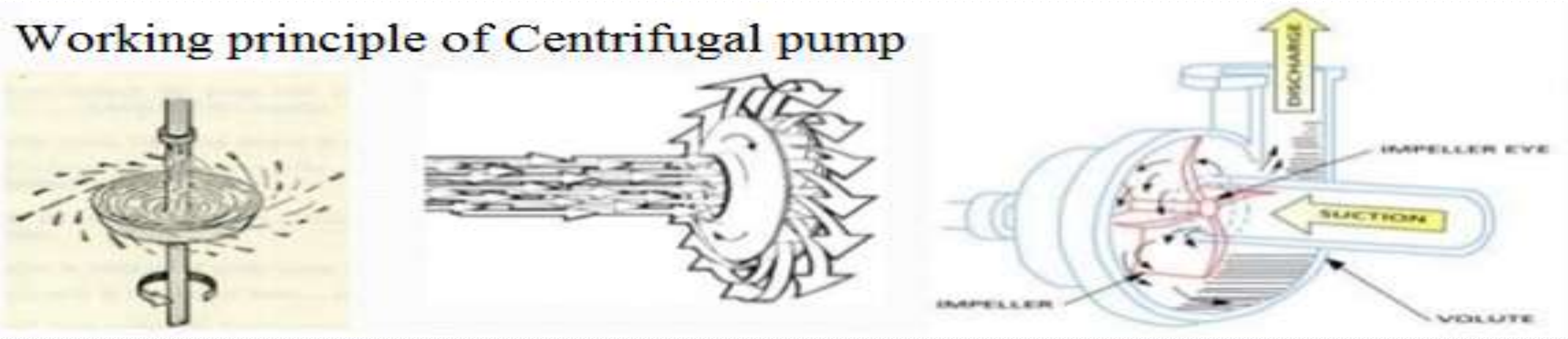






Working

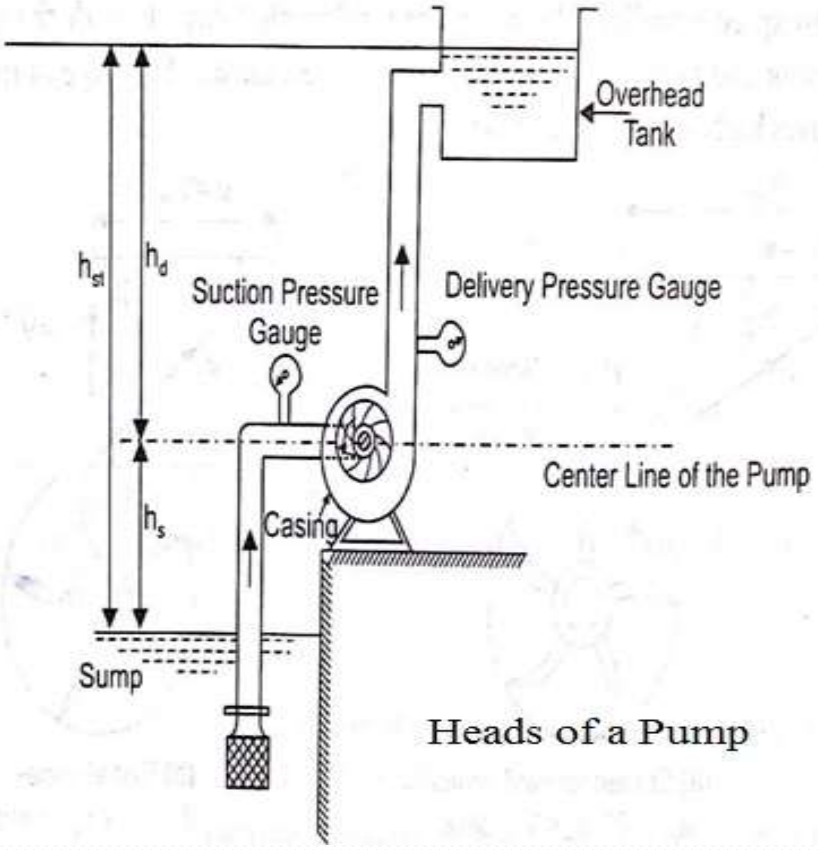
- Impeller in rotating motion forces water out towards the circumference due to centrifugal force effects.
- Due to this, negative pressure gets generated at the centre of the pump so water is sucked from the sump via suction pipe which is connected to the pump.
- The kinetic energy of high velocity water is converted into pressure energy because of diverging passage of casing.



Heads

The heads of a pump may be expressed as:

- Suction Head
- Delivery Head
- Static Head
- Manometric Head
- Total Head
- Euler’s Head



Heads of a Pump

- Suction Head (h_s): It is the vertical distance b/w liquid levels in the sump and the centre line of the pump. Usually, it is kept 7 to 8 m to avoid cavitation.
- Delivery Head (h_d): It is the vertical height of the liquid surface in the overhead tank to which the liquid is delivered above the centre line of the pump.
- Static Head (h_{st}): It is the vertical distance b/w liquid levels in the sump and the overhead tank. It is the sum of suction head and delivery head. ($h_{st}=h_s+h_d$).
- Manometric Head (H_m): The available head against which a centrifugal pump has to work is known as the manometric Head.
- Total Head (H): It is the total head which has to be developed by a pump to deliver the liquid from the sump into the overhead tank.

- Euler's Head (H_e): It is defined as the head developed by the impeller. It is denoted as H_e.

Losses

Energy losses in centrifugal pumps may be classified as follows:

a. Hydraulic Losses
b. Mechanical losses
c. Leakage Losses`

- Hydraulic Losses: There are two types of hydraulic losses which may occur in a pump.

a. Pipeline Losses: Major (due to friction) and minor (due to pipe bend) losses in pipes.

b. Pump Losses: Eddy or shock losses, frictional losses in impeller, guide vane/diffuser, casing.

- Mechanical Losses: Losses due to friction of main bearings and glands.
- Leakage Losses: slipping back of part of liquid through the clearance between the impeller and casing due to pressure difference b/w inlet and outlet. Energy carried by these liquid is ultimately wasted and this loss of energy of liquid is known as leakage losses.

Efficiencies

- Mechanical Efficiency (η_M):

(c) Mechanical efficiency,

$$\eta_m = \frac{\text{Power delivery by the impeller to the liquid}}{\text{Mechanical power input to the pump shaft}}$$

$$= \frac{\rho(Q+q)V_{w0}u_0}{P}$$

Its value lies between 96% – 98%.

- Volumetric Efficiency (η_V):

(b) Volumetric efficiency,

$$\eta_v = \frac{\text{Actual liquid discharge at the pump outlet per second}}{\text{Total liquid discharge per second passing through the impeller}}$$

$$= \frac{Q}{Q+q}$$

where Q = actual liquid discharge at the pump outlet per second, q = leakage of liquid per second from the impeller (through the clearance between the impeller and casing)

Its value lies betwen 98% – 99%.

- Hydraulic Efficiency (η_H)

(a) Hydraulic efficiency,

$$\eta_H = \frac{\text{Total head}}{\text{Head delivered to the liquid by the impeller}}$$

$$= \frac{H}{\frac{V_{wo} u_0}{g}} = \frac{gH}{V_{wo} u_o}$$

- Overall Efficiency (η_O)

(d) Overall efficiency,

$$\eta_o = \frac{\text{Actual hydraulic power developed by a pump}}{\text{Mechanical power input to the pump shaft}}$$

$$= \frac{\rho Q g H}{P}$$

also, $\eta_o = \eta_H \times v_V \times \eta_m$ for finite number of vanes

$= \eta_{man} \times \eta_V \times \eta_m$ for infinite number of vanes.

Advantages

- Small in size & space saving.
- Output is very steady and consistent.
- Easy for maintenance.
- No danger creates if discharge valve is closed while starting.
- Deal with large volume.
- Able to work on medium to low head.
- Able to work on medium to low viscous fluid.
- Almost no noise

Disadvantages

- Extra priming process requires.
- Cannot be able to work on high speeds.
- Cannot deal with highly viscous liquid.

Application

- Agriculture and irrigation purpose.
- Pumping of water in buildings.
- Transfer raw material.

Terima kasih

REFERENCES

1. **L. Nelik**. *Centrifugal and Rotary Pumps: Fundamentals with Applications*, CRC Press, Boca Raton, 1999.
2. **Sulzer Pumps**. *Centrifugal Pump Handbook*, 3rd edition, Sulzer Pumps Ltd., Winterthur, Switzerland, Elsevier, 2010.
3. **S. L. Dixon and C. A. Hall**. *Fluid Mechanics and Thermodynamics of Turbomachinery*, 6th Edition, Elsevier Inc., Amsterdam, 2010.
4. **M. P. Singh and G. M. Lucas**. *Blade Design and Analysis for Steam Turbines*, McGraw-Hill Companies, Inc., 2011.
5. **M. P. Boyce**. *Gas Turbine Engineering Handbook*, 3rd edition, GPM, Houston, Texas, 2005.
6. **C. Soares**. *Microturbines: Applications for Distributed Energy Systems*, Elsevier, Amsterdam, 2007.
7. **A. S. Leyzerovich**. *Wet-Steam Turbines for Nuclear Power Plants*, PennWell Corporation, Tulsa, Oklahoma, 2005.
8. **S. Yedidiah**. *Centrifugal Pump User's Guidebook: Problems and Solutions*, Chapman & Hall, New York, 1996.
9. **M. L. Adams Jr**. *Power Plant Centrifugal Pumps Problem Analysis and Troubleshooting*, CRC Press, Boca Raton, 2017.
10. **Sinaga, Nazaruddin**. *Energy Efficiency As Research and Business Opportunity*, Proceeding, International Workshop on Improvement of UNDIP Research Ability and Networking to Stimulate Sustainable Energy, Grand Candi Hotel, Semarang, October 2009.
11. **Cahyono, Sukmaji Indro, G. H. Choe, and Nazaruddin Sinaga**. *Numerical Analysis Dynamometer (Water Brake) Using Computational Fluid Dynamic Software*. Proceedings of the Korean Solar Energy Society Conference, 2009.
12. **Nazaruddin Sinaga, Abdul Zahri.** *Simulasi Numerik Perhitungan Tegangan Geser Dan Momen Pada Fuel Flowmeter Jenis Positive Displacement Dengan Variasi Debit Aliran Pada Berbagai Sudut Putar Rotor*, Jurnal Teknik Mesin S-1, Vol. 2, No. 4, Tahun 2014.
13. **Septianto, Fajar, A. Widodo dan N. Sinaga**. *Analisa Penurunan Efisiensi Motor Induksi Akibat Cacat Pada Cage Ball Bantalan*, Jurnal Teknik Mesin S-1, Vol. 4, No. 4, Tahun 2015.

14. ***Fatichuddin, Mochamad dan N.Sinaga***. *Pengaruh Komposisi Air Terhadap Kebutuhan Daya Kompresor Pada Sistem Pembangkit Listrik Biogas dari Limbah Tandan Kosong Kelapa Sawit*, Jurnal Ilmiah Momentum, Vol. 12 No. 2, Oktober 2016.
15. **Nazaruddin Sinaga**. *Perancangan Awal Conventer Kit LPG Sederhana untuk Konversi Mesin Bensin Skala Kecil*, Eksergi, Jurnal Teknik Energi POLINES, Vol. 13, No. 1, Januari 2017.
16. **Nazaruddin Sinaga**. *Kaji Numerik Aliran Jet-Swirling Pada Saluran Annulus Menggunakan Metode Volume Hingga*, Jurnal Rotasi Vol. 19, No. 2, April 2017.
17. **Nazaruddin Sinaga**. *Analisis Aliran Pada Rotor Turbin Angin Sumbu Horisontal Menggunakan Pendekatan Komputasional*, Eksergi, Jurnal Teknik Energi POLINES, Vol. 13, No. 3, September 2017.
18. **Muchammad, M., Sinaga, N., Yunianto, B., Noorkarim, M.F., Tauviqirrahman, M.** *Optimization of Texture of The Multiple Textured Lubricated Contact with Slip*, International Conference on Computation in Science and Engineering, Journal of Physics: Conf. Series 1090-012022, IOP Publishing, Online ISSN: 1742-6596 Print ISSN: 1742-6588.
19. **Nazaruddin Sinaga, Mohammad Tauiviqirrahman, Arif Rahman Hakim, E. Yohana.** *Effect of Texture Depth on the Hydrodynamic Performance of Lubricated Contact Considering Cavitation*, Proceeding of International Conference on Advance of Mechanical Engineering Research and Application (ICOMERA 2018), Malang, October 2018.
20. **Syaiful, N. Sinaga, B. Yunianto, M.S.K.T. Suryo**. *Comparison of Thermal-Hydraulic Performances of Perforated Concave Delta Winglet Vortex Generators Mounted on Heated Plate: Experimental Study and Flow Visualization*, Proceeding of International Conference on Advance of Mechanical Engineering Research and Application (ICOMERA 2018), Malang, October 2018.
21. **Nazaruddin Sinaga, K. Hatta, N. E. Ahmad, M. Mel**. *Effect of Rushton Impeller Speed on Biogas Production in Anaerobic Digestion of Continuous Stirred Bioreactor*, Journal of Advanced Research in Biofuel and Bioenergy, Vol. 3 (1), December 2019, pp. 9-18.
22. **Nazaruddin Sinaga, Syaiful, B. Yunianto, M. Rifal**. Experimental and Computational Study on Heat Transfer of a 150 KW Air *Cooled Eddy Current Dynamometer*, Proc. The 2019 Conference on Fundamental and Applied Science for Advanced Technology (Confast 2019), Yogyakarta, Januari 21, 2019.

23. **Nazaruddin Sinaga**. *CFD Simulation of the Width and Angle of the Rotor Blade on the Air Flow Rate of a 350 kW Air-Cooled Eddy Current Dynamometer*, Proc. The 2019 Conference on Fundamental and Applied Science for Advanced Technology (Confast 2019), Yogyakarta, Januari 21, 2019.
24. **Anggie Restue, Saputra, Syaiful, and Nazaruddin Sinaga**. *2-D Modeling of Interaction between Free-Stream Turbulence and Trailing Edge Vortex*, Proc. The 2019 Conference on Fundamental and Applied Science for Advanced Technology (Confast 2019), Yogyakarta, January 21, 2019.
25. **B. Yunianto, F. B. Hasugia, B. F. T. Kiono, N. Sinaga**. *Performance Test of Indirect Evaporative Cooler by Primary Air Flow Rate Variations*, Prosiding SNTTM XVIII, 9-10 Oktober 2019, 1-7.
26. **E. Yohana, N. Sinaga, I. Haryanto, E. Dharmawan**. *Taperless Type Blade Design with NACA 5513 Airfoil for Wind Turbine 500 TSD,* IOP Conference Series: Earth and Environmental Science 448 (2020) 012006, doi:10.1088/1755-315/448/1/012006.