Rotodynamic Machines

Raman Gahlaut
(Assistant Professor)
Mechanical Engineering Department
Shobhit Institute of Engineering & Technology
(Deemed to be University) MEERUT - 250110

Introduction

The Euler's equation for steady flow of an ideal fluid along a streamline is a relation between the velocity, pressure and density of a moving fluid. It is based on the Newton's Second Law of Motion. The integration of the equation gives Bernoulli's equation in the form of energy per unit weight of the fluid.

It is based on the following assumptions:

- The fluid is non-viscous (i,e., the frictional losses are zero).
- The fluid is homogeneous and incompressible (i.e., mass density of the fluid is constant).
- The flow is continuous, steady and along the streamline.
- The velocity of the flow is uniform over the section.
- No energy or force (except gravity and pressure forces) is involved in the flow.

History

The early part of the 18thcentury saw the burgeoning of the field of theoretical fluid mechanics pioneered by Leonhard Euler and the father and son Johann and Daniel Bernoulli. We introduce the equations of continuity and conservation of momentum of fluid flow, from which we derive the Euler and Bernoulli equations. The Bernoulli equation is the most famous equation in fluid mechanics. Its significance is that when the velocity increases in a fluid stream, the pressure decreases, and when the velocity decreases, the pressure increases. The Bernoulli equation is applied to the airfoil of a wind machine rotor, defining the lift, drag and thrust coefficients and the pitching angle.

MASS CONSERVATION OR CONTINUITY EQUATION

The continuity equation of fluid mechanics expresses the notion that mass cannot be created nor destroyed or that mass is conserved. It relates the flow field variables at a point of the flow in terms of the fluid density and the fluid velocity vector, and is given by:

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho \bar{V}) = 0 \qquad (1)$$

We consider the vector identity resembling the chain rule of differentiation

$$\nabla.(\rho \bar{V}) \equiv \rho \nabla.\bar{V} + \bar{V}.\nabla \rho \qquad (2)$$

where the divergence operator is noted to act on a vector quantity, and the gradient operator acts on a scalar quantity. This allows us to rewrite the continuity equation as:

Cont…

$$\frac{\partial \rho}{\partial t} + \bar{V}.\nabla \rho + \rho \nabla . \bar{V} = 0 \qquad (3)$$

SUBSTANTIAL DERIVATIVE:

We can use the substantial derivative

$$\frac{D}{Dt} \equiv \underbrace{\frac{\partial}{\partial t}}_{\substack{Local \\ Derivative}} + \underbrace{(\bar{V}.\nabla)}_{\substack{Convetive \\ Derivative}} \qquad (4)$$

where the partial time derivative is called the local derivative and the dot product term is called the convective derivative. In terms of the substantial derivative the continuity equation can be expressed as

$$\frac{D\rho}{Dt} + \rho \nabla . \bar{V} = 0 \qquad (5)$$

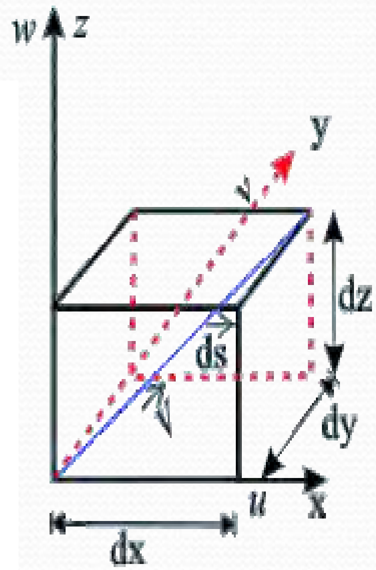
EULER EQUATIONS

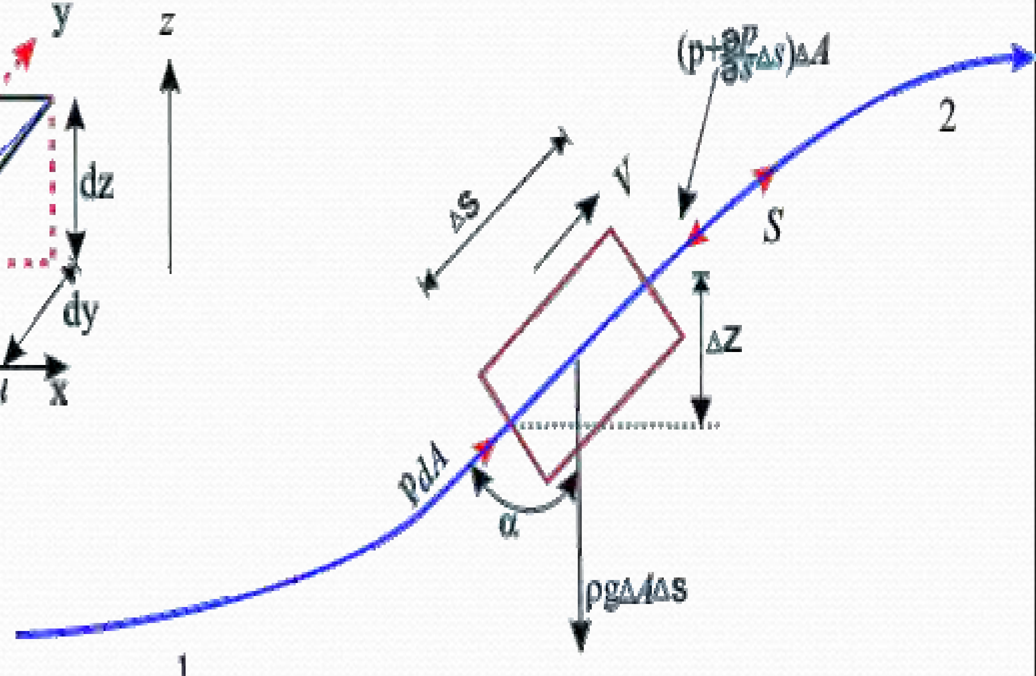
For a steady state flow the time partial derivatives vanish. For inviscid flow the viscous terms are equal to zero. In the absence of body forces the fx, fy, and fz terms disappear. The Euler equations result as:

$$\nabla.(\rho u\bar{V}) = -\frac{\partial p}{\partial x}$$

$$\nabla.(\rho v\bar{V}) = -\frac{\partial p}{\partial y}$$

$$\nabla.(\rho w\bar{V}) = -\frac{\partial p}{\partial z}$$





INVISCID COMPRESSIBLE FLOW

For an inviscid flow without body forces, the momentum conservation equations of fluid mechanics are

$$\rho \frac{Du}{Dt} = -\frac{\partial p}{\partial x}$$

$$\rho \frac{Dv}{Dt} = -\frac{\partial p}{\partial y}$$

$$\rho \frac{Dw}{Dt} = -\frac{\partial p}{\partial z}$$

These equations can also be written as:

$$\frac{\partial(\rho u)}{\partial t} + \bar{V}.\nabla(\rho u) = -\frac{\partial p}{\partial x}$$

$$\frac{\partial(\rho v)}{\partial t} + \bar{V}.\nabla(\rho v) = -\frac{\partial p}{\partial y}$$

$$\frac{\partial(\rho w)}{\partial t} + \bar{V}.\nabla(\rho w) = -\frac{\partial p}{\partial z}$$

Cont…

For steady flow the partial time derivative vanishes, and we can write

$$\rho u\frac{\partial u}{\partial x}+\rho v\frac{\partial u}{\partial y}+\rho w\frac{\partial u}{\partial z}=-\frac{\partial p}{\partial x}$$

$$\rho u\frac{\partial v}{\partial x}+\rho v\frac{\partial v}{\partial y}+\rho w\frac{\partial v}{\partial z}=-\frac{\partial p}{\partial y}$$

$$\rho u\frac{\partial w}{\partial x}+\rho v\frac{\partial w}{\partial y}+\rho w\frac{\partial w}{\partial z}=-\frac{\partial p}{\partial z}$$

Rearranging, we get:

$$u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial x}$$

$$u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial y}$$

$$u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z}=-\frac{1}{\rho}\frac{\partial p}{\partial z}$$

STREAMLINES DIFFERENTIAL EQUATIONS

The definition of a streamline in a flow is that it is parallel to the velocity vector. Hence the cross product of the directed element of the streamline and the velocity vector is zero: $d\overline{s} \times \overline{V} = 0$

where:

$$d\overline{s} = dx\,\hat{x} + dy\,\hat{y} + dz\,\hat{z}$$

$$\overline{V} = u\,\hat{x} + v\,\hat{y} + w\,\hat{z}$$

The cross product can be expanded in the form of a determinant as:

$$d\overline{s} \times \overline{V} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ dx & dy & dz \\ u & v & w \end{vmatrix}$$

$$= \hat{x}(w\,dy - v\,dz) + \hat{y}(u\,dz - w\,dx) + \hat{z}(v\,dx - u\,dy)$$

$$= 0$$

Cont…

The vector being equal to zero, its components must be equal to zero yielding the differential equations for the streamline f(x,y,z) =0, as:

$$w\,dy - v\,dz = 0$$

$$u\,dz - w\,dx = 0$$

$$v\,dx - u\,dy = 0$$

Euler’s Equation Derivation

Multiplying the flow equations respectively by dx, dy and dz, we get:

$$u\frac{\partial u}{\partial x}dx + v\frac{\partial u}{\partial y}dx + w\frac{\partial u}{\partial z}dx = -\frac{1}{\rho}\frac{\partial p}{\partial x}dx$$

$$u\frac{\partial v}{\partial x}dy + v\frac{\partial v}{\partial y}dy + w\frac{\partial v}{\partial z}dy = -\frac{1}{\rho}\frac{\partial p}{\partial y}dy$$

$$u\frac{\partial w}{\partial x}dz + v\frac{\partial w}{\partial y}dz + w\frac{\partial w}{\partial z}dz = -\frac{1}{\rho}\frac{\partial p}{\partial z}dz$$

Using the streamline differential equations, we can write:

$$u\frac{\partial u}{\partial x}dx + u\frac{\partial u}{\partial y}dy + w\frac{\partial u}{\partial z}dz = -\frac{1}{\rho}\frac{\partial p}{\partial x}dx$$

$$u\frac{\partial v}{\partial x}dx + v\frac{\partial v}{\partial y}dy + w\frac{\partial v}{\partial z}dz = -\frac{1}{\rho}\frac{\partial p}{\partial y}dy$$

$$u\frac{\partial w}{\partial x}dx + v\frac{\partial w}{\partial y}dy + w\frac{\partial w}{\partial z}dz = -\frac{1}{\rho}\frac{\partial p}{\partial z}dz$$

Cont…

The differentials of functions u = u(x,y,z), v = v(x,y,z), w =w (x,y,z) are:

$$du = \frac{\partial u}{\partial x}dx + \frac{\partial u}{\partial y}dy + \frac{\partial u}{\partial z}dz$$

$$dv = \frac{\partial v}{\partial x}dx + \frac{\partial v}{\partial y}dy + \frac{\partial v}{\partial z}dz$$

$$dw = \frac{\partial w}{\partial x}dx + \frac{\partial w}{\partial y}dy + \frac{\partial w}{\partial z}dz$$

This allows us to write:

$$udu = -\frac{1}{\rho}\frac{\partial p}{\partial x}dx$$

$$vdv = -\frac{1}{\rho}\frac{\partial p}{\partial y}dy$$

$$wdw = -\frac{1}{\rho}\frac{\partial p}{\partial z}dz$$

Cont…

Through integration we can write:

$$\frac{1}{2}d(u^2) = -\frac{1}{\rho}\frac{\partial p}{\partial x}dx$$

$$\frac{1}{2}d(v^2) = -\frac{1}{\rho}\frac{\partial p}{\partial y}dy$$

$$\frac{1}{2}d(w^2) = -\frac{1}{\rho}\frac{\partial p}{\partial z}dz$$

Adding the three last equations we get:

$$\frac{1}{2}d(u^2 + v^2 + w^2) = -\frac{1}{\rho}\left(\frac{\partial p}{\partial x}dx + \frac{\partial p}{\partial y}dy + \frac{\partial p}{\partial z}dz\right)$$

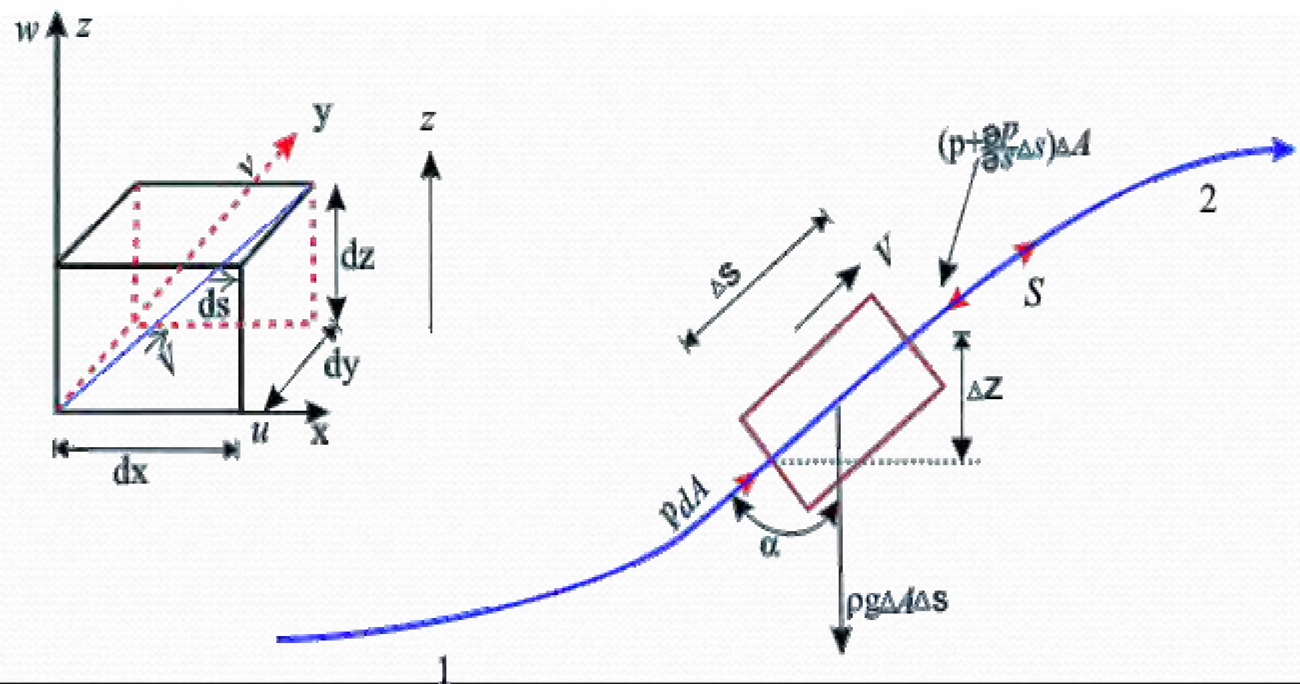
$$\frac{1}{2}d(V^2) = -\frac{1}{\rho}dp$$

Cont…

From the last equation we can write a simple form of Euler's equation as:

$$dp = -\rho V dV$$

Euler's equation applies to an inviscid flow with no body forces. It relates the change in velocity along a streamline dV to the change in pressure dp along the same streamline.



Physical interpretation of Bernoulli equation

- Integration of the equation of motion to give the Bernoulli equation actually corresponds to the work-energy principle often used in the study of dynamics.
- This principle results from a general integration of the equations of motion for an object in a very similar to that done for the fluid particle. With certain assumptions, a statement of the work-energy principle may be written as follows:

  The work done on a particle by all forces acting on the particle is equal to the change of the kinetic energy of the particle.
- The Bernoulli equation is a mathematical statement of this principle. In fact, an alternate method of deriving the Bernoulli equation is to use the first and second laws of thermodynamics (the energy and entropy equations), rather than Newton's second law. With the approach restrictions, the general energy equation reduces to the Bernoulli equation.

Physical interpretation of Bernoulli equation

An alternate but equivalent form of the Bernoulli equation is

$$\frac{p}{\gamma} + \frac{V^2}{2g} + z = constant$$

along a streamline.

Pressure head: $\frac{p}{\gamma}$

Velocity head: $\frac{V^2}{2g}$

Elevation head: z

The Bernoulli equation states that the sum of the pressure head, the velocity head, and the elevation head is constant along a streamline.

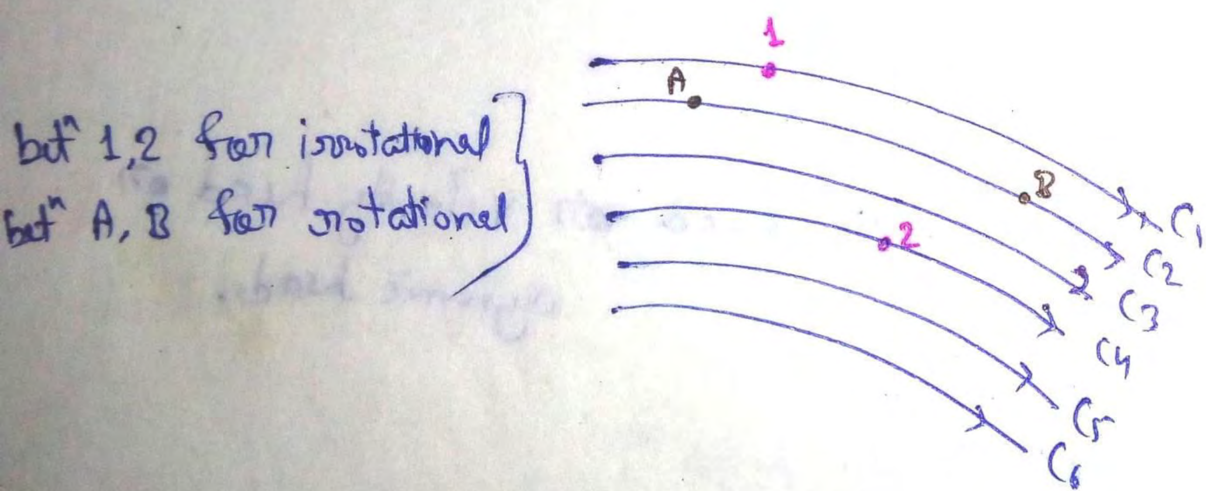
Bernoulli's theorem in Rotational Flows

- The energy conservation can also be applied in the rotational flows between the points which lie on the same stream line.

$$\frac{p}{\rho g} + \frac{v^2}{2g} + z = \text{Constant} = C$$

if irrotational flow
then $C_1 = C_2 = C_3 = C_4 = C_5 = C_6$

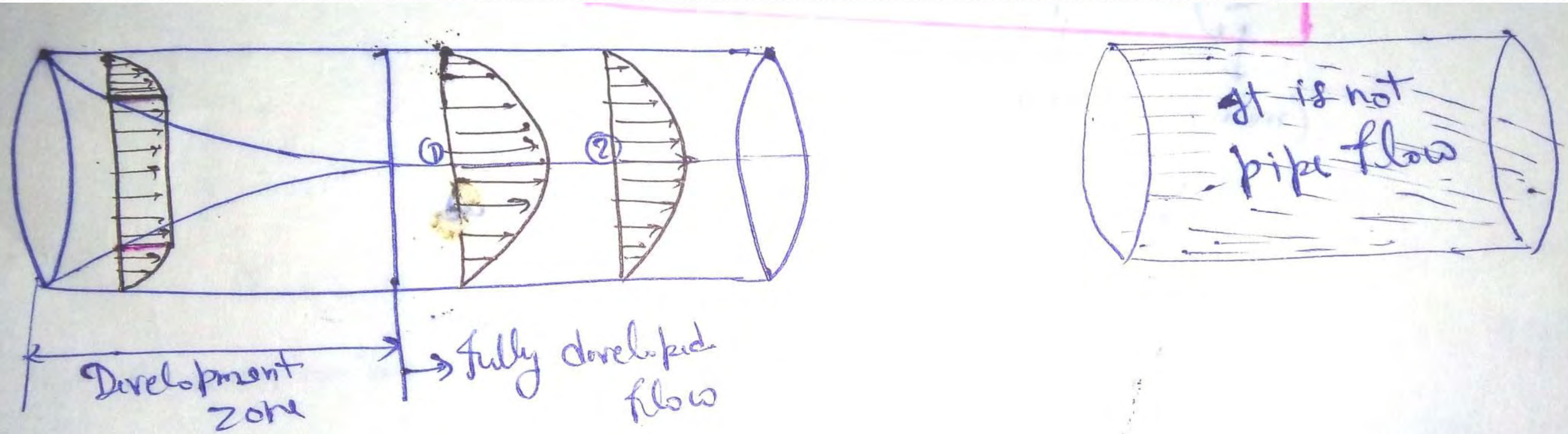
if rotational flow
$C_1 \neq C_2 \neq C_3 \neq C_4 \neq C_5 \neq C_6$



Bernoulli Theorem in a Real Fluid Flow

- Viscous Fluid Flow
- Internal Flows

Pipe Flow: Viscous Flow(Boundary layer will never finish)

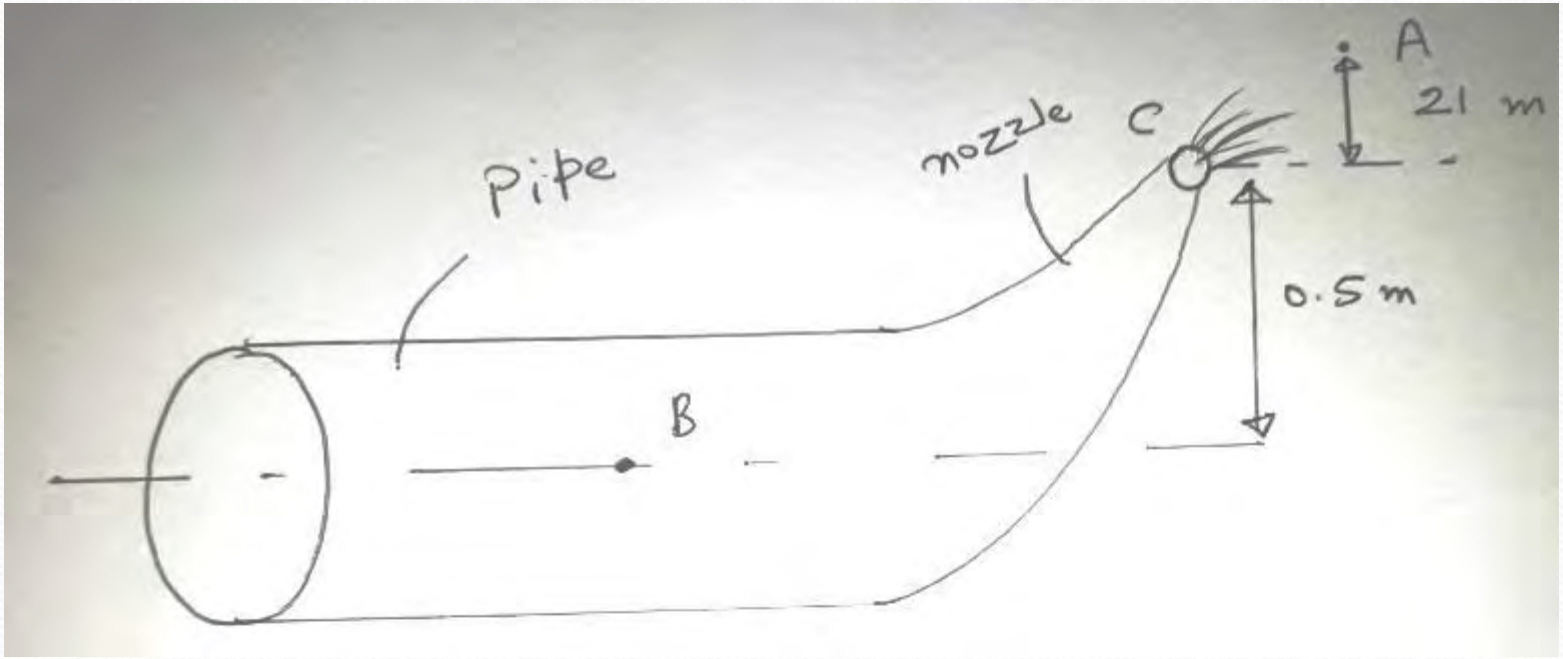


$$\left(\frac{p_1}{\rho g}+\frac{V_1^2}{2g}+z_1\right)=\left(\frac{p_2}{\rho g}+\frac{V_2^2}{2g}+z_2\right)+h_L$$

(h_L → head loss due to friction)

Do it Yourself

A free jet of water emerging from a nozzle of diameter 75 mm attached to a pipe of 225 mm diameter as shown in figure. The velocity of water at point A is 18 m/sec. Neglect friction in the pipe and nozzle. Nozzle tip velocity is Vc then find Vc and pressure at B in kpa.



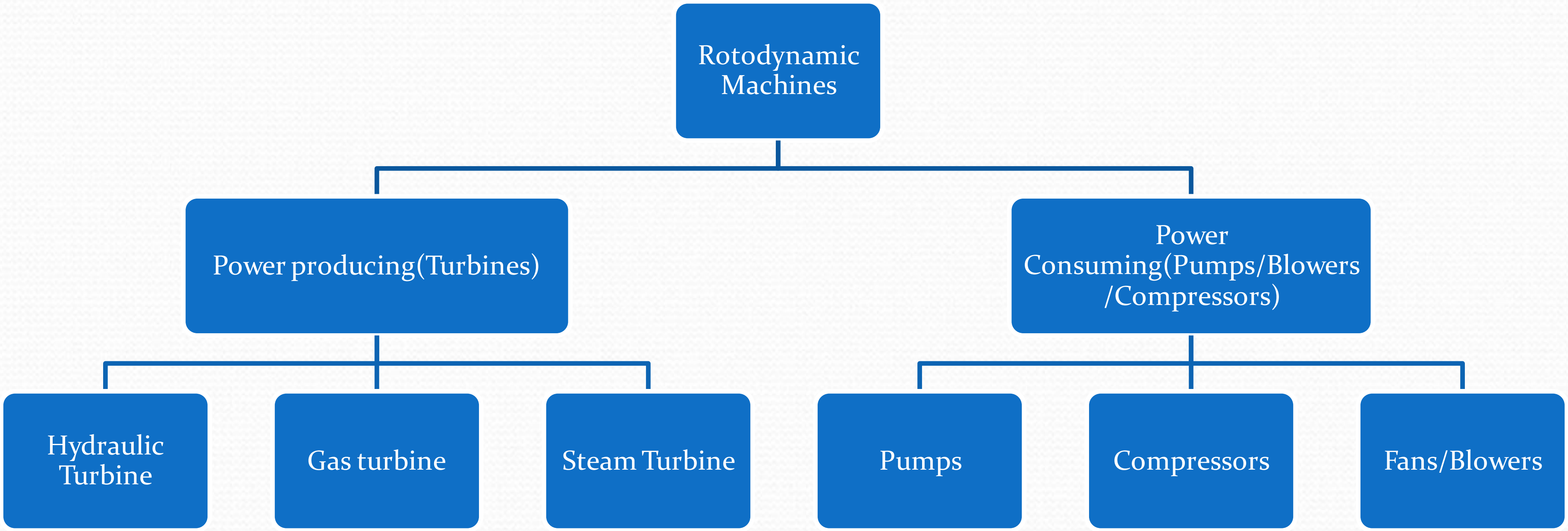
Rotodynamic Machines

- Rotodynamic machine (turbine, pump, compressor..), in general, is a rotor consisting of a number of vanes or blades
- There always exists a relative motion between the rotor vanes and the fluid.
- The fluid has a component of velocity tangential to the rotor and hence a momentum in a direction tangential to the rotor.
- The rate at which this tangential momentum changes corresponds to a tangential force on the rotor
- In a turbine, the tangential momentum of the fluid is reduced and therefore work is done by the fluid to the moving rotor.
- But in case of pumps and compressors there is an increase in the tangential momentum of the fluid and therefore work is absorbed by the fluid from the moving rotor.

Theory

- A mechanism for converting the energy of a moving liquid or gas into the energy of a rotating shaft (for example, a hydroturbine), or vice versa (for example, a ventilator). The power transfer to or from the flow takes place as a result of the change in the angular momentum of the fluid or gas during its passage through the rotor of the machine.
- Rotodynamic machines were known even before the Common Era (the reaction steam turbine of Hero of Alexandria and the hydraulic turbines of the ancient Romans); water-driven and wind-driven mills were in use long ago. Gas turbines and the axial compressor were developed in the late 19th century.
- The fundamental theory of rotodynamic machines was developed by L. Euler, who was the first to describe the basic hydromechanical flow sheet of their operation. The theory of latticed wing sections, which is the basis of the blade design for rotodynamic machines, was created by the Russian scientists N. E. Zhukovskii and S. A. Chaplygin.

Types of Rotodynamic Machines



Turbine Input: Stored energy of water
Turbine output: Mechanical Energy
Pump Input: Mechanical energy
Pump Output: Stored energy of water

Classification of Rotodynamic Pumps

Rotodynamic pumps can be classified on various factors such as design, construction, applications, service etc.

1. According to the types of stages:

- Single stage pumps:
  - It is known as single impeller pump.
  - It is simple in design and easy in maintenance.
  - It is ideal for large flow rates and low pressure installations.
- Two stage pump:
  - It has two impellers operating side by side.
  - It is used for medium use applications.
- Multistage Pumps:
  - It has three or more impellers in series.
  - They are used for high head applications

Cont…

2. According to the type of case – split:

- Axial split:
  - In these types of pumps the volute casing is split axially and split line at which the pump casing separates is at the shaft's center – line.
  - They are typically mounted horizontally due to ease in installation and maintenance.
- Radial split:
  - In it pump case is split radially, the volute casing split is perpendicular to shaft centre line.

3. According to the types of impeller design.

- Single suction:
  - It has single suction impeller which allows fluid to enter blades only through a single opening.
  - It has a simple design but the impeller has higher axial thrust imbalance due to flow coming through one side of impeller.
- Double Suction:
  - It has double suction impeller which allows fluid to enter from both the sides of blades.
  - They are most common types of pumps.

Cont…

4.According to the type of volute:

- Single volute pump:
  - It is usually used for low capacity pumps, as it has small volute size.
  - Small size volute casting is difficult but is good in quality.
  - They have higher radial loads.
- Double volute pump:
  - It has two volutes which are placed 180 degrees apart.
  - It has a good capability of balancing radial loads.
  - It is the most common design used.

Cont…

5. According to the shaft orientation:

- Horizontal Centrifugal pumps:
  - Easily available.
  - Easy to install, inspect, maintain and service.
  - It is suitable for low pressure.
- Vertical Centrifugal pumps:
  - Requires large headroom for installation, servicing and maintenance.
  - It can easily withstand higher pressure loads.
  - It is more expensive than horizontal pumps

Working of a Rotodynamic pump

Centrifugal Pump is the most common used pumping device in the hydraulic world. In which the water comes from the tank at the center of the impeller and exits at the top of the pump. The impeller is called the heart of the system. Which have three types 1. Open Impeller, 2. Semi-open impeller, 3. Enclosed impeller, in which the enclosed impeller gives the best efficiency. Enclosed impellers have a series of backward-curved vanes fitted between the two plates. It will always stay in the water. When impeller starts to rotate, the fluid in which the impeller lies will also rotate. When fluid starts to rotate, the centrifugal force will induced in the fluid particles. Due to centrifugal force, both pressure and kinetic energy of fluid will increases. As the centrifugal force occurs in the fluid particles, at the inlet nozzle (at the suction) side the pressure will decreases.

Cont…

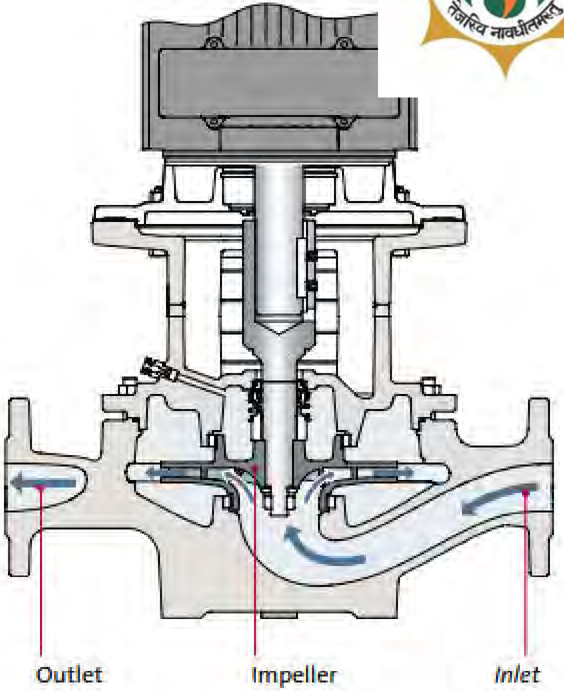
The pressure will comparatively less than the atmospheric pressure. Such low pressure will help to suck the fluid from the storage. But if the inlet nozzle (at the suction) is empty or filled with the air it will damage the impeller. The difference between pressure created at the inlet nozzle (at the suction) and the atmospheric pressure will be very less to suck the fluid from the tank. The impeller if fitted inside the casing. So the fluid has to be inside the casing. Casing will be designed such that it will give maximum pressure at the exit. In casing, the maximum diameter or space is at exit (discharge nozzle) and as we move inside the diameter will gradually decrease. Due to this, the volume of the fluid is more at the discharge nozzle, so the velocity will decrease, and as velocity and pressure both are inversely proportional the pressure will increase. And the increase in pressure is required because to overcome the resistance of the pumping system

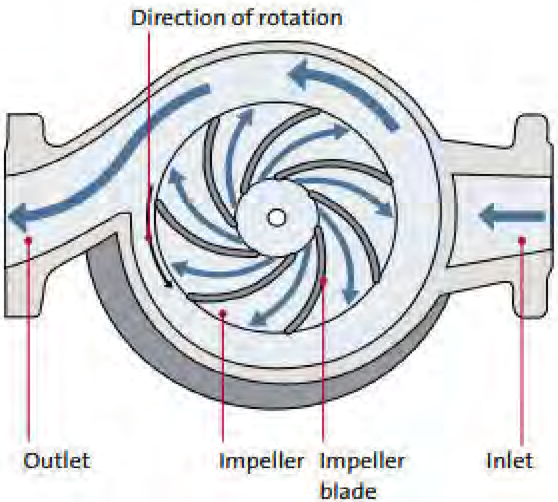
Introduction

- The centrifugal pump is the most used pump type in the world.
- The principle is simple, well-described and thoroughly tested, and the pump is robust, effective and relatively inexpensive to produce.
- There is a wide range of variations based on the principle of the centrifugal pump and consisting of the same basic hydraulic parts.
- The majority of pumps produced by Grundfos are centrifugal pumps.

The main parts of centrifugal pumps are:

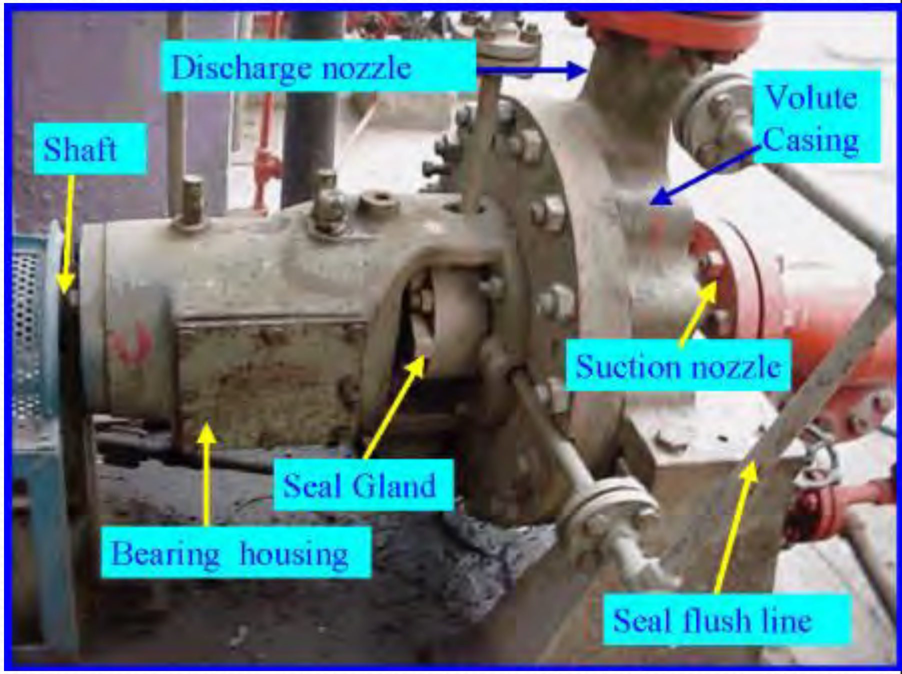
1. Impeller
2. Casing
3. Suction pipe
4. Delivery pipe
5. Strainer





Principle of the centrifugal pump

- An increase in the fluid pressure from the pump inlet to its outlet is created when the pump is in operation.
- This pressure difference drives the fluid through the system or plant. The centrifugal pump creates an increase in pressure by transferring mechanical energy from the motor to the fluid through the rotating impeller.
- The fluid flows from the inlet to the impeller centre and out along its blades.
- The centrifugal force hereby increases the fluid velocity and consequently also the kinetic energy is transformed to pressure. You can see in Figure given in previous slide an example of the fluid path through the centrifugal pump.

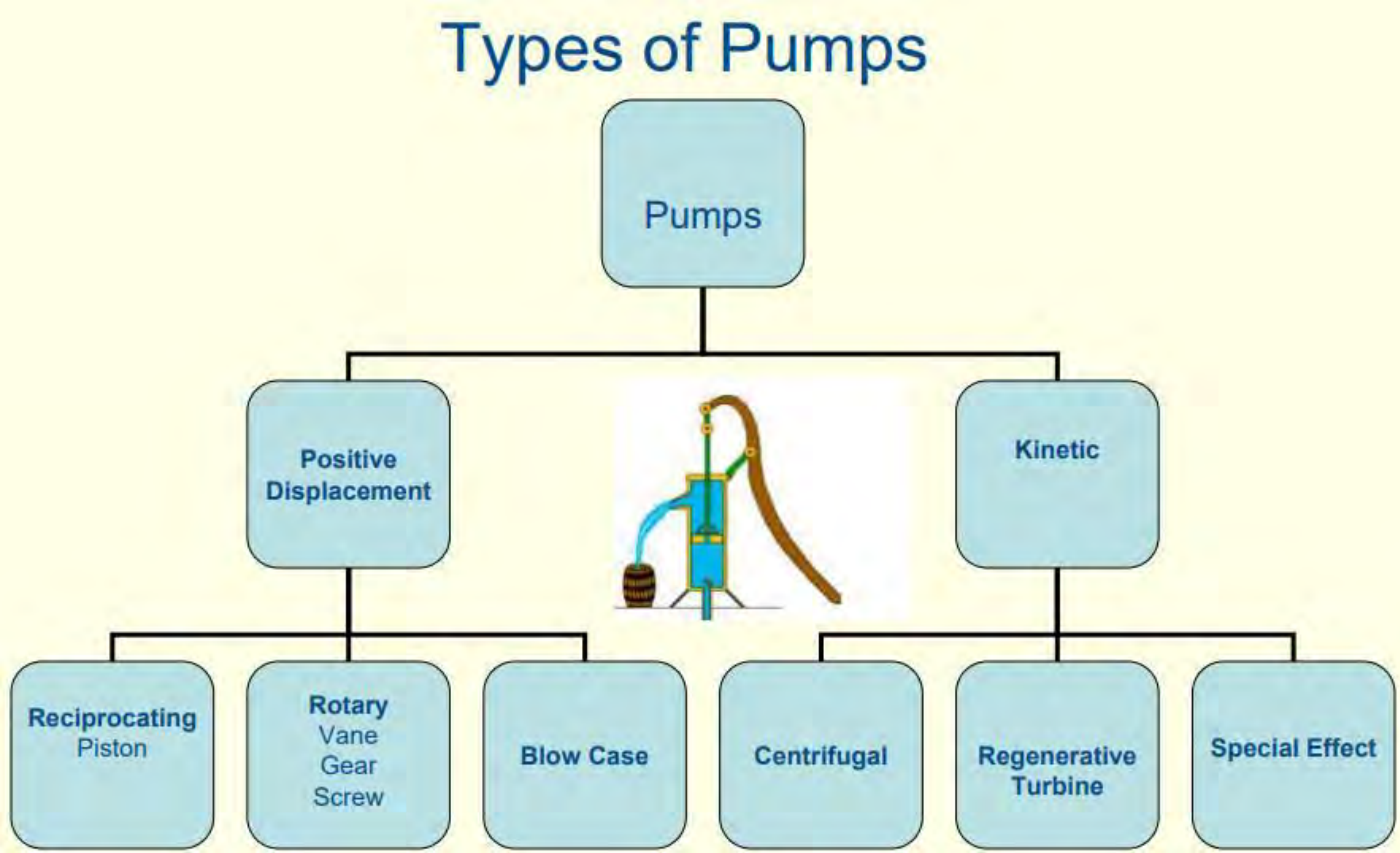


Working of a centrifugal pump

Working operation of a centrifugal pump is explained in the following steps

1. Close the delivery valve and prime the pump
2. Start the motor connected to the pump shaft, this causes an increase in the impeller pressure
3. Open the delivery valve gradually, so that the liquid starts flowing into the deliver pipe
4. A partial vacuum is created at the eye of the centrifugal action, the liquid rushed from the sump to the pump due to pressure difference at the two ends for the suction pipe.
5. As the impeller continues to run, move & more liquid is made available to the pump at its eye. Therefore impeller increases the energy of the liquid and delivers it to the reservoir.
6. While stopping the pump, the delivery valve should be closed first, otherwise there may be back flow from the reservoir. It may be noted that a uniform velocity of flow is maintained in the delivery pipe. This is due to the special design of the casing. As the flow proceeds from the tongue of the casing to the delivery pipe, the area of the casing increases. There is a corresponding change in the quantity of the liquid from the impeller. Thus a uniform flow occurs in the delivery pipe

Classification of Pumps



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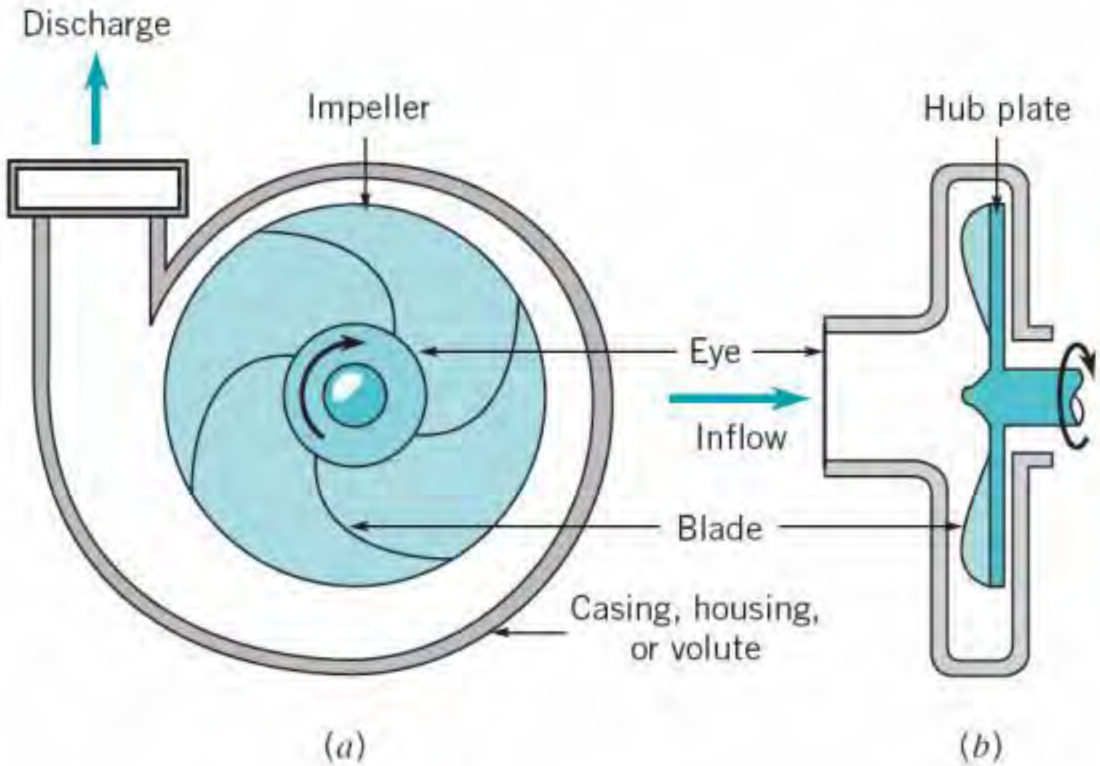
1. Positive Displacement Pump: –

   Operate by forcing a fixed volume of fluid from the inlet pressure section of the pump into the discharge zone of the pump. They add energy directly to a movable boundary, which imparts the energy to the fluid.

2. Kinetic Pumps: – Add energy directly through a rotating part in the form of velocity, and converts the velocity to pressure.
   - Centrifugal Pumps
   - Regenerative Pumps: Unique pump where the impeller is the only moving part. It is used when high head and low flows are required.
   - Special Effects Pumps: Miscellaneous pumps

Structure of a centrifugal pump

Centrifugal pump has two main components: an impeller and a stationary casing, housing, or volute.



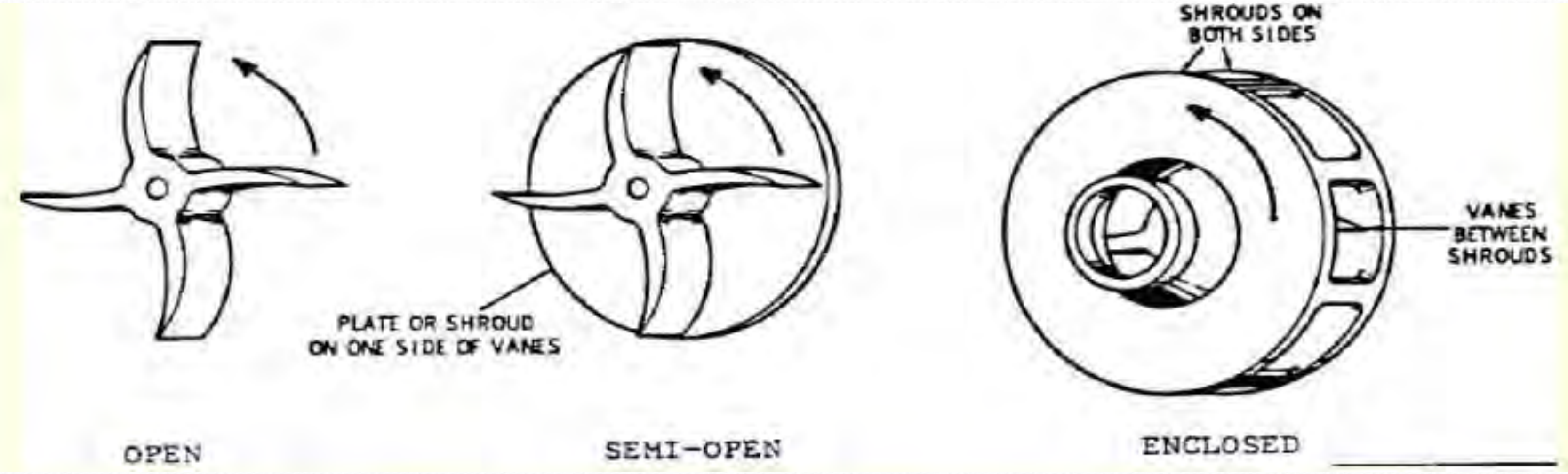
Structure of a centrifugal pump

- An impeller attached to the rotating shaft. The impeller An impeller attached to the rotating shaft. The impeller consists of a number of blades, also sometimes called consists of a number of blades, also sometimes called vanes, arranged in a regular pattern around the shaft. vanes, arranged in a regular pattern around the shaft.
- A stationary casing, housing, or volute enclosing the A stationary casing, housing, or volute enclosing the impeller. impeller.
- The casing shape is designed to reduce the velocity as the fluid leaves the impeller, and this decrease in kinetic energy is converted into an increase in pressure.
- The volute -shaped casing, with its increase area in the direction of flow, is used to produce an essentially uniform velocity distribution as the fluid moves around the casing into the discharge opening

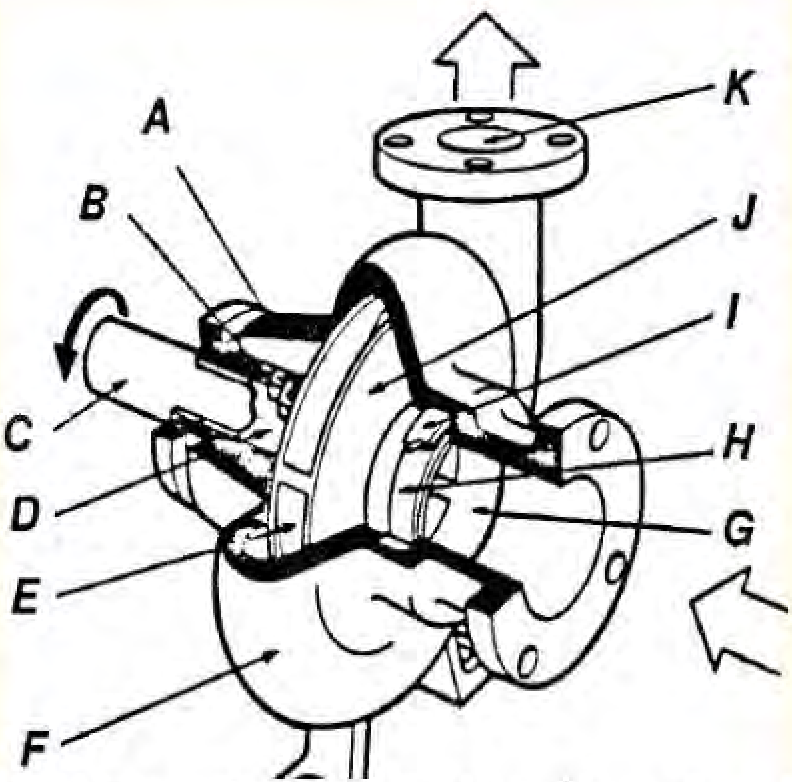
Different Types of Impeller

The impeller of a Centrifugal Pump can be of three types:

- Open Impeller: The vanes are cast free on both sides.
- Semi-Open Impeller: The vanes are free on one side and enclosed on the other.
- Enclosed Impeller: The vanes are located between the two discs, all in a single casting.



Nomenclature and Description of Centrifugal pump



This figure does not show bearing housing!

A/Stuffing Box	F/Volute or Casing
B/Packing	G/Inlet
C/Shaft	H/Impeller Wear Ring
D/Shaft Sleeve	I/Wear Ring
E/Impeller-Discharge Ports	J/Closed Impeller Face
	K/Discharge

Advantages and Disadvantages of Centrifugal Pumps

Centrifugal Pumps are the most widely used type of pump for the transfer of liquids. There are many advantages and disadvantages associated with Centrifugal Pumps:

Advantages:

- Simple operation.
- Low first cost and maintenance.
- Insignificant excessive pressure build up in casing.
- Impeller and shaft are the only moving parts.
- Quiet operations.
- Wide range of pressure, flow and capacities.
- Utilize small floor space in different positions.

Advantages and Disadvantages of Centrifugal Pumps contd.

Disadvantages:

– High viscous liquids are not handled well.

– Centrifugal Pumps usually don’t have the capabilities of handling high pressure applications in comparison to other types of pumps, i.e., Regenerative turbines.

– In general, Centrifugal pumps cannot deliver high pressure without changes in design and are not suitable for high pressure delivery at low volumes except the multistage pumps

Application of centrifugal pump

1. Centrifugal pumps are used in buildings for pumping the general water supply, as a booster and for domestic water supplies.
2. The design of a centrifugal pump makes them useful for pumping sewage and slurries.
3. They are also used in fire protection systems and for heating and cooling applications.
4. Beverage industry: Used to transfer juice, bottled water, etc.
5. Dairy industry: Used to transfer dairy products such as milk, buttermilk, flavored milk, etc.
6. Various industries **(Manufacturing, Industrial, Chemicals, Pharmaceutical, Food Production, Aerospace, etc.)** – for the purposes of cryogenics and refrigerants.
7. Oil Energy – pumping crude oil, slurry, mud; used by refineries, power generation plants.

Priming and why It is necessary

Priming can be defined as the process in which the suction pipe, casing, delivery pipe up to the delivery valve, which is filled completely with liquid to be raised from an outside source before starting the motor.

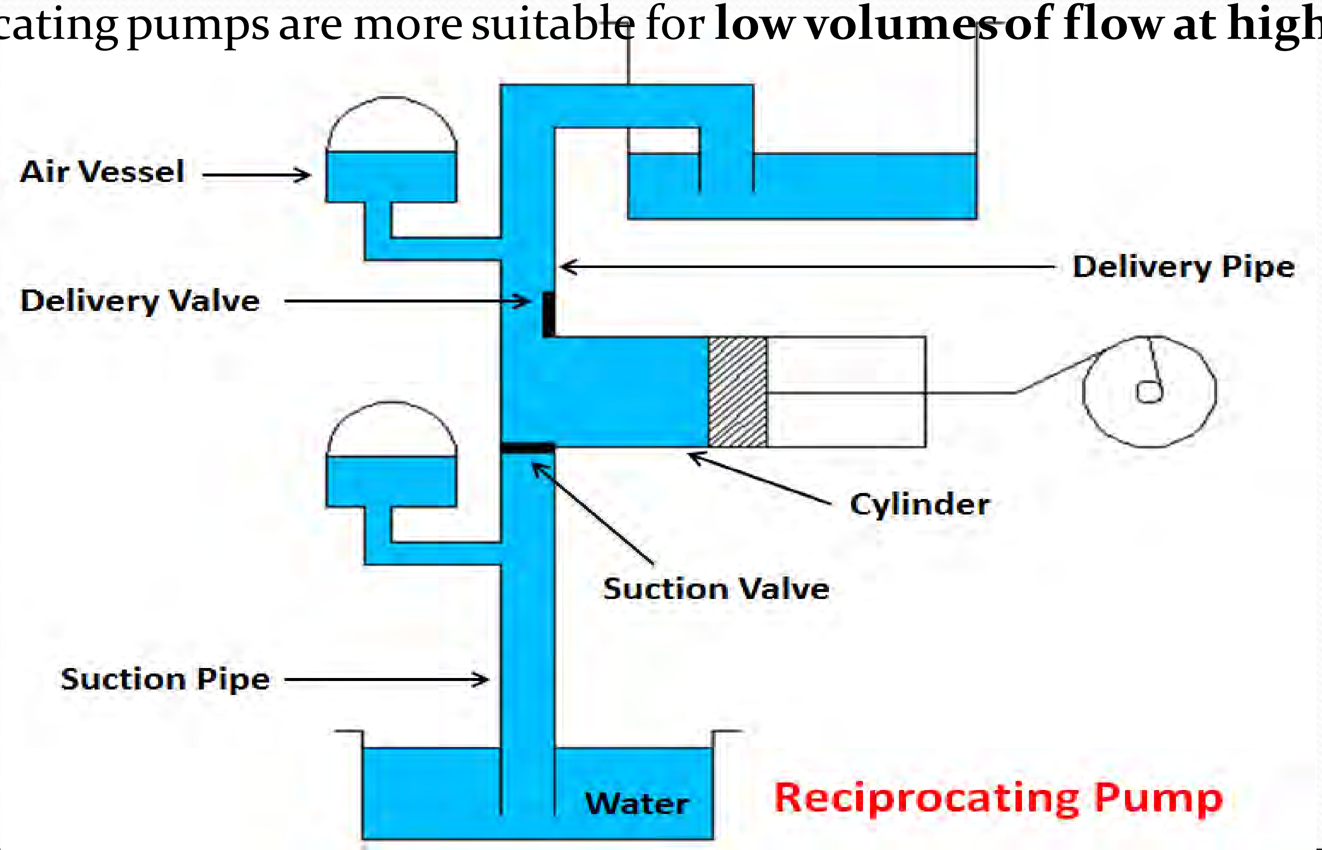
The main reason for priming in the pump is to remove the air from the pump.

If air is not removed from the pump then a small negative pressure is created at the suction pipe and it can not suck the water from the water sump.

So it is advised to fill the pump with water before starting it.

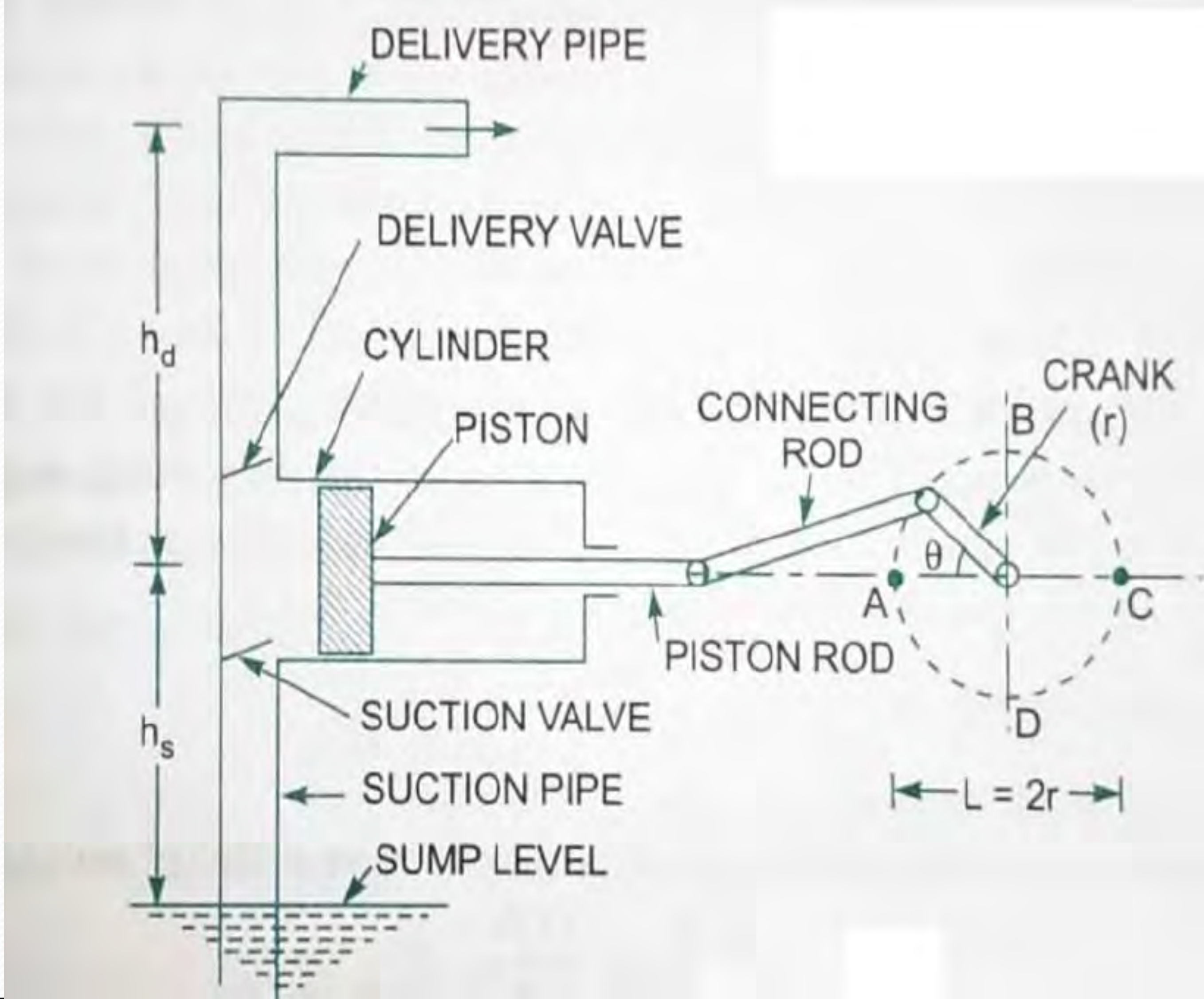
Definition of a Reciprocating Pump:

- A reciprocating pump is a **hydraulic machine which converts the mechanical energy into hydraulic energy.**
- Here a certain volume of liquid is collected in the enclosed volume and is discharged using pressure to the required application.
- Reciprocating pump can be single acting or double acting.
- Reciprocating pumps are more suitable for **low volumes of flow at high pressures.**



A reciprocating pump consists of several parts

- *Suction Pipe*
- *Suction Valve*
- *Delivery Pipe*
- *Delivery Valve*
- *Cylinder*
- *Piston and Piston Rod*
- *Crank and Connecting Rod*
- *Strainer*
- *Air Vessel*



Parts of Reciprocation pump

Suction Pipe:

- It is used to **suck the water from the water reservoir to the cylinder.**
- It connects the inlet of the pump with the water tank.

Suction Valve:

- The suction valve is a **non-return valve which means the only one-directional flow is possible in this** type of valve.
- This is placed between the **suction pipe inlet and the cylinder.**
- During suction of liquid, it is opened and during discharge, it is closed.

Delivery Pipe:

- It is a pipe that is used to deliver the water from the cylinder to the desired location.
- It connects the outlet of the pump to the tank where the water is to be delivered.

Delivery Valve:

- Delivery valve also **non-return valve placed between the cylinder and delivery pipe outlet.**
- It is in a closed position during suction and in opened position during discharging of liquid.

Parts of Reciprocation pump

Cylinder:

- A hollow cylinder made of steel alloy or cast iron.
- An arrangement of **piston and piston rod is inside this cylinder.**

Piston and Piston Rod:

- A piston is a solid type cylinder part which moves backward and forwards inside the hollow cylinder, to perform suction and delivery of liquid.
- Piston rod helps the piston to its **linear motion**.

Crank and Connecting Rod:

- Crank is a **solid circular disc which is connected to the power source like motor**, **engine**, **etc**, **for its** rotation.
- Connecting rod connects the **crank to the piston, as a result, the rotational motion of the crank gets converted into linear motion of the piston.**

Strainer:

- A strainer is provided at the end of the suction pipe to prevent the **entrance of the solids particle** from a water source into the cylinder. Otherwise, solid particle choked the delivery.

Air Vessel:

- Air vessels are connected to both suction and delivery pipes to **eliminate the frictional head and to** give a uniform discharge rate.

Working Principle of a Reciprocating Pump

- This type of pump is consists of a **piston that moves forward and backward in a close-fitting cylinder.**
- The movement of the piston is obtained by connecting the piston rod to crank by means of a connecting rod. The crank is rotated by means of an electric motor.
- Suction and Delivery Pipes with a suction valve and a delivery valve are connected to the **cylinder.**
- The suction and delivery valves are **non return valves, which allow the water to flow in one direction** only.
- The suction valve allows water from the suction pipe to the cylinder and where the delivery valve allows water from the cylinder to the delivery pipe only.
- When the crank starts rotating, the piston moves in the cylinder.

Cont…

- From the given diagram given in previous slide, When a crank is at A, the piston is at the extreme left position in the cylinder. As the crank is rotating from A to C,(θ=0º to 180º) the piston is moving towards the right in the cylinder.
- The movement of the piston towards the right creates a partial vacuum in the cylinder. But on the surface of the liquid in the sump atmospheric pressure is acting, which is more than the pressure inside the cylinder.
- Thus the liquid is forced into the suction pipe from the sump. This liquid opens the suction valve and enters into the cylinder.
- When a crank is rotating from C to A (θ=180º to 360º), the piston from the extreme right position starts moving toward left in the cylinder.
- The movement of the piston towards the left increases the pressure of the liquid inside the cylinder more than the atmospheric pressure.
- Hence the Suction valve closes and the delivery valve opens. The liquid is forced into the delivery pipe and is raised to a Required Height.

Reciprocating pump Types

1. According to Mechanism:

- Single-acting
- Double-acting Reciprocating Pump

2. According to air vessel:

- Pump with air vessel and
- Pump without air vessel.

3. According to Number of cylinders:

- Single cylinder
- Double cylinder and
- Triple cylinder pump.

Reciprocating pump Types

Single-acting Reciprocating pump:

- As the name itself "single" that means there is only one suction and deliver valve, suction and delivery pipe.
- The fluid sucks only in one direction that is suction stroke and it delivers that is called deliver stroke.

Double-acting Reciprocating Pump:

- Here It has two suction and delivers valve, suction and delivery pipe.
- Consider, when the **piston in a cylinder is in between then one suction and a delivery pipe is on one** side(Piston left) and one pipe at another side (piston right).

Pump with air vessel:

- It means a continuous flow of water at a uniform rate. It accumulates water by compressing air in the vessel.

Reciprocating pump Types

Pump without air vessel:

- Pump without air vessel means there is some amount of air present in the water. As per the work requirement at the domestic place, these types of pumps used.

Single Cylinder:

- Here only one cylinder is connected to a shaft.

Double cylinder:

- There is a two-cylinder attached to a single shaft. The main difference from the single-cylinder pump is here there is separate suction and the delivery valve is provided to each cylinder.

Triple cylinder:

- In this pump, there is a three-cylinder connected to it.

Reciprocating Pump Application:

The main application of Reciprocating pump are:

- *Oil drilling operations.*
- *Pneumatic pressure systems.*
- *Light oil pumping.*
- *Feeding small boilers condensate return, etc.*

Reciprocating Pump Advantages:

There are four major advantages of a Reciprocating Pump and those are the following:

- *High pressure is obtained at the outlet.*
- *The priming process is not needed in this pump.*
- *Reciprocating Pump provides high suction lift.*
- *It is also used for air.*

Cont…

Reciprocating Pump Disadvantages:

The major disadvantages of Reciprocating Pumps are:

- *It requires high maintenance, because of more wear and tear of the parts.*
- *Low flow rate (it discharges a low amount of water).*
- *They are heavy and bulky in size.*
- *The initial cost is High.*