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水泵
Pump

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1 Pump Classifications

The pump types most often employed in process plant applications fall into the following classes:
centrifugal, axial, regenerative turbine type, reciprocating, metering and rotary.

There are two categories of pumps under which these classes are grouped:
dynamic pumps and positive displacement pumps.

1.1 Dynamic pumps

- Dynamic pumps include the classes centrifugal and axial. These pumps operate by developing a high liquid velocity and converting the velocity to pressure in a diffusing flow passage.
- In general, they tend to have lower efficiency than positive displacement pumps.
- However, they do operate at relatively high speeds to permit high flow rate in relation to the physical size of the pump.
- Also, dynamic pumps usually have significantly lower maintenance requirements than positive displacement pumps.

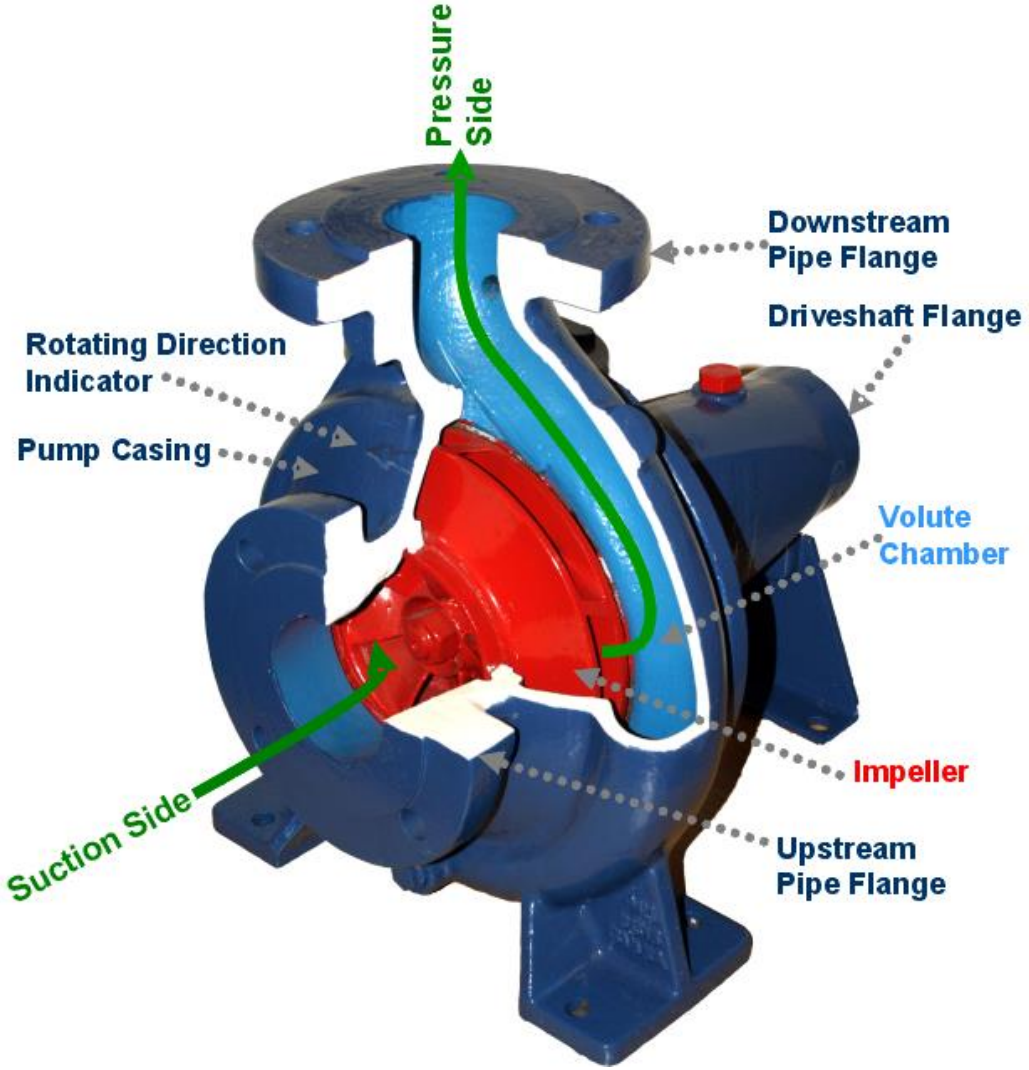
1.2 Positive displacement pumps

- 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. With reciprocating pumps this is performed intermittently.
- In the case of rotary screw and gear pumps it is done continuously.
- This category of pumps operates at lower rotative speeds than dynamic pumps.
- Positive displacement pumps also tend to be physically larger than equal-capacity dynamic pumps.

2 Centrifugal Pumps

- Centrifugal pumps accomplish the generation of pressure by the conversion of velocity head into static head.
- The rotary motion of impellers adds energy to the service fluid in the form of a velocity increase.
- Centrifugal pumps have no valves. The flow is uniform and free of low-frequency pulsations.
- A pump operating at a fixed speed will develop the same theoretical head in feet of flowing fluid, regardless of density.
- However, the pressure corresponding to the developed head depends on the fluid density.

2 Centrifugal Pumps



2.1 Single-Stage Overhung

- This design has a single-stage overhung impeller. Its casing is supported at the centerline.
- Two shaft bearings are mounted close together in the same bearing bracket, with the impeller cantilevered or overhung beyond them.
- This type design usually has top suction and discharge flanges; wearing rings both on the front and back of the impeller and casing; a single suction, closed impeller; and a single stuffing box fitted with a mechanical seal.
- There are also water cooling options on the pedestal, stuffing box and bearings. This pump type is well suited for high-temperature operation and can be used for handling flammable liquids.

2.2 Two-Stage Overhung

- This is simply a modified version of the single-stage process pump. It is capable of higher head than its single-stage counterpart.
- In this style, the stuffing box pressure is roughly halfway between suction and discharge pressures.

2.3 Single-Stage (Impeller-Between-Bearings)

- These designs have their impellers mounted between the bearings and thus have two stuffing boxes.
- Single-stage versions are capable of developing heads up to 330 meters.
- Casings can be axially split for temperatures up to 260℃ and radially split for temperatures up to 455℃.

2.4 Inline Pumps

- These are vertical pumps with casings designed to be bolted directly to piping (similar to a valve).
- There are two basic configurations: coupled and close-coupled.
- Service life and maintenance requirements for both styles are about the same.
- Generally, this type of pump is preferred if the cost of piping associated with installation can be reduced over the conventional horizontal styles.

2.5 High-Speed Centrifugal Pumps

- These pumps are single-impeller models designed for speeds typically in the range of 170 to 280 rps and as high as 400rps. They are capable of heads up 1600 meters. Pumping temperature are limited to about 260℃.
- High-speed pumps tend to have high NPSH requirement due to the sudden velocity increase as the liquid enters the impeller.
- Maintenance requirements for these pumps tend to be higher than for conventional speed, single-stage pumps; however, it is about the same as multistage models, with which they compete for high head services.

2.6 Chemical Pumps

- This class of pumps is designed with casing shapes that are cast in high-cost alloys.
- Casings are more frequently foot supported or bearing bracket supported than centreline supported.
- These pumps are limited to relatively low temperature, pressure and flowrates.

2.7 Slurry Pumps

- Slurry pumps are used in services that have severe conditions of slurry pumping. They have a number of special design features that make them well-suited for this type service:

1. Wide flow passages to avoid clogging;
2. Open/semiopen impellers, which are less sensitive than closed impellers to clogging;
3. Arrangements that break up large particles;
4. Low fluid velocities, as low rotating and peripheral speed are possible;

2.7 Slurry Pumps

- Slurry pumps are used in services that have severe conditions of slurry pumping. They have a number of special design features that make them well-suited for this type service:

5. Adjustable rotor position to restore axial clearance without dismantling the pump; and

6. Replaceable wearing plates and pumping plates on back of impeller, instead of wearing rings, which are subject to erosion

2.8 Canned Pumps

- These are motor pump units with the rotating rotor and impeller housed entirely within a pressure casing.
- This type design eliminates the need for a stuffing box.
- The pumped fluid serves both as a lubricant for bearings and as a coolant for the motor.
- Designs are limited to low-flow, low-pressure and low-temperature service.

2.9 Horizontal and Vertical Multistage Pumps

- Horizontal multistage pumps are limited to about 12 stages due to the difficulty in limiting deflection over the long span between bearings. T
- hey have NPSH requirements that match those of single-stage pumps of the same capacity.
- These pumps are well suited for corrosive fluids handling.

2.9 Horizontal and Vertical Multistage Pumps

- Vertical multistage pumps may have as many as 24 (sometimes more) stages.
- Below roughly 370 meters head, pumps for as low as 0.3 meter NPSH at the suction flange are available.
- High specific speed impellers are frequently used.
- These pumps are sensitive to damage by solids ingestion and by dry or two-phase generating conditions.
- In general, maintenance requirements for vertical multistage pumps are greater than for their horizontal counterparts.

2.10 Regenerative Turbine Pumps

- In general, this type pump greatly resembles a conventional centrifugal pump but has the distinction of a much steeper head-capacity curve.
- The impeller consists of a solid disc with fluted vanes on each side of the perimeter, which impart energy to the liquid by multiple excursions from the impeller to the stator and back to the impeller.
- This type pump is extremely sensitive to dirt, temperature shocks, and to piping forces and moments on the pump flanges.

3 Positive Displacement Pumps

- Positive displacement pumps operate by forcing a fixed volume of liquid from the inlet pressure zone of the pump into the discharge zone of the pump.
- A brief description of each of the major types of positive displacement pumps is given below.

3.1 Reciprocating Pumps

- Reciprocating pumps produce pulsating flow, develop high shutoff or stalling pressure, display constant capacity when motor driven, and are subject to vapour binding at low NPSH conditions.
- There are several construction styles.
- One type, the direct acting steam pump, consists of a steam cylinder end in line with a liquid cylinder end, with a straight rod connection between the steam piston and the pump piston or plunger.

3.1 Reciprocating Pumps

- Another construction style is the power pump.
- Power pumps convert rotary motion to low-speed reciprocating motion via speed reduction gearing, a crankshaft, connecting rods and crossheads.
- Plungers or pistons are driven by the crosshead drives.
- Three or more plungers substantially reduce flow pulsation relative to simplex and even duplex pumps.
- In general, power pumps have high efficiency and are capable of developing very high pressures. They can be driven either by electric motors or turbines

3.2 Metering Pumps

- Metering pumps are positive displacement pumps that provide precision control of very low flow rates.
- Flow rates can range from 1.6×10^{-3} to 0.16 gpm; However, there are some higher-capacity models that provide flows up to 0.66 gpm.
- Flow accuracy is typically within $\pm 1\%$.
- Control schemes for metering pumps are used for controlling the proportioning of additives injected into the main flow stream.
- Other names for these type pumps are “proportioning pumps” and “controlled volume” pumps.

3.3 Diaphragm Pumps (Membrane Pumps)

- This type of positive displacement pump operates by the periodic movement of a flexible diaphragm. It has the advantages of no stuffing boxes and high tolerance to abrasive slurries.
- The diaphragm is flexed by pulsating fluid pressure on the drive side. Compressed air normally is used; however, steam and hydraulic oil systems are also available.
- Drive pressures normally pulsate between 0 and 15 psi (1-105 kPa) above the average discharge pressure level in the process stream.

3.4 Rotary Pumps

- There are a wide variety of rotary pumps on the market; however, liquid services are limited primarily to external gear pumps and screw pumps.
- The single screw pump is a special type of screw pump for handling slurries with relatively large particles.
- This design allows little fracturing of particles and very little abrasion damage to the pump.

3.4 Rotary Pumps

- Single-screw pumps are employed extensively in the food processing and chemical industries for handling solid/liquid mixtures that are either abrasive or require gentle handling of the solid particles.
- The working principle of the screw pump is that of Archimede's screw, invented by the Greek mathematician about 200 BC.
- Screw pump applications include fuel, lube and crude oil service; navy and marine cargo; oil burners; slurry handling; and a variety of high-viscosity materials such as polymers, copolymers and elastomers, syrups, fats and grease, soaps and solvents.

4 Characteristics of Centrifugal Pumps

- The selection of a centrifugal pump for an energy-efficient pumping system requires an understanding of the principles of mechanics and physics that can affect the pumping system and the pumped liquid.
- The efficiency of a centrifugal pump is also dependent on the behavior of the liquids being pumped.
- The principles of centrifugal pump operation that govern head and flow must be understood clearly before pump performance can be evaluated accurately.

4 Characteristics of Centrifugal Pumps

- The behavior of a fluid depends on its state-liquid or gas. Liquids and gases offer little resistance to changes in form.
- Typically, fluids such as water and air have no permanent shape and readily flow to take the shape of the containing enclosure when even a slight shear loading is imposed.
- Factors affecting behavior of fluids include:

1. Viscosity
2. Specific gravity
3. Vapor pressure

4 Characteristics of Centrifugal Pumps

- Liquid viscosity is very important in analyzing the movement of liquids through pumps, piping and valves.
- In piping system, a liquid with a high viscosity has a high energy gradient against which a pump must work, and more power is required than for pumping low-viscosity liquids.

4 Characteristics of Centrifugal Pumps

- **Specific gravity** is the ratio of the density of substance to that of a reference substance at a specified temperature.
- **Vapor pressure** is the pressure at which a pure liquid can exist in equilibrium with its vapor at a specified temperature.

4 Characteristics of Centrifugal Pumps

- Centrifugal pump characteristics remain constant unless an outside influence causes a change in operating conditions. Three conditions can alter pump performance:

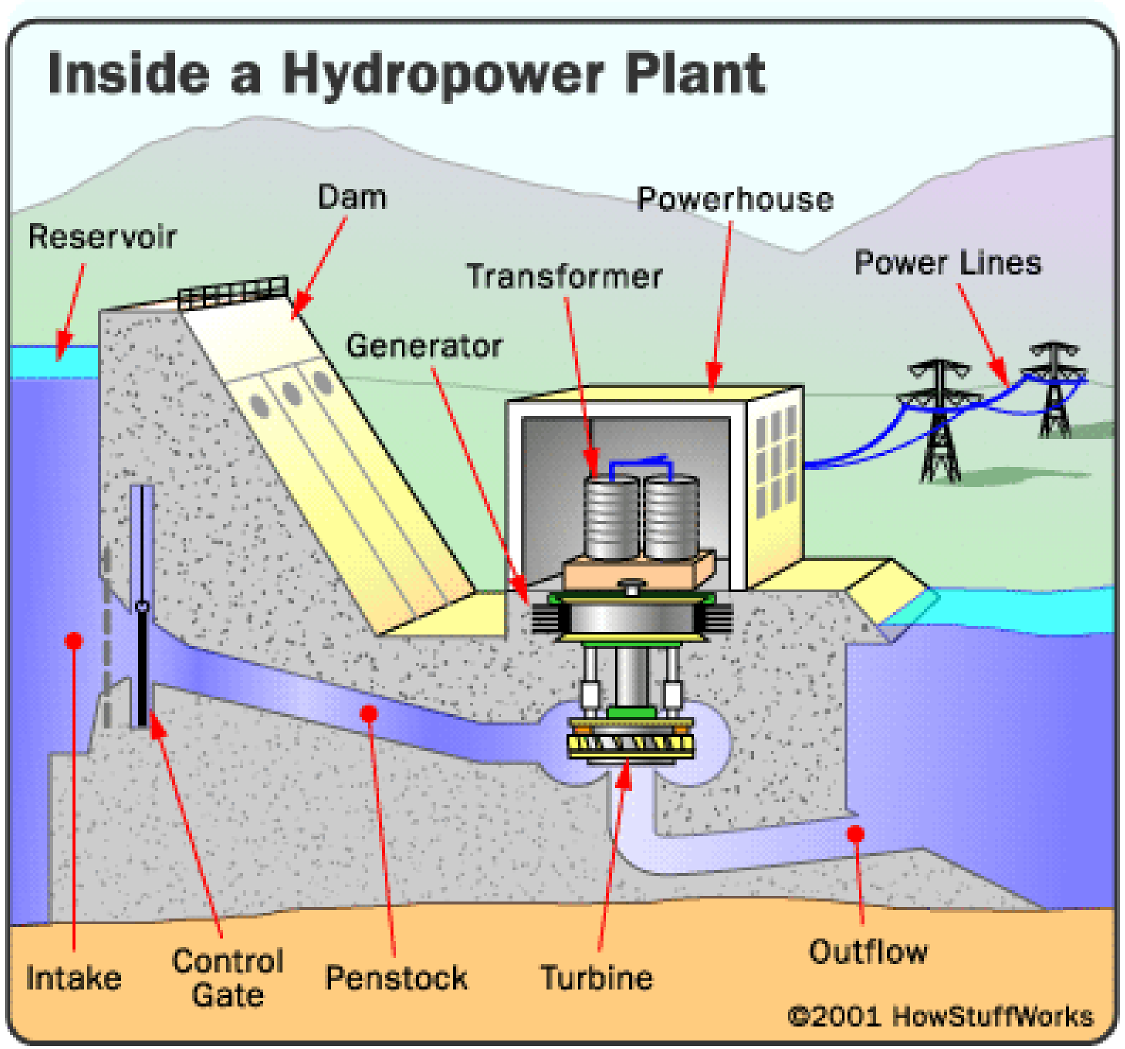
1. changes in impeller or casing geometry;
2. increased internal pumping losses caused by wear; and
3. Variation of liquid properties.

4 Characteristics of Centrifugal Pumps

- Cavitation in a centrifugal pump can be a serious problem.
- Liquid pressure is reduced as the liquid flows from the inlet of the pump to the entrance to the impeller vanes.
- If this pressure drop reduces the absolute pressure on the liquid to a value equal to or less than its vapor pressure, the liquid will change to a gas and form vapor bubbles.
- The vapor bubbles will collapse when the fluid enters the high-pressure zones of the impeller passages.

5 Hydraulic Turbines

- A water/hydraulic turbine is a rotary engine that takes energy from moving water.
- Water turbines were developed in the nineteenth century and were widely used for industrial power prior to electrical grids.
- Now they are mostly used for electric power generation. They harness a clean and renewable energy source.

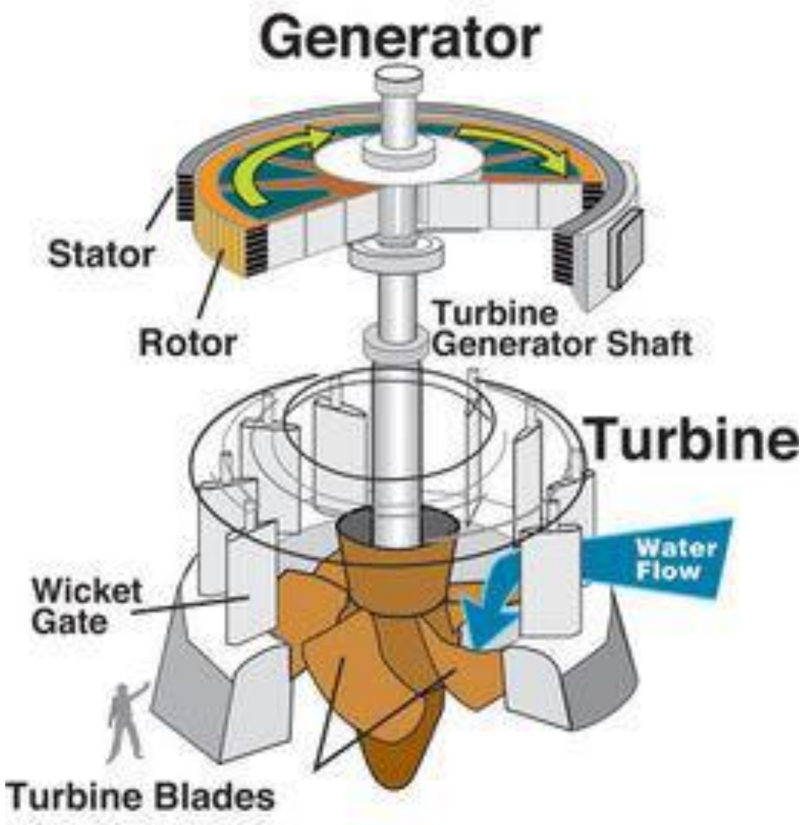


5 Hydraulic Turbines

- The word turbine was introduced by the French engineer Claude Bourdin in the early 19th century.
- The main difference between early water turbines and water wheels is a swirl component of the water which passes energy to a spinning rotor.
- This additional component of motion allowed the turbine to be smaller than a water wheel of the same power.
- They could process more water by spinning faster and could harness much greater heads.

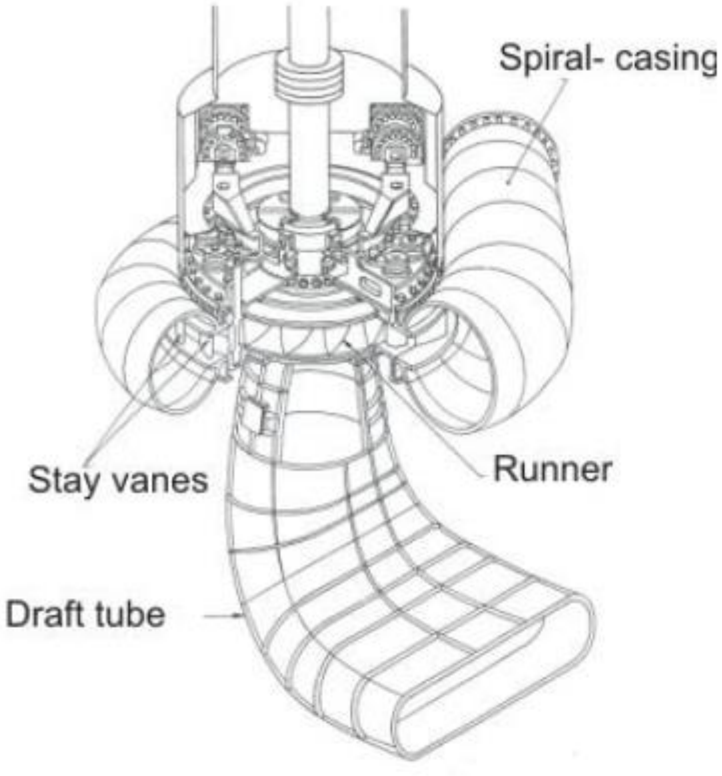
5.1 Theory of Operation

- Flowing water is directed on to the blades of a turbine runner, creating a force on the blades.
- Since the runner is spinning, the force acts through a distance (force acting through a distance is the definition of work).
- In this way, energy is transferred from the water flow to the turbine.
- The precise shape of water turbine blades is a function of the supply pressure of water, and the type of impeller selected.

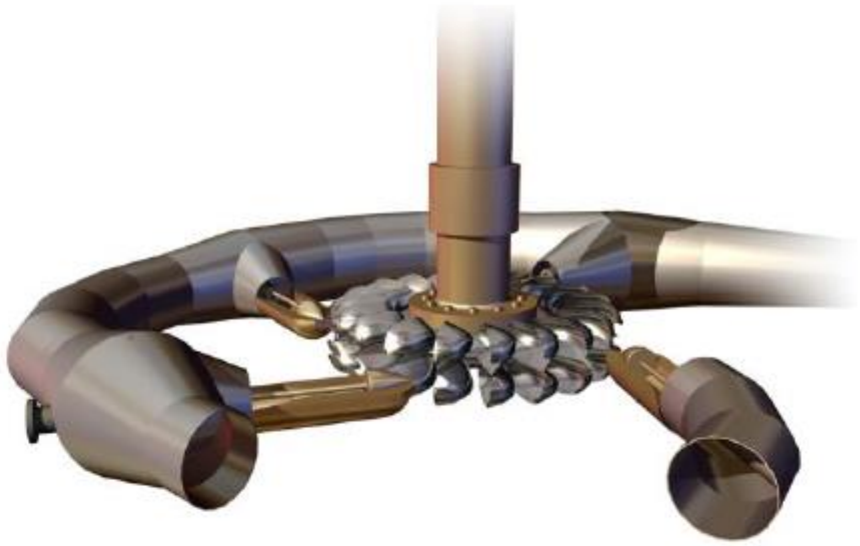


5.2 Types of Hydraulic Turbomachine

➢ Water turbines are divided into two groups:



Reaction turbines



Impulse turbines

5.2.1 Reaction Turbines

- Reaction turbines are acted on by water, which changes pressure as it moves through the turbine and gives up its energy.
- They must be encased to contain the water pressure (or suction), or they must be fully submerged in the water flow.
- Newton's third law describes the transfer of energy for reaction turbines.
- Most water turbines in use are reaction turbines and are used in low <30m and medium 30-300m head applications.
- In reaction turbine, pressure drop occurs in both fixed and moving blades.

5.2.2 Impulse Turbines

- Impulse turbines change the velocity of a water jet. The jet impinges on the turbine's curved blades which change the direction of the flow. The resulting change in momentum causes a force on the turbine blades.
- Since the turbine is spinning, the force acts through a distance (work) and the diverted water flow is left with diminished energy.
- Prior to hitting the turbine blades, the water's pressure (potential energy) is converted to kinetic energy by a nozzle and focused on the turbine.
- No pressure change occurs at the turbine blades, and the turbine doesn't require a housing for operation.

5.2.2 Impulse Turbines

- A Pelton turbine consists of a set of buckets or cups mounted around a hub.
- Pelton turbines are not immersed in water. Instead, a Pelton turbine operates in air with the wheel driven by jets of high pressure water hitting the buckets or cups.
- Kinetic energy of the water jets is transferred to the turbine.

5.2.2 Impulse Turbines

- A type of hydro turbine in which the entire generator is mounted inside the water passageway as an integral unit with the turbine.
- These installations can offer significant reductions in the size of the powerhouse.
- The bulb turbine is a reaction turbine of Kaplan type which is used for extremely low heads.
- The characteristic feature of this turbine is that the turbine components as well as the generator are housed inside a bulb, from which the name is developed.

5.2.2 Impulse Turbines

- The Kaplan turbine is a propeller-type water turbine that has adjustable blades.
- It was developed in 1913 by the Austrian professor Viktor Kaplan.
- The Kaplan turbine was an evolution of the Francis turbine.
- Its invention allowed efficient power production in low-head applications that was not possible with Francis turbines.
- Kaplan turbines are now widely used throughout the world in high-flow, low-head power production.

5.2.2 Impulse Turbines

- The Francis turbine is a type of water turbine that was developed by James B. Francis.
- It is an inward flow reaction turbine that combines radial and axial flow concepts.
- Francis turbines are the most common water turbine in use today.
- They operate in a head range of ten meters to several hundred meters and are primarily used for electrical power production.

5.2.2 Impulse Turbines

- Very tiny amounts of electrical energy can be stored in capacitors.
- These are extensively used in electronic circuits, but are impractical to store large quantities of energy.
- The only alternative is to convert electricity into another form of energy, which can be stored easily.
- It must also be possible to reconvert the stored energy back into electricity, when it is required.
- The most widely used method is to store electricity as hydro energy in pumped Hydro Storage schemes.