6 WATER TURBINES

hydraulic machine that converts the hydraulic energy into mechanical energy is called *turbine*, while the machine that converts the mechanical energy into hydraulic energy s called a *pump*. A water turbine is a rotary engine that takes energy from moving water.

lassification of water turbines

The classifications of water turbines are as follows:

1. *According to the type of energy at inlet:*
   (i) Impulse or velocity turbine, and
   (ii) Reaction or pressure turbine
2. *According to the direction of flow of water through runner:*
   (i) Tangential flow turbine,
   (ii) Radial flow turbine,
   (iii) Axial flow turbine, and
   (iv) Mixed flow turbine.
3. *According to the available water head at inlet:*
   (i) High head turbine,
   (ii) Medium head turbine, and
   (iii) Low head turbine.

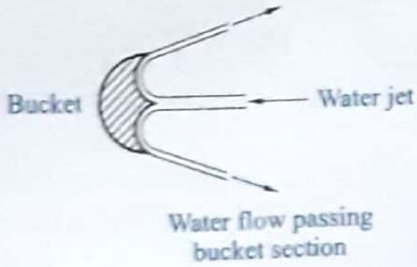
Impulse turbine

In impulse turbine, the water's potential energy (pressure) is converted to kinetic energy by a nozzle and the jet of water is directed on the turbine's curved blades which reverse the flow. The resulting impulse spins the turbine and leaves the fluid flow with diminished kinetic energy. Newton's second law describes the transfer of energy for impulse turbine. No pressure change occurs at the turbine blades.

Pelton wheel

Pelton wheel is a tangential flow impulse turbine, water flows along the tangent to the path of the runner. It operates under a high head of water and therefore requires a comparatively less quantity of water. Water is conveyed from the reservoir to the turbine through a *penstock*. The penstock is connected to a branch pipe fitted with a nozzle. A powerful jet issue out of the nozzle, impinges on the buckets provided on the periphery of a wheel as shown in fig. 6.1. The shape of the bucket is that of a double hemispherical cup having dividing wall known as splitter at the center. The splitter

Pelton wheel



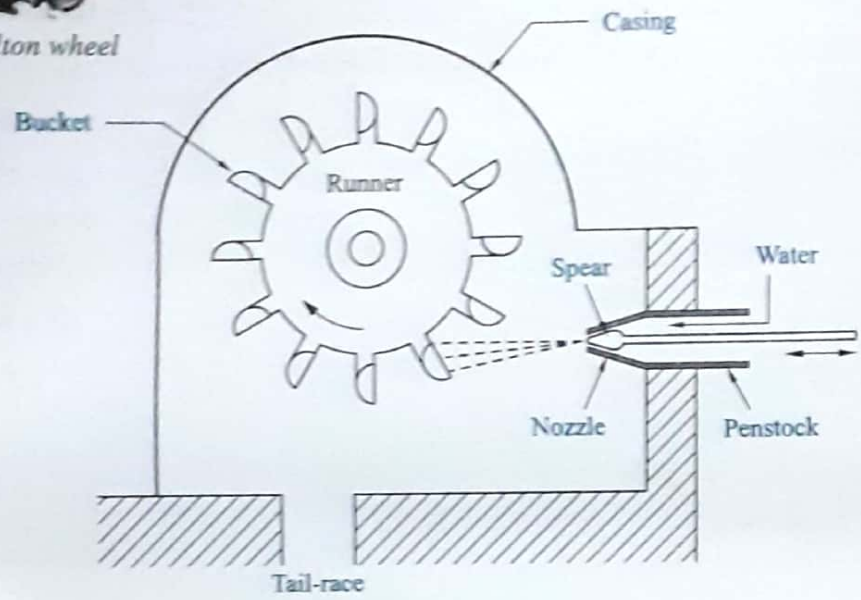


Fig. 6.1 Pelton wheel

divides the impinging jet into two halves, which are deflected backward. As there is no pressure variation in flow, the fluid partly fills the buckets, and it remains in contact with the atmosphere. The nozzle is provided with a spear mechanism to control the quantity of water. The actual energy transfer from jet to wheel is by changing the momentum of the stream. The water after imparting its energy to the turbine is discharged into the tail-race.

Reaction turbine

Reaction turbines are acted on by water, which changes pressure as it moves through the turbine. The change in fluid velocity and reduction in its pressure causes a reaction on the turbine blades. They must be enclosed in an air tight casing to contain the water pressure or they must be fully submerged in the water flow. Newton's third law describes the transfer of energy for reaction turbines. The turbine is located between the high pressure water source and the low pressure water exit, usually at the base of a dam.

Most water turbines in use are reaction turbine. They are used in low and medium head applications. Francis turbine and Kaplan turbine are the examples of reaction turbine.

Francis turbine

In Francis turbine, water flow radially into the turbine and exists the turbine axially. It is suitable for intermediate heads and intermediate rates of flow. Some smaller machines of this type have horizontal shafts, the majorities have vertical shafts as shown in fig. 6.2. The fluid enters a volute casing which completely surrounds the runner. The cross sectional area of the volute decreases along the fluid path in such a way as to keep the fluid velocity constant in magnitude. From the volute, the fluid passes between stationary guide vanes called *wicket gates* mounted all around the periphery of the runner. The function of these guide vanes is to direct the fluid on to the runner at required angle. This radial flow acts on the runner vanes, causing the runner to spin. The guide vanes may be adjusted to alter the flow rate through the machine. In its passage through the runner, the runner blades deflect the fluid so that its angular momentum is changed. From the center of the runner the fluid is turned into the axial direction and flows to tail-race via the *draft tube*. The lower end of the draft tube must, under all conditions of operation, be submerged below the level of water in the tail-race. Only in this way can it be ensured that a hydraulic turbine is full of water.

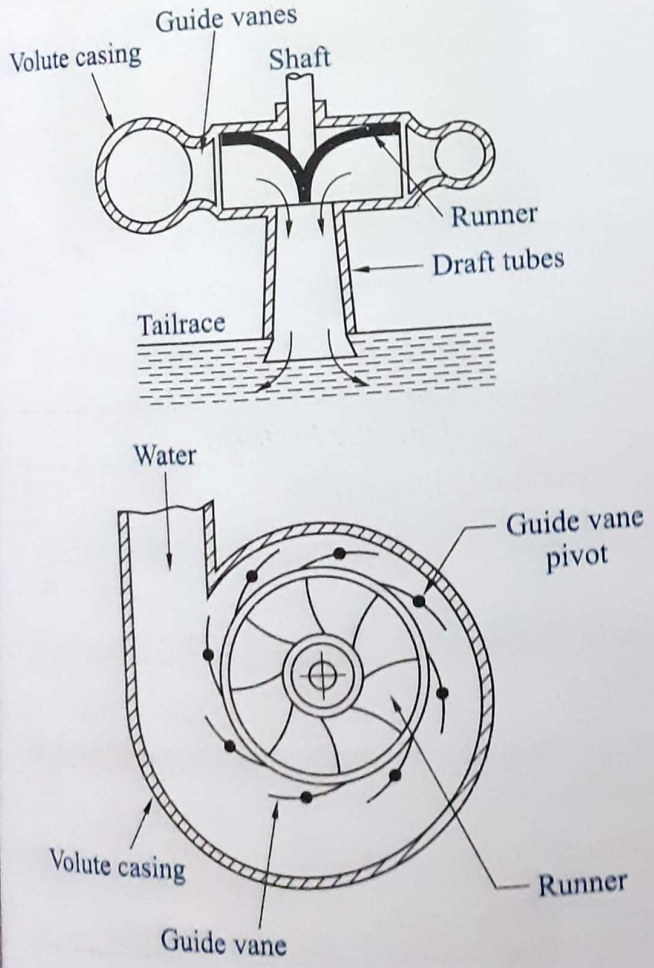


Fig. 6.2 Francis turbine

Francis turbine runner

A draft tube has gradual increase in cross-sectional area. The velocity of water at the runner outlet is very high. By employing a draft tube, a part of the kinetic energy that was going as a waste is recovered as a gain in the pressure head and this increases the overall efficiency of the turbine.

Kaplan turbine

Axial flow turbine is used for low heads, at high rotational speeds and large rates of flow. Kaplan turbine is an axial flow reaction turbine having a small number of blades, usually from four to six and closely resembles a ship's propeller. The blade angle may be varied by turning the blades about their own axes. The turbine is enclosed in a spiral casing which receives water from the mains. From the casing the water is directed to the runner blades by guide vanes. The arrangement of guide vanes is similar to that of a Francis turbine. When both guide vane and runner blade angle may thus be varied, a high efficiency can be maintained over a wide range of operating conditions. Kaplan turbine operates in an entirely closed conduit from inlet to tail-race as shown in fig. 6.3.

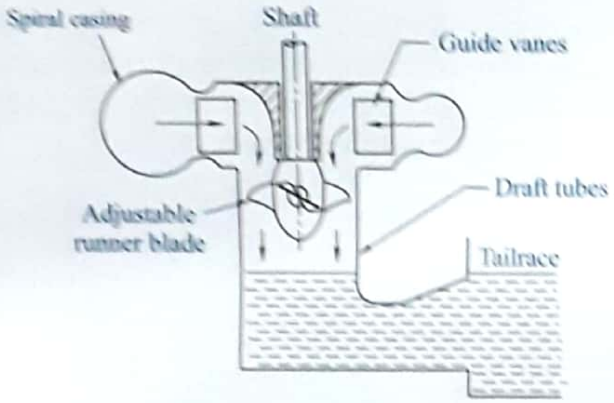
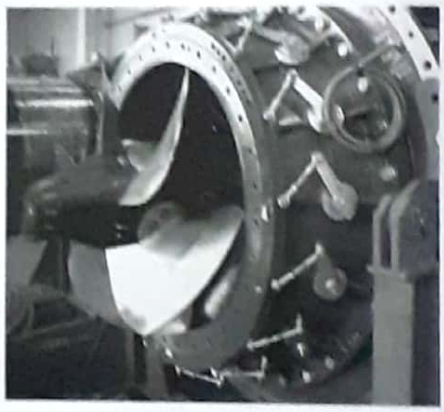


Fig. 6.3 Kaplan turbine



Kaplan turbine runner

Differences between Francis and Kaplan turbines

Francis turbine	*Kaplan turbine*
1. It is a mixed flow turbine	It is an axial flow turbine
2. Suitable for intermediate heads and intermediate flow rates	Suitable for low heads and large flow rates
3. More number of blades on the runner (16 to 24)	Smaller number of blades on the runner (4 to 6)
4. Guide vanes are used to regulate the flow	Guide vanes and runner blades are used to regulate the flow
5. Free from cavitation	Cavitation may exist
6. Requires large space	Requires less space

Differences between impulse and reaction water turbines

Impulse turbine	*Reaction turbine*
1. There is no pressure change of the fluid in the turbine rotor blades	The pressure of the water changes as it passes through the turbine rotor blades
2. The entire water energy is converted into kinetic energy	No energy conversion
3. Workdone is by the change in kinetic energy of the jet	Work done is partly by the change in the velocity head and almost entirely by the change in pressure head
4. The water flows through the nozzle and impinges on the buckets	The water is guided by the guide blades to flow over the moving vanes
5. Draft tube is not necessary	Draft tube is necessary
6. Newton's second law describes the transfer of energy	Newton's third law describes the transfer of energy

Choose the correct answer:

1. A water turbine is a device which converts
   (a) Hydraulic energy into electrical energy
   (b) Hydraulic energy into mechanical energy
   (c) Mechanical energy into hydraulic energy
   (d) Electrical energy into mechanical energy

2. A turbine is called impulse, if the total energy at the inlet is
   (a) Pressure energy (b) Kinetic energy
   (c) Sum of pressure and kinetic (d) None of the above

3. A turbine is called reaction, if the total energy at the inlet is
   (a) Kinetic energy (b) Pressure energy
   (c) Kinetic and pressure energy (d) None of the above

4. A Pelton wheel is
   (a) Radial flow impulse turbine (b) Axial flow reaction turbine
   (c) Mixed flow turbine (d) Tangential flow impulse turbine

5. The pipe which carries water from reservoir to turbine is
   (a) Tailrace (b) Penstock (c) Headrace (d) Surge tank

6. Flow of water through the runner, parallel to axis of rotation is known as
   (a) Tangential flow (b) Radial flow (c) Axial flow (d) Mixed flow

7. An impulse turbine is used for
   (a) Low head of water (b) Medium head of water
   (c) High head of water (d) Any one of these
8. An example for tangential flow turbine is,
   (a) Pelton wheel (b) Kaplan turbine
   (b) Thomson turbine (d) Modern Francis turbine
9. Pelton wheel is ideally suited for
   (a) High head and low discharge (b) High head and high discharge
   (b) Low head and low discharge (d) Medium head and medium discharge
10. A draft tube is used with
    (a) Impulse turbine (b) Pelton wheel
    (c) Francis turbine (d) Water wheel
11. A draft tube converts
    (a) Pressure energy into kinetic energy
    (b) Velocity head into pressure head
    (c) Potential head into pressure head
    (d) Kinetic energy into mechanical energy
12. Francis turbine is best suited for
    (a) Medium head of water (b) High head of water
    (c) Low head of water (d) All types of heads
13. Wicket gates are used in
    (a) Water wheel (b) Pelton wheel (c) Francis turbine (d) Kaplan turbine
14. Francis turbine is ------ turbine
    (a) Impulse (b) Reaction (c) Both (d) None
15. The movable wicket gates of a reaction turbine are used to
    (a) Control the flow of water passing through the turbine
    (b) Control the working pressure
    (c) Control the velocity of flow
    (d) Reduce the size of the turbine
16. Kaplan turbine is used for
    (a) Low head and low flow rate (b) Low head and high flow rate
    (c) High head and high flow rate (d) High head and low flow rate

Review questions

1. Define the term hydraulic turbine.
2. How are turbines classified?
3. Define the term impulse turbine and reaction turbine.
4. Describe a Pelton wheel with suitable sketch.
5. Why is a Pelton wheel suitable for high heads only?
6. Describe Francis turbine with suitable sketch.
7. Describe Kaplan turbine with suitable sketch.
8. Why draft tube is used in reaction turbine?
9. Differentiate between: (i) Impulse and reaction turbines and (ii) Radial and axial flow turbines.
10. How are water turbines classified? What is the speciality of Kaplan turbine ? (VIT, Jan 2004)
11. Sketch and explain the working of Pelton wheel. (VIT, July 2004)
12. Sketch and explain the working principle of Francis turbine. (VTU, July 2004)
13. Sketch and explain the working principle of Kaplan turbine. (VTU, Feb 2005)
14. Differentiate between impulse and reaction water turbines. (VTU, July 2009)
15. With a neat sketch, explain the construction and working of a Kaplan turbine. What are its advantages and disadvantages? (VTU, June 2010)
16. List the important parts of a Pelton wheel and explain their functions. (VTU, Dec. 2011)
17. Define radial flow, axial flow and mixed flow water turbine. (VTU, July 2013)