5.1 INTRODUCTION

Hydraulic machine are defined as those machines which converts either hydraulic energy (energy possessed by water) into mechanical energy (which is further converted into electrical energy) or mechanical energy into hydraulic energy.

The hydraulic machines which converts the hydraulic energy into mechanical energy are called turbines while the hydraulic machines which convert the mechanical energy into hydraulic energy are called pumps. Thus, the study of hydraulic machines consists of study of turbines and pumps. Turbines consists of mainly study of Pelton turbine, Francis turbine and Kaplan turbine while pump consist of study of centrifugal pump and Reciprocating pumps.

5.2 LAYOUT OF A HYDROELECTRIC POWER PLANT

Figure 1 shows a general layout of a hydroelectric power plant, consists of:

(i) A dam is constructed across a river to store water.

(ii) Pipes, made of steel or reinforced concrete, of large diameter called penstocks, which carry water under pressure from the storage reservoir to the turbine.

(iii) Turbines having different types of vanes fitted to the wheels.

(iv) Tail race which is a channel which carries water away from the turbines after the water has worked on the turbines. The surface of water in the tail race is also known as tail race.

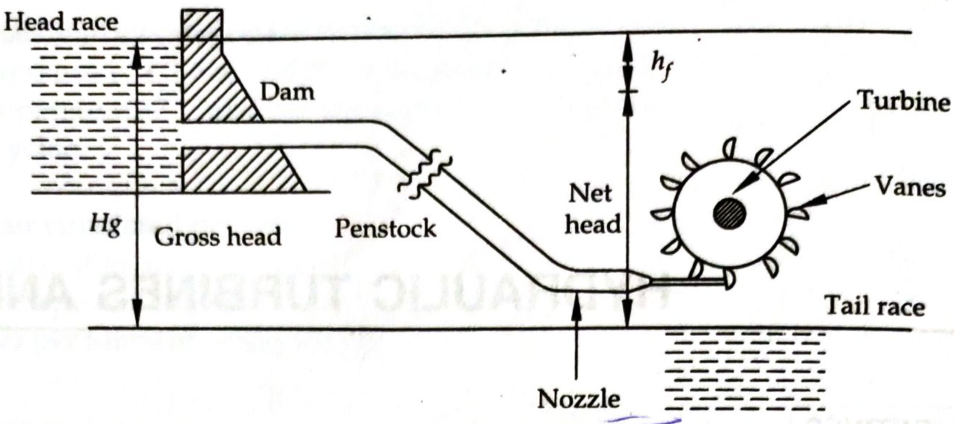


Fig. 1

Gross Head: The difference between head race level and tail race level when no water is flowing is known as Gross Head. It is denoted by *Hg*.

Net Head: Head available at the inlet of the turbine

$$H = Hg - h_f$$

where $h_f = \dfrac{4 \times f \times L \times V^2}{D \times 2g}$

V = Velocity of flow in penstock

L = Length of penstock.

D = Diameter of penstock.

5.3 CLASSIFICATION OF HYDRAULIC TURBINES

Turbines may be classified in the following manners:

1. According to the hydraulic action
2. According to the direction of flow of water in runner.
3. According to the head.
4. According to the specific speed.
5. According to the Inventor's name.
6. According to the position of the main shaft.

1. According to the hydraulic action: According to the hydraulic action, turbine may be classified as:

(a) Impulse Turbine (b) Reaction Turbine.

(a) *Impulse Turbine*: If the water possesses only kinetic energy at the inlet of the turbine, the turbine is known as Impulse Turbine.

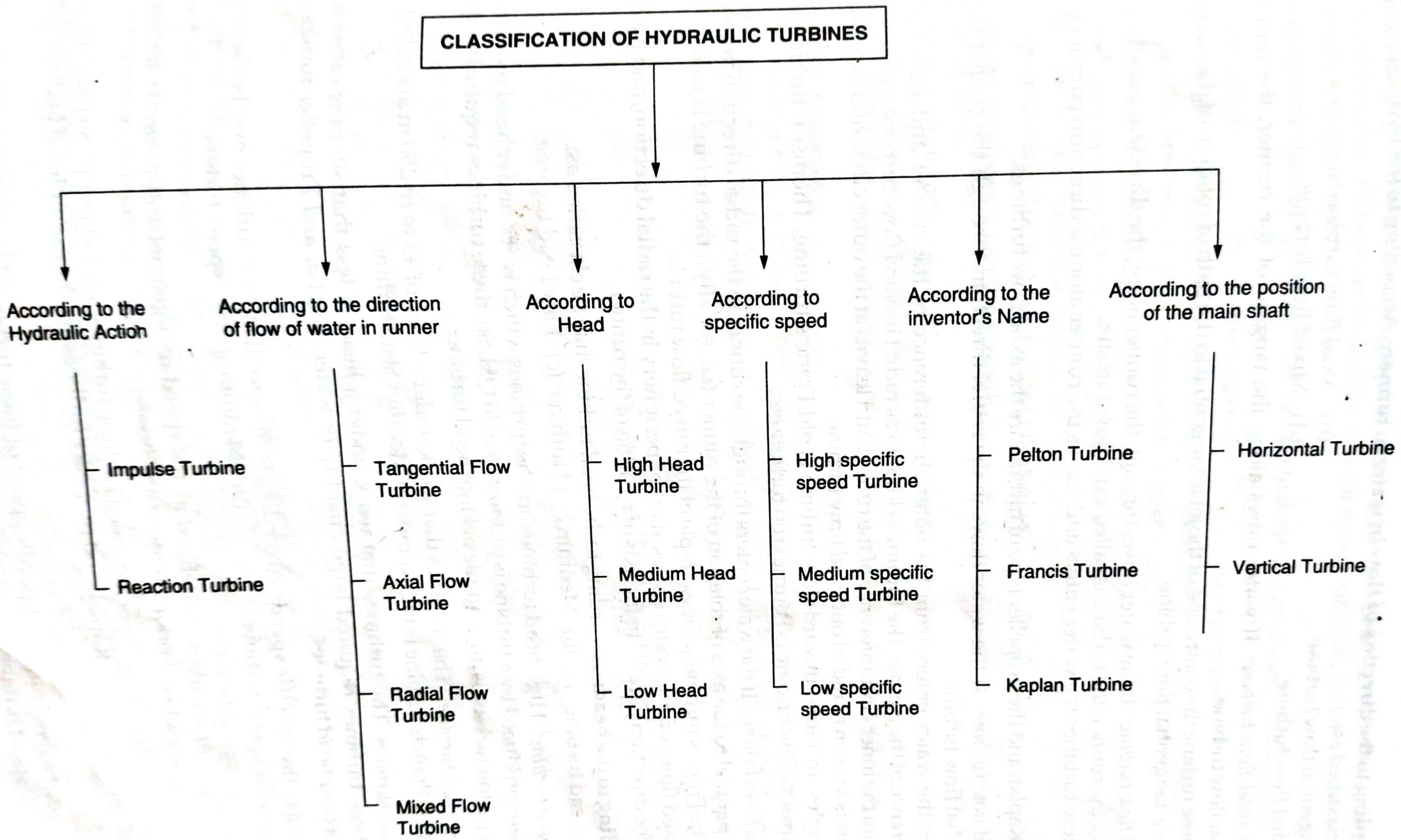
In case of impulse turbines the available hydraulic energy is first converted into kinetic energy by means of nozzles. So that the energy available at the inlet of the turbine is only kinetic energy. The high velocity jet from nozzle strikes a series of buckets fixed on the rotor shaft. It will move buckets and ultimately shaft rotates. These turbines have no effect of pressure change as it works at atmospheric pressure. Examples of impulse turbine are pelton wheel.

(b) *Reaction Turbine:* If the water possesses kinetic energy as well as pressure energy at the inlet of turbine, the turbine is known as reaction turbine.

In case of reaction turbine some part of the total available hydraulic energy is converted into kinetic energy, and the remaining part still remains in form of pressure energy. Thus, at the inlet of the turbine the water possesses both kinetic energy as well as potential energy.

As the water flow through the runner, the water is under pressure and the pressure energy goes on changing into kinetic energy.

The examples of reaction turbines are Francis turbine, Kaplan turbine, Propeller turbine. etc.


CLASSIFICATION OF HYDRAULIC TURBINES
According to the Hydraulic Action
Impulse Turbine
Reaction Turbine
According to the direction of flow of water in runner
Tangential Flow Turbine
Axial Flow Turbine
Radial Flow Turbine
Mixed Flow Turbine
According to Head
High Head Turbine
Medium Head Turbine
Low Head Turbine
According to specific speed
High specific speed Turbine
Medium specific speed Turbine
Low specific speed Turbine
According to the inventor's Name
Pelton Turbine
Francis Turbine
Kaplan Turbine
According to the position of the main shaft
Horizontal Turbine
Vertical Turbine

2. According to the direction of flow in water in runner: According to the hydraulic action, turbine may be classified as:

(a) Tangential flow turbine
(b) Axial flow turbine
(c) Radial flow turbine
(d) Mixed flow turbine

(a) Tangential flow turbine: If water flows along the tangent of the runner, the turbine is called tangential flow turbine.

In these turbine the centre line of the jet is tangential to the path of rotation of the runner. A pelton turbine is a tangential flow turbine.

(b) Axial flow turbine: If the water flows through the runner along the direction parallel to the axis of rotation of the runner, the turbine is called axial flow turbine.

In these turbines the water enters and leaves the runner along a direction parallel to the axis of the shaft.

The Kaplan and the propeller type of turbine are the axial flow turbines.

(c) Radial flow turbine: If the water flows in the radial direction through the runner the turbine is called radial flow turbine.

When the water enters from the outer circumference of the runner and leaves at the inner circumference of the runner, the turbine is known as radial inward flow turbine and when the water enters from the inner circumference of the runner and leaves at the outer circumference of the runner, the turbine is known as radial outward flow turbine.

Examples for radial inward flow turbine is old Francis turbine, Thomson turbine etc. and for Radial outward flow turbine is Fourneyron turbine etc.

(d) Mixed flow turbine: If the water enters through the runner in the radial direction but leaves in the direction parallel to the axis of rotation of the runner (*i.e.* Axially), the turbine is called mixed flow turbine. The Francis turbine is the example of the mixed flow turbine.

In mixed flow turbine water enters at outer periphery in the radial direction, and leaves it at the centre in the direction parallel to the axis of rotation of the runner.

3. According to the head: According to the head turbine may be classified as:

(a) High head turbine
(b) Medium head turbine
(c) Low head turbine

(a) High head turbine: High head turbines are the turbines which work under head more than 250 m. As the power produced by a turbine is proportional to QH. So, these turbines require less quantity of water. The pelton turbine is an example of High head turbine.

(b) Medium head turbine: The turbines that work under a head of 45 m to 250 m are called medium head turbines. Francis turbine is the example of Medium head turbine.

(c) Low head turbine: The turbines that work under a head of less than 45 m is called low head turbine. These turbines required large quantity of water. Kaplan and Propeller turbines are the examples of Low head turbines.

4. According to the specific speed: According to the specific speed, turbines may be classified as:

(a) High specific speed turbine
(b) Medium specific speed turbine
(c) Low specific speed turbine.

Specific speed of a turbine is defined as the speed of a geometrically similar turbine which produce a unit power when working under a unit head.

(a) High specific speed turbine: Specific speed of these turbines are 250 to 850. So these are called as high specific speed turbines. Kaplan and propeller turbines are the examples of high specific speed turbines.

(b) Medium specific speed turbine: Specific speed of these turbines are 50 to 250. So these are called medium specific speed turbine. Francis turbine is the example of medium specific speed turbine.

(c) Low specific speed turbine: Specific speed of these turbines are 8 to 30 with single nozzle and up to 50 with multi nozzles. So these are called low specific speed turbines. Pelton turbine is the example of low specific speed turbine.

5. **According to the inventor's Name:** According to the inventor's Name, turbines may be classified as:

(a) Pelton turbine (b) Francis turbine (c) Kaplan turbine.

(a) Pelton turbine: It is named in honour of Allen Pelton (1829 – 1908) of California (USA), is an impulse type of turbine used for high head and low discharge.

(b) Francis turbine: It is named in honour of James Bichens Francis (1815 – 1892) who was born in England and later went to USA, is a reaction type of turbine for medium head and medium discharge.

(c) Kaplan turbine: It is named in honour of Victor Kaplan (1876 – 1934) of Bruenn (Germany) is a reaction type of turbine for low head and large discharge.

6. **According to the position of the main shaft:** According to the position of the main shaft, turbines may be classified as:

(a) Horizontal shaft turbines (b) Vertical shaft turbines

(a) *Horizontal shaft turbine*: Pelton turbines usually have horizontal shaft.

(b) *Vertical shaft turbine*: Turbines except Pelton turbine all are vertical shaft turbines.

5.4 PELTON TURBINE

A pelton turbine is shown in Fig. 2. Pelton turbine is a tangential flow impulse turbine. The water strikes the bucket along the tangent of the runner. The energy available at the intel of the turbine is only kinetic energy.

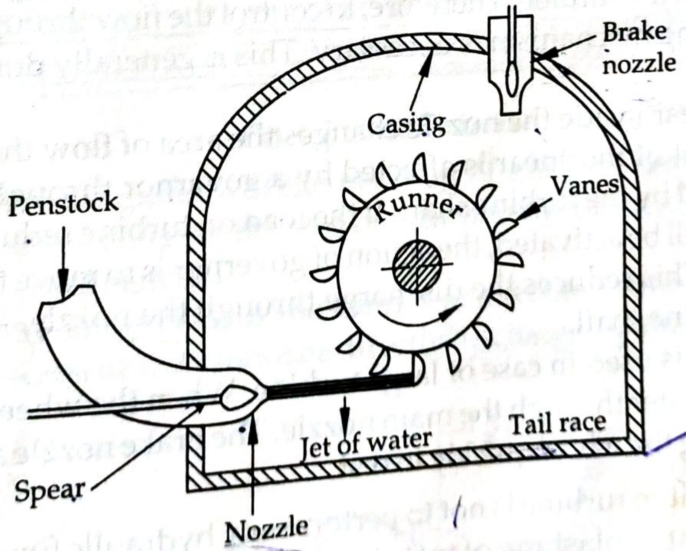


Fig. 2 Pelton Turbine

Water from the reservoir is brought to the turbine through penstocks, at the end of which a nozzle is fitted. The nozzle converts whole of the available head into the kinetic head in the form of a high velocity jet. The jet strikes the buckets mounted on the rim of a wheel called *runner*. The force of jet causes the runner to rotate and mechanical power is produced. In the end, the water goes to the tail race.

Number of nozzles depends upon specific speed. However, maximum number of nozzles can be up to 6.

Components of a pelton turbine

(1) *Runner with Bucket*: The runner of a pelton turbine consists of a number of double cupped buckets