

Name of Faculty: Dr. Yogesh Dewang

Designation: Associate Professor

Department: Mechanical Engineering

Subject: Turbomachinery (ME-603-A)

Unit:3

Topic: Introduction to Hydraulic

Turbines (Turbines, Classification,

Radial flow turbines, Axial flow

turbines)

INTRODUCTION TO HYDRULIC TURBINES

(Turbines, Classification, Radial flow turbines, Axial flow turbines)

- A hydraulic machine is a device in which mechanical energy is transferred from the liquid flowing through the machine to its operating member (runner, piston and others) or from the operating member of the machine to the liquid flowing through it.
- Hydraulic machines in which, the operating member receives energy from the liquid flowing through it and the inlet energy of the liquid is greater than the outlet energy of the liquid are referred as hydraulic turbines.
- Hydraulic machines in which energy is transmitted from the working member to the flowing liquid and the energy of the liquid at the outlet of the hydraulic machine is less than the outlet energy are referred to as pumps.
- It is well known from Newton's Law that to change momentum of fluid, a force is required. Similarly, when momentum of fluid is changed, a force is generated.

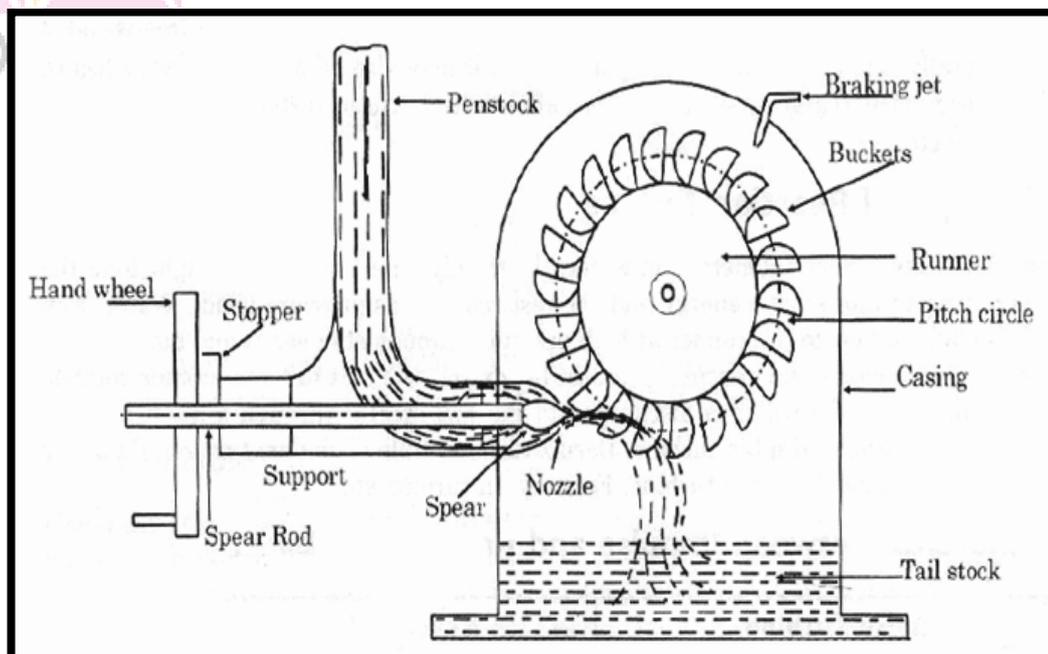
This principle is made use in hydraulic turbine.

- In a turbine, blades or buckets are provided on a wheel and directed against water to alter the momentum of water. As the momentum is changed with the water passing through the wheel, the resulting force turns the shaft of the wheel performing work and generating power.
- A hydraulic turbine uses potential energy and kinetic energy of water and converts it into usable mechanical energy. The mechanical energy made available at the turbine shaft is used to run an electric power generator which is directly coupled to the turbine shaft.

- The electric power which is obtained from the hydraulic energy is known as Hydro- electric energy. Hydraulic turbines belong to the category of rotor dynamic machinery.
- The hydraulic turbines are classified according to type of energy available at the inlet of turbine, direction of flow through vanes, head at the inlet of the turbines and specific speed of the turbines.

According to the type of energy at inlet:

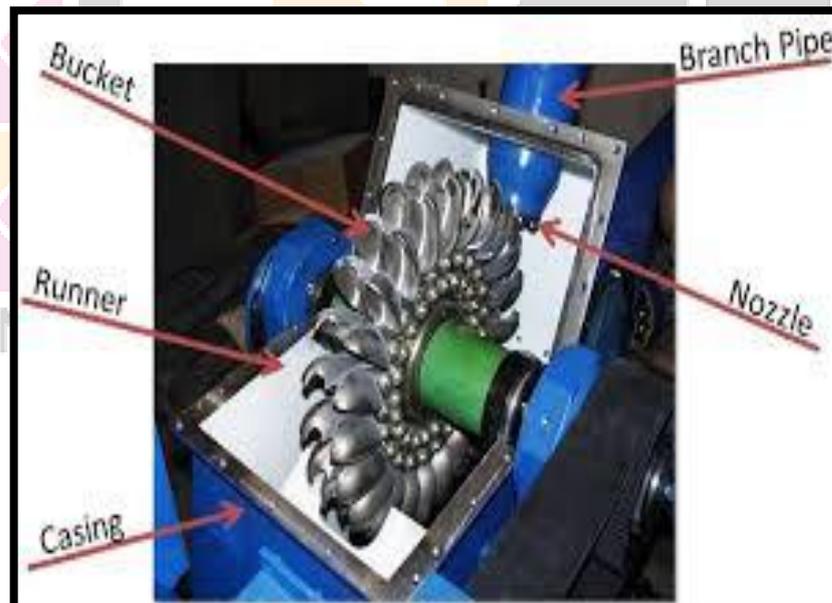
- **Impulse turbine:** - In the impulse turbine, the total head of the incoming fluid is converted in to a large velocity head at the exit of the supply nozzle. That is the entire available energy of the water is converted in to kinetic energy. Although there are various types of impulse turbine designs, perhaps the easiest to understand is the Pelton wheel turbine. It is most efficient when operated with a large head and lower flow rate.



(a)



(b)



(c)

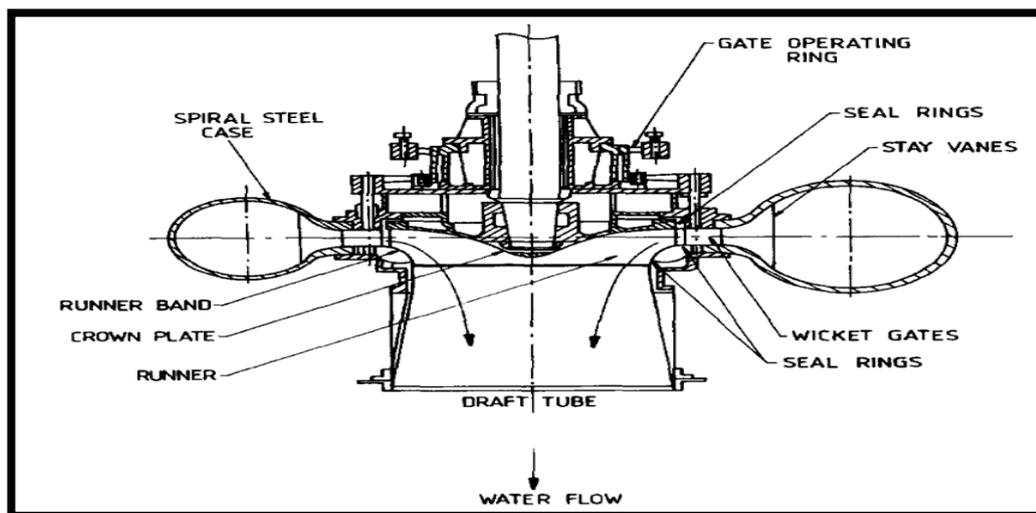
Figure 1. Pelton Wheel Turbine (a) Main parts (b) runner design (c) actual turbine

- **Reaction turbine:** Reaction turbines on the other hand, are best suited -for higher flow rate and lower head situations. In this type of turbines, the rotation of runner or rotor (rotating part of the turbine) is partly due to impulse action and partly due to change in pressure over the runner blades; therefore, it is called as reaction turbine. For, a reaction turbine, the penstock pipe feeds water to a row of

fixed blades through casing. These fixed blades convert a part of the pressure energy into kinetic energy before water enters the runner. The water entering the runner of a reaction turbine has both pressure energy and kinetic energy. Water leaving the turbine is still left with some energy (pressure energy and kinetic energy). Since, the flow from the inlet to tail race is under pressure, casing is absolutely necessary to enclose the turbine. In general, Reaction turbines are medium to low-head, and high-flow rate devices. The reaction turbines in use are Francis and Kaplan turbines.



(a)



(b)

Figure 2 . Francis Turbine (a) Working model (b) Cross-sectional view

According to the direction of flow through runner:

- Tangential flow turbines: In this type of turbines, the water strikes the runner in the direction of tangent to the wheel. Example: Pelton wheel turbine.
- Radial flow turbines: In this type of turbines, the water strikes in the radial direction. accordingly, it is further classified as,
 - a. Inward flow turbine: The flow is inward from periphery to the centre (centripetal type). Example: old Francis turbine.
 - b. Outward flow turbine: The flow is outward from the centre to periphery (centrifugal type). Example: Fourneyron turbine.
- Axial flow turbine: The flow of water is in the direction parallel to the axis of the shaft. Example: Kaplan turbine and propeller turbine.
- Mixed flow turbine: The water enters the runner in the radial direction and leaves in axial direction. Example: Modern Francis turbine.

According to the head at inlet of turbine:

- High head turbine: In this type of turbines, the net head varies from 150m to 2000m or even more, and these turbines require a small quantity of water. Example: Pelton wheel turbine.
- Medium head turbine: The net head varies from 30m to 150m, and also these turbines require moderate quantity of water. Example: Francis turbine.
- Low head turbine: The net head is less than 30m and also these turbines require large quantity of water. Example: Kaplan turbine.

According to the specific speed of the turbine:

- The specific speed of a turbine is defined as, the speed of a geometrically similar turbine that would develop unit power when working under a unit head (1 m head). It is prescribed by the relation,

$$N = \frac{N\sqrt{P}}{H^{\frac{5}{4}}}$$

- Low specific speed turbine: The specific speed is less than 50. (varying from 10 to 35 for single jet and up to 50 for double jet) Example: Pelton wheel turbine
 - Medium specific turbine: The specific speed is varies from 50 to 250. Example: Francis turbine.
 - High specific turbine: the specific speed is more than 250. Example: Kaplan turbine.

Radial flow turbines

- Radial flow turbines are those turbines in which the water flows in radial direction. The water may flow radically from outwards to inwards or from inwards to outwards.
- If the water flows from outwards to inwards through the runner, the turbine is known as inward radial flow turbine. If the water flows from inwards to outwards, the turbine is known as outward radial flow turbine.
- Reaction turbine means that the water at inlet of turbine possesses kinetic energy as well as pressure energy.

- The main parts of a radial flow reaction turbine are:
 - *Casing:* - The water from penstocks enters the casing which is of spiral shape in which area of cross section of casing goes on decreasing gradually. The casing completely surrounds the runner of the turbine.
 - *Guide mechanism:* - It consists of stationary circular wheel all round the runner of the turbine. The stationary guide vanes are fixed on guide mechanism. The guide vanes allow the water to strike the vanes fixed on the runner without shock at inlet.
 - *Runner:* - It is a circular wheel on which a series of radial curved vanes are fixed. The surfaces of the vanes are made very smooth. The radial curved are so shaped that the water enters and leaves without shock.
 - *Draft tube:* - The pressure at the exit of the runner of reaction turbine is generally less than atmospheric pressure. The water exit cannot be directly discharged to the tail race. A tube or pipe of gradually increasing area is used for discharging water from the exit of turbine to the tailrace. This tube of increasing area is called draft tube.

Axial flow turbines

- If the water flows parallel to the axis of the rotation of the shaft, the turbine is known as axial flow turbine.
- If the head at the inlet of the turbine is the sum of pressure energy and kinetic energy and during the flow of water through runner a part of pressure energy is converted into kinetic energy, the turbine is known as reaction turbine.

- For the axial flow reaction turbines, the shaft of the turbine is vertical. The lower end of the shaft is made larger which is known as hub. The vanes are fixed on the hub and hence hub acts as runner for axial flow reaction turbine.
- The following are the important type of axial flow turbines:
 1. Propeller turbine
 2. Kaplan turbine
- When the vanes are fixed to the hub and they are not adjustable, the turbine is known as propeller turbine.
- If vanes on hub are adjustable the turbine is known as a Kaplan turbine. This turbine is suitable where a large quantity of water at low heads is available.

Difference between Impulse and Reaction turbine

Impulse turbine	Reaction turbine
The entire available energy of the water is converted into kinetic energy.	Only a portion of the fluid energy is converted into kinetic energy before the fluid enters the turbine runner.
The work is done only by the change in the kinetic energy of the jet.	The work is done partly by the change in the velocity head, but almost entirely by the change in pressure head.
Flow regulation is possible without loss.	It is not possible to regulate the flow without loss.
Unit is installed above the tailrace.	Unit is entirely submerged in water below the tail-race.
Casing has no hydraulic function to perform, because the jet is unconfined and is at atmospheric pressure. Thus, casing serves only to prevent splashing of water.	Casing is absolutely necessary, because the pressure at inlet to the turbine is much higher than the pressure at outlet. Unit has to be sealed from atmospheric pressure.
It is not essential that the wheel should run full and air has free access to the buckets.	Water completely fills the vane passage.