HYDRAULIC MACHINES & FLUID MECHANICS

Semester: 5TH

STUDY MATERIAL

HMIF

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HYDRAULIC TURBINES

Chapter1

Hydraulic Machine:-

"Hydraulic Machine may be defined as that branch of Engineering Science which deals with Machines run by water under some head or raising the water to higher level."

Hydraulic Turbine:-

- Turbine are defined as the Hydraulic Machine which convert hydraulic energy into mechanical energy.
- This mechanical energy is used in running an electric generator which is directly coupled to the shaft of the turbine.
- Thus the mechanical energy is converted into electrical energy**.**

Water Turine:-

A Turbine that extracts energy from moving water and converts into electrical energy is called water turbine o

Classification of Turbine:-

According to the type of energy at inlet

1-Impulse Turbine:-

If the energy available at the inlet of turbine is only kinetic energy,the turbine is known as impulse turbine.

2-Reaction Turbine:-

If the energy available at the inlet of the turbine is kinetic energy as well as pressure energy, the turbine is known as Reaction turbine.

Acoording to the head at the inlet of Turbine:-

1-High Head Turbine :-The net head varies in this turbine is from 150m to 2000m or even more.It requires small quantity of water.e.g-Pelton turbine

2-Medium Head Turbine:-In this turbine net head varies from 30m to 150m.It bine is known as Reaction turbine.It requires moderate quantity of water.e.g-Francis turbine

3-Low Head Turbine :-In low head turbines,the net head is less than 30m.It requires large quantity of water.e.g-Kaplan turbine

According to the direction of flow through runner:-

1-Tangential flow Turbine:-If the water flows along the tangent of the runner,the turbine is known as tangential flow turbine.

2-Radial flow Turbine:-If the water flows along the radial direction through the runner,the turbine is called radial flow turbine.

3-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.

4-Mixed flow Turbine:-If the water flows through the runner in the radial direction but leaves in the direction parallel to the axis of rotation of the runner, the turbine is called mixed flow turbine.

According to the specific speed of turbine:-

1-High specific speedTurbine:-The specific speed is more than 250
e.g- Kaplan turbine.

2-MediumSpecificspeedTurbine:-The specific speed varies from 50 to 250.e.g-Francis turbine.

3-Low Specific speed Turbine:-It has specific speed less than 50.e.g-Pelton wheel turbine

Working principle of Turbine:-

. In general a Hydraulic turbine consist of a wheel called runner or Rotor having a number of specially designed vanes or blades or buckets.

.The water possessing a large amount of hydraulic energy when strikes the runner, it does work on the runner and causes it to rotate.

.The mechanical energy so developed is supplied to generator which is coupled to runner to generate electrical energy.

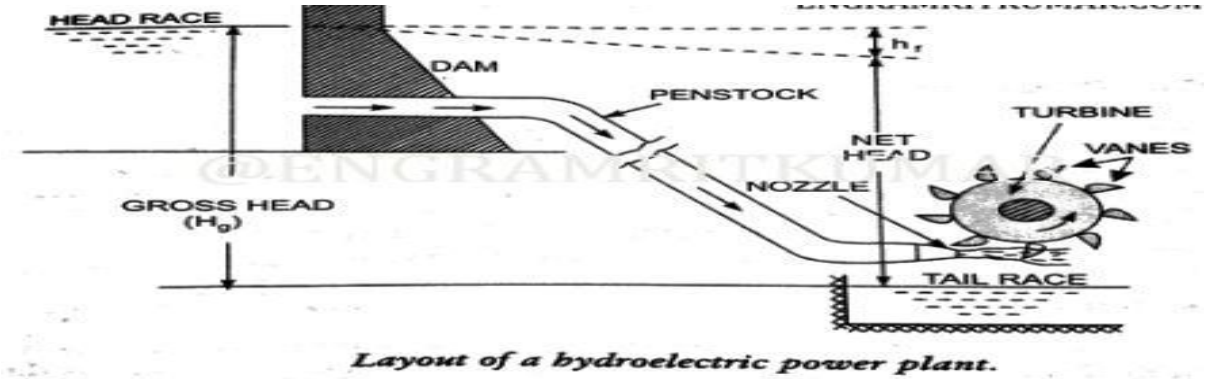
General Layout of Hydroelectric Power Plant:-

.A Dam is constructed across a river to store water.

.Pipes of large diameters called penstock , which carry water under pressure from the storage reservoir to the turbines.These pipes are made of steel or reinforced concrete.

.Turbines having different types of vanes fitted to the wheels.

.Tailrace which is a channel which carries water away from the turbines after the water has worked on the turbines. The surface o f water in the tailrace channel is also known as Tailrace.



Layout of a hydroelectric power plant.

Gross Head-The difference between the head head race level and the tail race level when no water is flowing is known as Gross head.

Net Head-

Net Head-=Gross Head-Friction Head

Essential Elements of HydroPower Plant:-

1)Reservoir:.-A reservoir is employed to store water which is further utilized to generate power by running the hydroelectric turbines.
.In a reservoir the water collected from the catchment area is stored behind a dam.
.Catchment area gets its water from rains and streams.
.The level of water surface in the reservoir is called head water level.

2)Dam:-A dam is a barrier which confines or raise water for storage or diversion to create a hydraulic head. Dam's are generally made of concrete or stone masonary or rock fill

3.Spillways:-There are times when the river flow exceeds the storage capacity of the reservoir. Such a situation arises during heavy rainfall in the catchment area.
.In order to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam, spillways are used.
.Spillways are constructed of concrete piers on the top of the dam.

4.Gate:-A gate is used to regulate or to control the flow of water from the dam.

5.Pressure tunnel:-It is a passage that carries water from the reservoir to the surge tank. he purpose of dam is to store water and to regulate the outgoing flow of water.

6.Penstock:

.Penstocks are open or closed conduits which carry water to the turbines .
.They are generally made of reinforced concrete or steel.
.Concrete penstocks are suitable for low heads& The steel penstock can be designed for any heads.

7.Surge tank:-Additional storage for near to turbine ,usually provided in high head plants.
.Located near the beginning of the penstock.
.As the load on the turbine decreases or during load rejection by the turbine the surge tank provides space for holding water.

ImpulseTurbine(Pelton Wheel):-

. ImpulseTurbine is basic type of turbine used in power generation in hydro power plant.

.It works on the basic principle of impulse.When the jet of water strikes at the turbine blade with full of its speed,it generates a large force which used to rotate the turbine.

.The force depends on the time interval and velocity jet strikes the blades .This turbine used to rotate the generator which produces electric power.Impulse turbine mostly used at high heads.

Construction:-

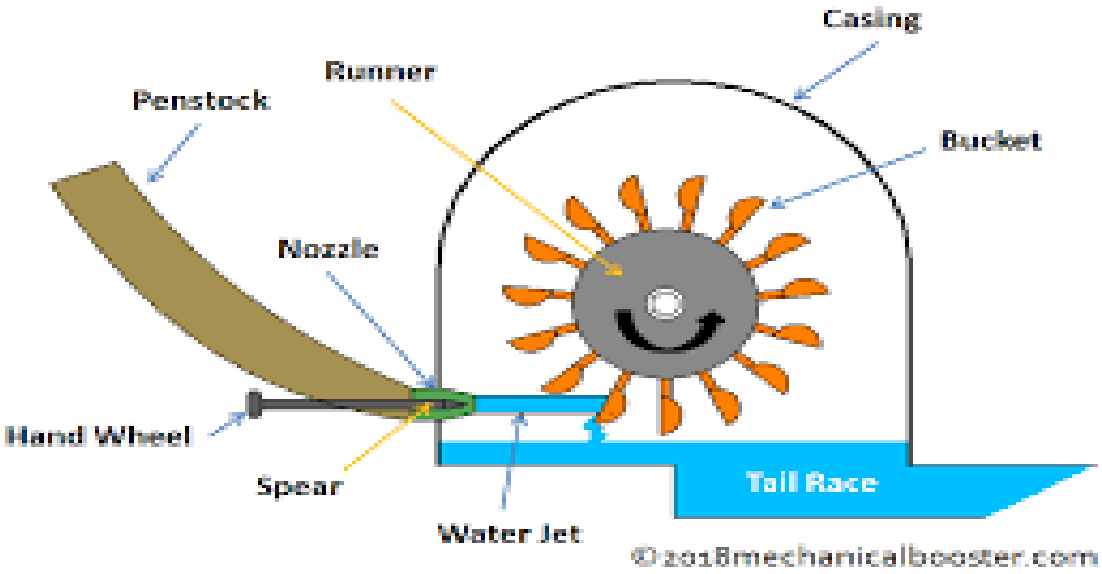
1.Blades:-The number of blades is situated over the rotary. They are concave in shape. The water jet strikes at the blades and change the direction of it. The force exerted on blades depends upon amount of change in direction of jet. So the blades are generally concave in shape.

2.Rotor:-Rotor which is also known a wheel is situated on the shaft. All blades are pinned into the rotor. The force exerted on blades are pinned into the rotor. The force exerted on blades passes to the rotor, which further rotates the shaft.

3.Nozzle:-A nozzle play main role of generating power from impulse turbine. It is a diverging nozzle which converts all pressure energy of water into kinetic energy and forms the water jet. The high speed water strikes the blades and rotates it.

4.Casing:-Casing is the outside are which prevent the turbine from atmosphere. The main function of casing is to prevent discharge the water from vanes to tailrace. There is no change in pressure of water from nozzle to tailrace. So this turbine works at atmospheric pressure.

5.Braking nozzle:-A nozzle is provided in opposite direction of main nozzle. It is used to slow down or stop the wheel**.**the blades and rotates it



Main Parts of Impulse Turbine

Working:-

.High pressure water flow from dam(High head) to nozzle(low head).

.This water flows through divergent nozzle where its all pressure energy change into kinetic energy. It forms a water jet.

.The water jet strikes the blade at high speed which rotates the rotor.

.It transfers all kinetic energy of water to the rotor ,which further use to rotate the generator.

.After transferring energy, water flows to the tailrace.

.This process run co ntinuously until sufficient power generates..

Advantages:-

1.It can works at low discharge or at low flow rates.

2.This turbine has high efficiency.

3.Impulse turbine is flexible according to load condition. At higher load more than one nozzle are used.

4.They work at atmospheric pressure so no problem of leakage.

5.It is easy to assemble.

Disadvantages:-

1.Large size compare to others.

2.Efficiency decreases with time.

3.It required high head which is hard to control.

4.It is costly to install.

Applications:-

1.It is used worldwide to produce electrical energy in a number of hydro-power plants.

2.Turbochargers in automobiles uses the pressure energy of exhaust gases through impulse turbine. Where hot and pressurized gases coming out of exhaust are converted into high velocity jet by passing them through nozzle.

3.It is also used in reverse osmosis plant, where waste water jet velocity is used to run turbine, thus acts as an energy recovery system.

Efficiencies of Turbine:-

1)Hydraulic Efficiency(η_h)

2)Mechanical Efficiency(η_m)

3) Volumetric Efficiency(η_v)

4)Overall Efficiency (η_o)

1.Hydraulic Efficiency (η_h) :-

=Power developed by the runner of a Turbine/Power supplied by the water at the inlet of turbine

2.Mechanical Efficiency (η_m) :-

=Power at the shaft of the turbine/Power developed by the runner

η_m =shaft power/Runner power=SP/RP

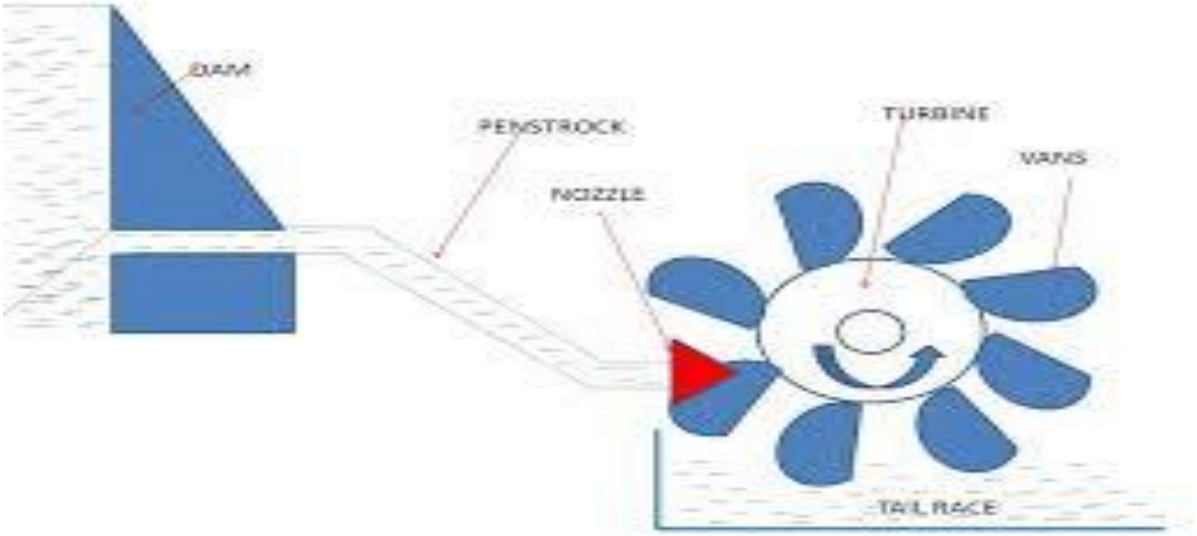
3.Volumetric efficiency(η_v):-

=Volume of water actually striking the runner/Volume of water supplied to the turbine

4.Overall efficiency(η_o):-

=Power available at the shaft of the turbine/Power supplied at the inlet of turbine

η_O=SP/RP



Power produced by Impulse Turbine:-

The power produced by an Impulse turbine

P= wQH kw

Where w=Specific weight of water(9.81kN/m^3)
Q=Discharge of the turbine in m^3/s
H=Head of water in metres

For pelton wheel turbine:-

1-The velocity of the jet at inlet is given byV_1= $C_V\sqrt{2gH}$

Where C_V=Coefficient of velocity=0.98 or 0.99
H=Net head on turbine

2-The velocity of wheel is given by$U= {}^{\varphi}\sqrt{2gH}$
Where Φ=speed ratio, The value of speed ratio varies from 0.43 to 0.48

Reaction Turbine:-

Introduction:-

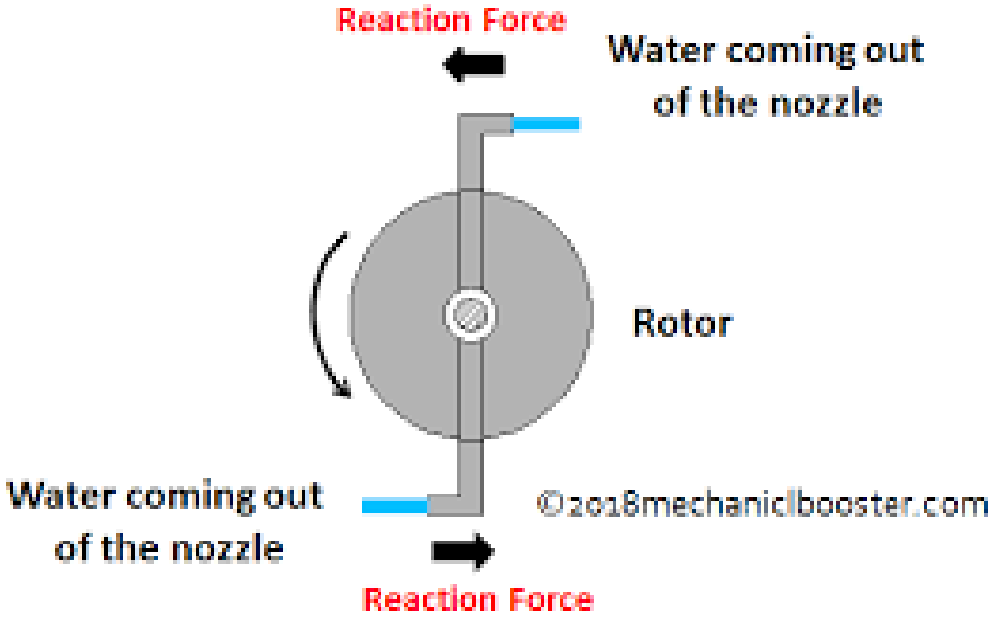
.From the wind mills to hydro power plants we have reaction turbines all around the world to generate electricity efficiently.

.Almost 60% of turbines used in hydro-power plants are reaction turbine.

.Unlike Impulse turbine they remain dipped in water and use the pressure energy of water to generate power.

. If the inlet of the turbine, the water possesses kinetic energy as well as pressure energy, the turbine is known as reaction turbine.
e.g.-Francis turbine, Kaplan turbine.

.In this case, the water reacts with the vanes and transfers its pressure energy to the vanes so that the vanes move in turn rotating the runner on which they are mounted.



.The rotor having moving nozzles and water of high pressure is coming out of the nozzle.

.As the water leaves the nozzle, a reaction force is experienced by the nozzle. This reaction force rotates the rotor at very high speed.

.In The same way in reaction turbine, a reaction force is generated by the fluid moving on the runner blades.

. The reaction force produced on the runner blades makes the runner to rotate.

.Fluid after moving over the runner blades enters into draft tube and finally to the tail race.

Main components of a reaction turbine:-

Main components of a reaction turbine:-

1.Penstock:-Large diameter tube through water from dam comes to turbine inlet. It is made from steel.

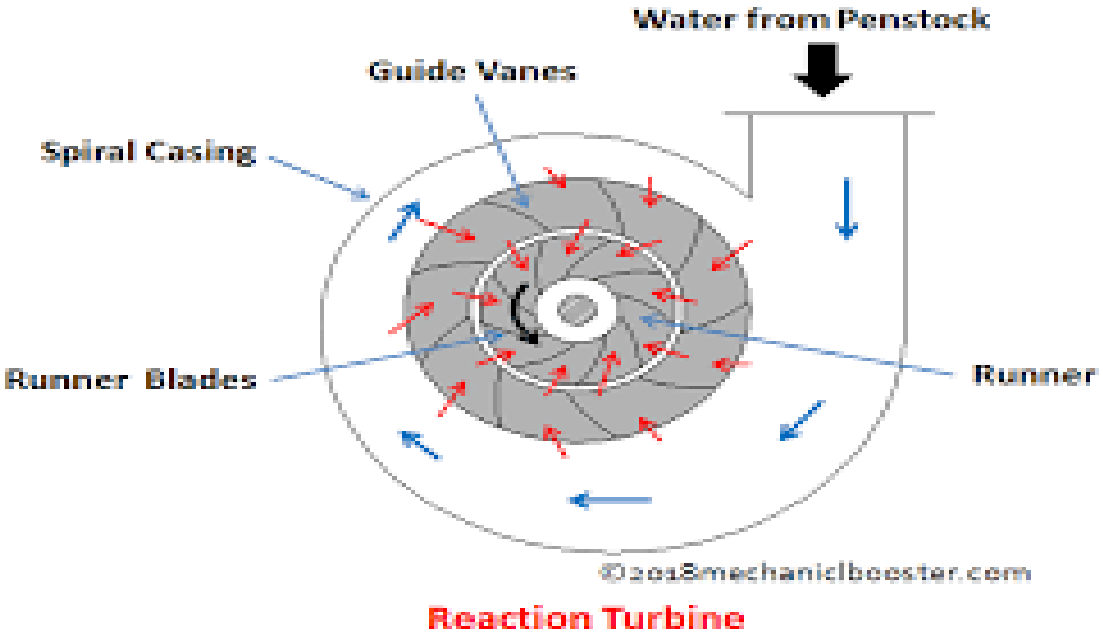
2.Spiral casing:-

a.In case of reaction turbine ,casing and runner are always full of water.

b. It is a Spiral casing, with uniformly decreasing cross-section area, along the circumference. Its decreasing cross-section area gives a uniform velocity of water striking the runner blades, as we have openings for water flow in to the runner blades from the very starting of the casing,so pressure would decrease as it travels along the casing. So we reduce its cross-section area along its circumference to make pressure uniform, thus uniform velocity striking the runner blades. The spiral casing is made of concrete, cast steel or plate steel.

3.Guide vanes:-

a.Guide vanes are installed in the spiral casing.
b.The most important function is that water striking the runner blades must have a direction along length of the axis of turbine otherwise the flow would be highly swirling as it moves through spiral casing ,make it in-efficient to rotate runner blades.
c.It convert a part of pressure energy into kinetic energy.
d.The angle of these guide vanes is adjustable in modern turbines, and we can adjust the water flow rate by varying the angle of these guide vanes according to the load on the turbine.



4.Runner Blades-

Runner blades are said to be heart of reaction turbine.It is the shape of the runner blades which uses pressure energy of water to run turbine.Their design plays a major role in deciding the efficiency of a turbine.In modern turbines these blades can pitch about their axis.Thus can vary the pressure force acting on them according to the load and available pressure.

5.Runner-

It is a circular wheel on which a series of radial curved vanes are fixed.The surface of the vanes are made vry smooth.The radial curved vanes are so shaped that the water enters and leaves the runner without shock.The runners are made of cast steel,cast iron and stainless steel.They are keyed to the shaft.

6.Draft Tube-

The pressure at the exit of the runner of a reaction turbine is generally less than atmospheric pressure.Hence water ar exit cannot be odirectly discharged to tail race.It is gradually expanding tube which discharge water passing through the runner to tail race.

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