TURBINES

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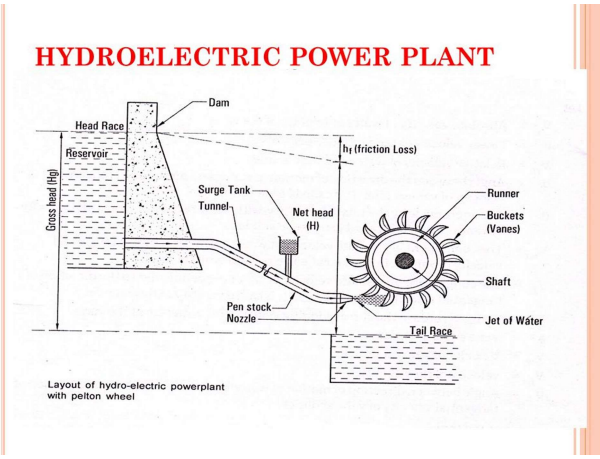
Hydraulic machinery

Hydraulic turbine or water turbine is a rotary machine that converts potential energy and kinetic energy of water into mechanical work. In this article, we are going to discuss the Hydraulic Turbine along with its Definition, Classification, Advantages, Disadvantages & Applications.
Before going into the main topic, let's see the difference between Turbine and pump.



Difference between Turbine and Pump:

If a machine transforms mechanical energy into hydraulic energy it is called a pump whereas, If a machine transforms hydraulic energy into mechanical energy it is called a Turbine.
Thus in turbines, fluid does work on the machine, and the machine produces power. but, the pump absorbs the power, and work is done on the fluid.
The mechanical energy developed is utilized for running an electric generator which is directly coupled to the shaft of the turbine.
The electric power developed by the electric generator is known as hydroelectric power.
So, the generation of hydroelectric power is cheaper than the other resources like coal, oil, etc.
Some parts of the hydroelectric power plant are a reservoir, dam, gates, surge tank, penstock, turbine, generator, etc.

What is Hydraulic Turbine?

Hydraulic Turbine is the main prime over which helps to converts hydraulic energy into electrical energy by the help of a generator. When a stream of water is hit the blades of the turbine, it forces the turbine to rotate hence there is a generator fitted with the turbine so the generator has also come in rotation and produces the electrical energy.

Classification of Hydraulic Turbines:

The hydraulic Turbines were classified according to the following conditions.

1. The direction of flow of water
2. Available head
3. Specific speed
4. Action of water

An Explanation for the Classification of Hydraulic Turbines is as follows.

1. Classification of Turbine based on the direction of flow of water:

- **Tangential Flow:**

If the water strikes the blades of the runner tangential to the path of rotation called Tangential flow.
For example, Pelton wheel turbine.

- **Radial Flow:**

If the water strikes the blades of the runner radially and coming out axially called as Radial flow.
For example, Francis turbine

- **Axial Flow:**

In this flow, the water flows parallel to the axis of the turbine.
For example, Kaplan turbine
Mixed Flow: modern francis turbine

2. Classification of Turbine based on Available head:

- **High head**:

The turbine capable of working under the high potential head of water above 300m
For example, Pelton wheel turbine.

- **Medium head**:

The turbine is capable of working under a medium range of potential head about 60m to 300m
For example, Francis turbine.

- **Low head**:

The turbine is capable of working under a low range of potential head less than 60m

3. Classification of Turbine based on Specific speed:

- **Low Specific Speed:**

Turbine works in the range of **10-50**.
For example, Pelton wheel turbine

- **Medium Specific Speed:**

Turbine works in the range of **50-350**.
For example, Francis turbine

- **High Specific Speed:**

Turbine works in the range of **250-850**.
For example, Kaplan turbine

4. Classification of Turbine based on Action of water:

- **Impulse:**

There is no pressure drop on the runner or rotor. Kinetic Energy of water coming from the jet is used to run the runner or rotor.
For example, Pelton wheel turbine.

- **Reaction:**

There is a loss of Kinetic Energy as well as pressure energy on the runners of the blade.
For example, Francis turbine

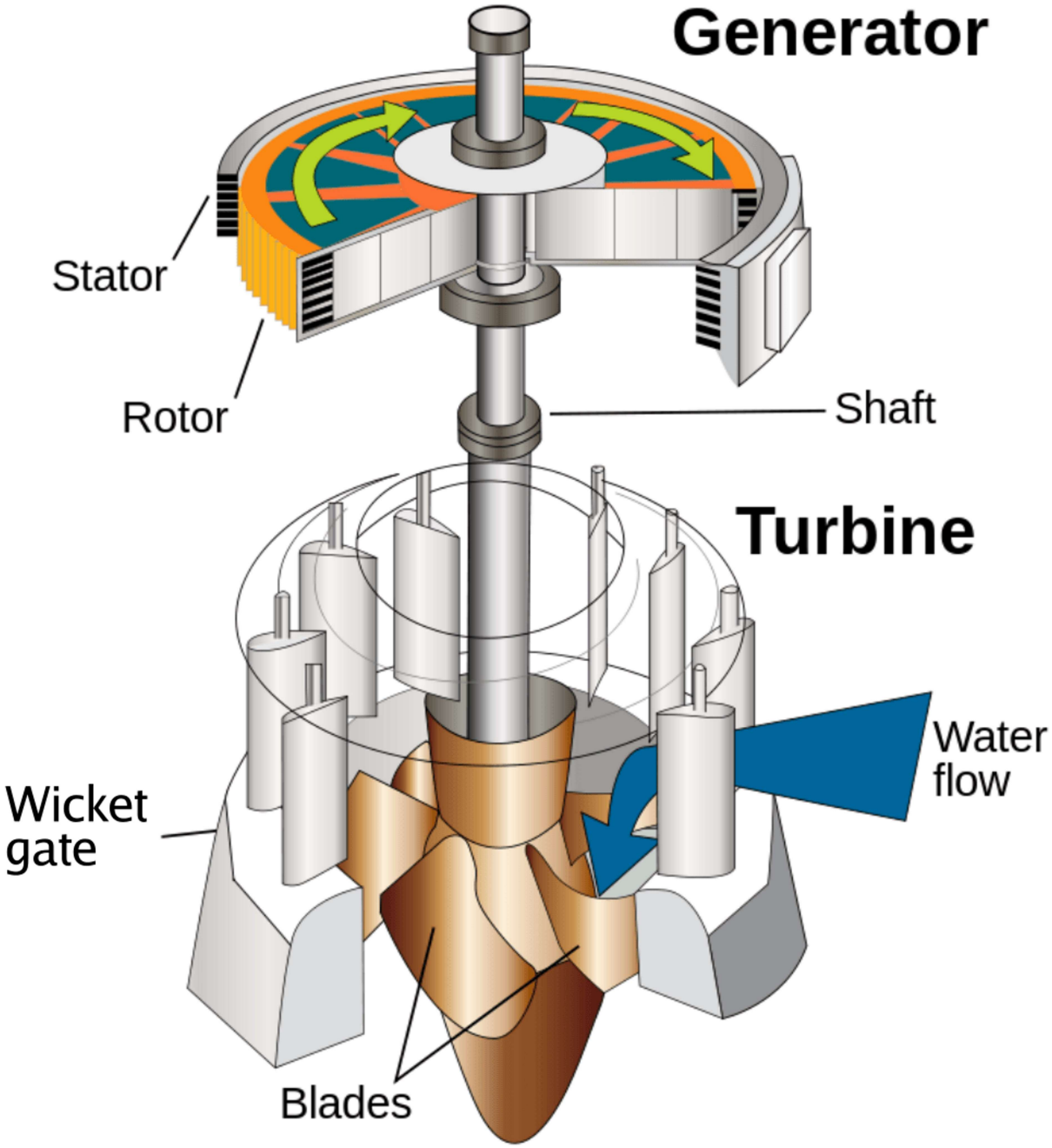
Difference between Impulse and Reaction Turbine:

The difference between impulse and reaction turbine is shown below in a tabular column.

Impulse Turbine	Reaction Turbine
Available energy is converted into kinetic energy	A major part of available energy is converted to pressure energy
Pressure in the turbine is constant	Pressure gradually reduces while water flows on the turbine blades
The wheel and the blades should have access to free air and must not run fully.	The blades are always under the action of pressure, the wheel must always run fully.
Only one face of the blade is active	Both sides
Regulation of flow and power is easier without loss of energy	Difficult
Used for high heads	Low and medium heads
Efficiency is less	Efficiency is more
Energy transfer is a change in kinetic energy	Due to a change in pressure head

How a Hydraulic Turbine Work?

In general, the principal component of a turbine is a rotor. The rotor is a wheel carrying a number of plates and vanes on its periphery.
The rotor is housed in a stationary casing and water possesses a good amount of potential energy which is allowed to flow through pipes and finally discharged through nozzles and thus gaining kinetic energy.



Whenever the water strikes the runner and causes it to rotate, the mechanical energy developed is supplied to the generator coupled to the runner which generates electricity.

Advantages of Hydraulic Turbine:

The Advantages of Hydraulic Turbine are as follows:

- Hydraulic Turbine's running coast is less compared to other turbines.
- It is a renewable source of energy.
- The efficiency of this system is high.
- Environmental pollution is almost zero.

Disadvantages of Hydraulic Turbine:

The disadvantages of Hydraulic Turbine are as follows:

- The installation cost is very high.
- It can be placed at only those regions where there is a surplus of water.
- The population of aquatic animals can be impacted.

Usages of Hydraulic Turbine :

The applications of Hydraulic Turbine are as follows.

- It is used for the generation of electric power in dams.
- It will control the floods in the rivers.
- The water which stays in a reservoir can be used for agriculture purposes.

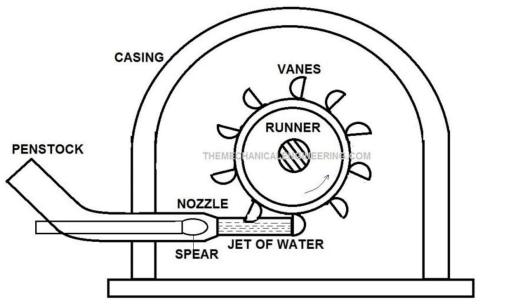
Pelton Wheel Turbine Definition:

Pelton Wheel Turbine is the type of impulse or hydraulic turbine which is used for high heads for the generation of power. In this, the jet after leaving the nozzle runs in the open air and strikes the bucket or vane.

Pelton Wheel Turbine Construction or Parts:

The following construction or parts of Pelton wheel Turbine:

- **Casing**
- **Spear**
- **Break Nozzle**
- **Runner or Rotor**
- **Penstock**
- **Governing Mechanism**



PELTON WHEEL TURBINE LINE DIAGRAM

Casing :

The Pelton wheel casing prevents the splashing of water and it will provide a discharge of water from the nozzle to the tailrace.

The casing surrounding the wheel has no hydraulic function to perform, unlike the reaction turbine where the casing plays an important hydraulic function.

Spear:

Needle Spear will control the water flow and it moves insides the nozzle and provides smooth flow so there can be very less energy loss.

When the nozzle is completely closed by moving the spear in the forward direction the amount of water striking the runner is reduced is zero but the runner due to inertia continues revolving for a long time.

Break Nozzle:

To stop the runner to rest in a short time a breaking jet is provided which directs the water on the bucket. this is called breaking jet.

Runner or Rotor:

A Pelton wheel has a runner that rotates and has kinetic energy, at the periphery of the runner equally spaced hemispherical or double ellipsoidal buckets.

Penstock:

These are the channels or pipelines from high head source water is transferred to the actual power station

Governing mechanism:

Governing of Pelton turbine is done by means of oil pressure governor.

Working principle of pelton wheel turbine

The working principle is water is coming from the storage reservoir through a penstock to the Inlet of the nozzle which is the inlet of the turbine so the hydraulic energy of the water is mainly converted into kinetic energy.

The water releases in the form of jet form the nozzle strikes the vanes for small time durations
Since a very high force is exerted on the vanes by the jet of water for a very small time duration so these turbines are known as Impulse turbines.

Bucket changes the direction of run/flow of water jet and momentum transfer takes place.

All events happen in open air i.e at atmospheric pressure. The nozzle is used to convert the head available with water into a dynamic head and the water comes out from the nozzle in the form of a jet.

As the jet strikes over the runner vane, it will apply a large magnitude force for a small amount of time over the runner called Pelton force the Pelton force will rotate the runner.

Pelton Wheel Turbine Advantages:

The following advantages of Pelton Turbine are:

- The Pelton Turbine simple in design and also the construction is not complex.
- The water which is clean cannot cause very rapid wear in high heads.
- The overhaul and inspection are much easier than another turbine.
- Cavitation is not an ever-present danger.
- The water hammer effect is not there.
- The overall efficiency is quite high as compared to reaction turbines.
- There is no requirement for the draft tube here.
- It can work on relatively less Q(discharge) of flow rate.
- In the Hydraulic Turbine, it is the most efficient turbine.
- The parts assemble of the Pelton turbine is very easy. No complexity here.
- The water striking and leaving the runner at atmospheric pressure only.
- This is a tangential flow turbine. It can move in axial flow or radial flow direction.

Pelton Wheel Turbine Disadvantages:

The following disadvantages of Pelton Wheel Turbine is:

- In the Pelton turbine, the variation in the operating head cannot be easily controlled because it works at high heads.
- The ratio of maximum and minimum operating heads can be even less.
- The operating head cannot be utilized when the variation in the tailwater level is relatively large when compared to the total head.
- The mechanical efficiency of the Pelton wheel decreases faster compare to the Francis turbine.
- The size of the runner, generator, powerhouse required is large and not economical if the Pelton turbine is used instead of the Francis turbine for the same power generation.

Pelton Wheel Turbine Application:

The following application of Pelton Wheel Turbine is:

- The Pelton Turbine wheel turbine is used in Hydro Power Plant where Less discharge and High Heads are required.
- This is used to get more velocity of the fluid for maximum power and efficiency [Because the turbine and wheel are designed in such a way that the water jet velocity is twice the rotating bucket velocity].
- It is also used to drive the generator and who is attached to the turbine shaft here the Mechanical energy gets converted into Electrical Energy.

Francis Turbine:

Francis turbine is a hydraulic and reaction turbine and it is the most preferable hydraulic turbine. Francis Turbine contributes more than 60 percent of hydraulic energy capacity to the world. The Francis turbine was developed by James B. Francis around 1855.
Francis Turbine is an inward flow reaction turbine and has a purely radial flow runner, the pressurized water will enter the vanes in the radial direction and discharge out of the runner axially. The Francis turbine operates under medium heads (45-400 meters) and also which are guiding types and it is employed to have medium discharge (10-700 cube meters per second).

Francis Turbine Main Parts or Construction:

The **following main parts or Construction of Francis turbine are**:

- **Penstock**
- **Casing**

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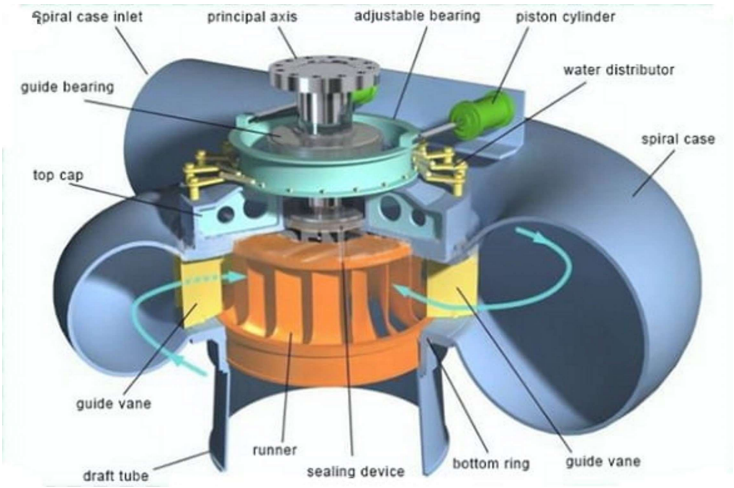
- **Penstock**
- **Casing**
- **Guide Vanes**
- **Governing Mechanism**
- **Runner and Runner Blades**
- **Draft tube**



Let's study one by one,

Penstock:

The penstock is also known as the Input pipe. The diameter lies between 1 to 10 meters. The penstock is a large size conduit that conveys water from the upstream of the dam or reservoir to the turbine runner.

Casing:

The casing has a passage that is the closed type and has a cross-sectional area gradually decreasing along the direction of the flow area and it becomes maximum at the inlet and zeroes at the exit.

Guide Vanes:

These vanes direct the water onto the runner at an angle appropriate to the design. The motion to them is given by means of a handwheel or automatically by a governor.

Governing Mechanism:

It changes the position of the guide blades/vanes to affect a variation in water flow rate when the load conditions on the turbine changes.

Runner and Runner blades:

The driving force on the runner is both due to impulsive and reaction effects. The number of runner blades will be around 16 to 24.

The modern Francis turbine is an inward mixed Flow reaction turbine. Water comes to the turbine via penstock and it will hit on no. of stationary blades. These stationary orifices are commonly called as guide vanes or wicket gates.

The head acting on the turbine is partly transformed into kinetic energy and the rest remains as pressure head. Due to this pressure difference, it is called a reaction turbine and is responsible for the motion of the runner that is why a Francis turbine is also known as a reaction turbine.

The Francis turbine the pressure at the inlet is more than at the outlet. After doing the work the water is discharged to the tailrace through a closed of gradually enlarging section like a tube. This is known as the draft tube.

Draft Tube:

It is an expanding tube used to discharge water through the runner and to the tail race. The main function of the tube is to reduce the velocity of (water flowing) at the time of discharge.

Francis Turbine Advantages or Merits:

The Francis turbine has following advantages:

- The variation in the operating head can be more easily controlled.
- In Francis's turbine, the ratio of maximum and minimum operating heads can be even two

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- The operating head can be utilized even when the variation in the tailwater level is relatively large when compared to the total head
- The mechanical efficiency of the Pelton wheel decreases faster with wear than Francis turbine
- The size of the runner, generator, and powerhouse required is small and economical if the Francis turbine is used instead of a big Pelton wheel for the same power generation.

Francis Turbine Disadvantages or Drawbacks:

The following disadvantages of Francis turbine are:

- The Francis turbine will lose its efficiency if it is run a 50 percent load for max time.
- Water that is not clean can cause very rapid wear in high head Francis turbines.
- There can be difficulty in the overhauling of the turbine and also difficulties contained in the inspection.
- Cavitation is an ever-present danger.
- Chances of water hammer can be there.

Francis Turbine Application:

The following applications of Francis turbine are:

- This is the most efficient hydro turbine and used for the generation of Electricity.
- This turbine efficiency is great comparatively another turbine.
- It can be used for a wide range of water head and flow rates.
- In addition to electrical production, also be used for pumped storage, a reservoir is filled by the turbine (acting as a pump) driven by the generator.

Kaplan Turbine

Kaplan Turbine was developed in 1913 by Viktor Kaplan (Austrian Professor). Kaplan Turbine is a type of reaction turbine which works is to produce electrical energy and it is used for high discharge and low heads.

Various aspects of **Kaplan Turbine** are:

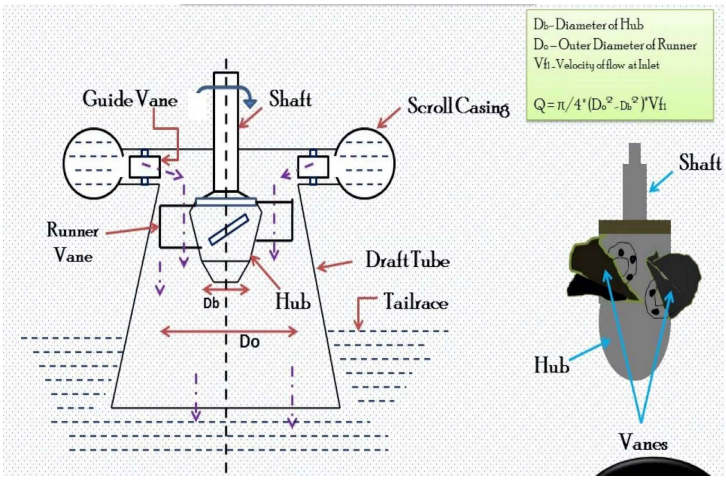
- This is a low head, high discharge reaction turbine.
- It is an axial flow turbine not mixed or radial. Its blades are adjustable i.e pitch of blades, blade inlet, and outlet angle are adjusted according to varied discharge and head.
- This adjustment is done for maximum efficiency over wide operating conditions.

  Since the flow of fluid in the Kaplan turbine is axial, the number of blades in Kaplan is 3 to 6 as compared to 16 to 24 in another turbine, So less contact surface and fewer friction losses.

Kaplan Turbine Construction or Main Parts:

Kaplan Turbine consists of following main parts:

- **Turbine Shaft**
- **Guide Vane**
- **Runner Vanes**
- **Scroll Casing**
- **Draft Tube**
- **Tail Race**



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Turbine Shaft:

This is an important component that is used for rotating the motor to generated electricity. In the runner blades, the turbine shafts are attached.

When the runner blades rotate the turbine shafts also rotate which helps to generate electrical energy.

Turbine Shaft must have heat-resistant properties because it rotates at a high speed of 1800-3600 rpm. The turbine shaft material is structural steel and others.

Guide Vane:

Guide vanes act as a control gate that means It is regulating the flow of water depending on the requirement.

When guide vanes open full then there is a maximum flow of water and it strikes the turbine blades hence more energy can be generated.

When guide vanes open half therefore the flow rate of water is low comparatively. So less water strikes with low force on the turbine blades hence less generation of electricity.

Runner Vanes:

This is an important part of this turbine. The blades are attached to the runner.

From the runner, the shaft is attached and connected with the generator. When the runner rotates, the shaft also rotates.

Scroll Casing:

The scroll casing is a special type of casing that decreases the cross-sectional area as you can see in the diagram and scroll casing is the upper part of the turbine which helps to protect the runner, runner blades, and so on.

The water is entered into the scroll casing via penstock and then the water flows to the guide vanes. Now from here, the water comes at the runner.

Draft Tube:

Draft Tube is used in the reaction turbine and it is similar to pipe but on one side has a long cross-sectional area.

Draft Tube increases the pressure of the fluid. The water can not send directly to the tailrace therefore this tube has been inserted. It works is to discharge the water from the tailrace.

There are four different types of Draft tube:

1. Simple Elbow,
2. Elbow with the varying cross-section,
3. Moody Spreading and,
4. Conical Diffuser or Divergent Draft Tube.

Tail Race:

In simple the tail race is used to release the water which is already used for the rotation of the runner blades or turbine blades.

Now lets study working of Kaplan turbine,

Kaplan Turbine Working Principle:

The head at the inlet of the turbine is the sum of pressure and kinetic energy and during the flow of water through the runner, a part of the pressure energy is converted into kinetic energy the turbine.

The shaft of an axial flow reaction turbine is vertical, the lower end of the shaft is made larger which known as a hub or boss.

The vanes are fixed on the hub and it is acting runner But the water enters the runners in an axial direction and leaves axially.

The pressure at the inlet of the blades is larger than the pressure at the exit of the blades. The energy transfer is due to the reaction effect, i.e the change in the magnitude of relative velocity across the blades.

Now lets study how it is **working,**

The water is entered into the spiral casing of the turine. The turbine shafts conncted with runner blades or turbine blades. The water comes to the guide vanes. Guide vane is like controlling the flow of water. Now if it opens the water strikes the runner baldes.

The runner strats rotating due to this turibe shaft also rotates. The turbine shafts is connected to the generator for electric generation.

The water which is used for rotating the runner blades now will come to draft tube. And from Draft tube the water goes to tail race and to the river.

Here you can watch the video of Kaplan Turbine:

Kaplan Turbine Advantages:

The following **advantages of Kaplan Turbine** are:

- The Kaplan Turbine is used for the low head.
- The size of this turbine is not large.
- Therefore Space requirement is also low because of limited size.
- It can be used for high discharge applications.
- A very high specific speed can be obtained.
- There can be less loss of efficiency at part loads.

Kaplan Turbine Disadvantages:

The following **disadvantages of Kaplan Turbine** are:

- The maintenance cost is high.
- There is cavitation that occurs when the pressure drops at the draft tube. To overcome this problem we can use stainless steel for pipe material and so on.
- The generator chamber got water leakage and there can be troublesome due to condensation.

Kaplan Turbine Application:

The following **application of Kaplan Turbine** are:

- The main application of the Kaplan Turbine is in Hydro electrical power production.
- The Kaplan turbine is smaller in size and construction is also easy.
- At low water heads, the Kaplan turbine works more efficiently and with high flow rates compared to other types of turbines.
- The overall efficiency of this turbine is good.