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PELTON WHEEL

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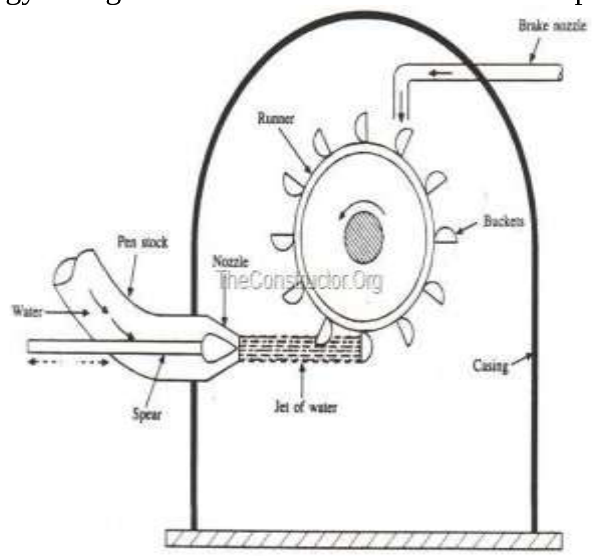
ABSTRACT

The thesis includes a literature survey of Pelton turbine, incorporating a historical review. Pelton hydraulic turbines are impulse-type turbo machines commonly used in hydroelectric plants with medium-to-high water head and in various energy recovery applications. This turbine more specifically Pelton wheel will be used to do lab experiment in Fluid Machinery Laboratory.
The aim of the present work is to provide detailed performance measurements on a Pelton turbine model, along with the design and geometrical dimensions of its runner/buckets and nozzle. The measurements include the net water head, flow rate and the torque and rotation speed of the runner, from which the corresponding efficiency and shaft power are computed. Flow is varied and head is measured for each variance to calculate the power in the system. Other parameters necessary for the study are also measured and recorded for the study.
The results are presented in graphical method and the properties of the graph are used to discuss the properties of the turbine under study.
The Pelton wheel under study is of a smaller scale though it acts as a representative of a similar system in large scale.

KEYWORDS Pelton Wheel, Impulse Turbine, Penstock, Nozzle, Spear, Runner.

INTRODUCTION:

Pelton wheel Turbine is impulse turbine. An impulse turbine first converts the water head through a nozzle into a high-velocity jet, which then strikes the buckets at one position as they pass by. The runner passages are not fully filled, and the jet flow past the buckets is essentially at constant pressure. Impulse turbines are ideally suited for high head and relatively low power.
Since the water jet is always open to atmosphere, inlet and exit pressure of water jet will be same and will be same as atmospheric pressure. However absolute velocity of fluid will have huge drop from inlet to exit of bucket. This kinetic energy drop is the maximum energy the bucket can absorb.
So, it is clear that Pelton turbine gains mechanical energy purely due to change in kinetic energy of jet, not due to pressure energy change. Which means Pelton turbine is a pure impulse machine.



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Impulse force produced by water jet is high when jet is having high velocity. Water stored at high altitude can easily produce high jet velocity. This is the reason why Pelton turbine is most suitable for operation, when water is stored at high altitude. The primary feature of the impulse turbine is the power production as the jet is deflected by the moving buckets.
Assuming that the speed of the exiting jet is zero (all of the kinetic energy of the jet is expended in driving the buckets), negligible head loss at the nozzle and at the impact with the buckets (assuming that the entire available head is converted into jet velocity).
The Pelton Wheel is the only form of impulse turbine in common industrial use. It is a robust and simple machine which is ideal for the production of power from low volume water flows at a high head with reasonable efficiency.

Figure. A Pelton turbine

The water strikes the bucket along the tangent of the tangent of the runner. The energy available at the inlet of the turbine is only Kinetic Energy. The pressure at the inlet and outlet is atmospheric pressure. The nozzle increases the kinetic energy of the water flowing through the penstock. At the outlet of the nozzle, the water comes out in the form of a jet and strikes the buckets (vanes) of the runner.
Pelton Wheel Turbine is used for High Heads. Pelton Wheel Turbine has a Specific Speed less than 30(S.I) for single jet and between 30 and 60 (S.I) for multi-jet
Water leaving those wheels typically still had high speed, carrying away much of the dynamic energy brought to the wheels. Pelton's paddle geometry was designed so that when the rim ran at ½ the speed of the water jet, the water left the wheel with very little speed; thus, his design extracted almost all of the water's impulse energy—which allowed for a very efficient turbine.

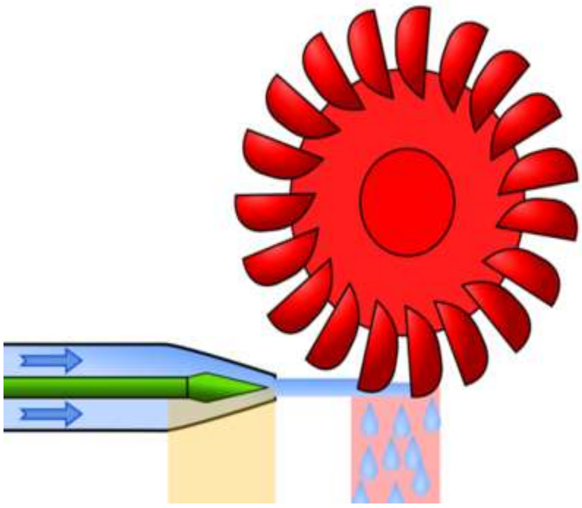

Figure : A nozzle turns hydraulic head into a high velocity (with high velocity head) stream of water which hits the Pelton turbine and makes it spin. The water coming out the bottom has very little energy left.

LITRATURE AND REVIEW:

A typical setup of a system generating electricity by using Pelton Turbine will have a water reservoir situated at a height from the Pelton Wheel.

The water from the reservoir flows through a pressure channel to the penstock head and then through the penstock or the supply pipeline to the nozzles, from where the water comes out as high-speed jets striking the blades of the Pelton Turbine.

The penstock head is fitted with a surge tank which absorbs and dissipates sudden fluctuations in pressure. For a constant water flow rate from the nozzles the speed of turbine changes with changing loads on it.

For quality hydroelectricity generation the turbine should rotate at a constant speed. To keep the speed constant despite the changing loads on the turbine water flow rate through the nozzles is changed.

To control the gradual changes in load servo-controlled spear valves are used in the jets to change the flow rate. And for sudden reduction in load the jets are deflected using deflector plates so that some of the water from the jets do not strike the blades. This prevents over speeding of the turbine.

OBJECTIVE:

The main objective is to generate electricity by using a Pelton wheel turbine. A Pelton-wheel impulse turbine is a hydro mechanical energy conversion device which converts gravitational energy of elevated water into mechanical work. This mechanical work is converted into electrical energy by means of running an electrical generator.

The kinetic energy of the Water-jet is directed tangentially at the buckets of a Pelton-wheel. The Water-jet strikes on each bucket's convex profile splitter and get split into two halves. Each half is turned backwards, almost through 180° relative to the bucket on a horizontal plane. Practically this angle may vary between 165° to 170°.

Normally all the jet energy is used in propelling the rim of the bucket wheel. Invariably some jet water misses the bucket and passes onto the tail race without doing any useful work. This hydro device is a good source of hydro-electrical energy conversion for a high-water head. Both kinetic and potential energy of the water source is consumed by the runner wheel.

Considerable gravitational effect of the water jet is exploited by means of some modifications in a conventional Pelton wheel. A comparatively heavy generator can be run by this modified Pelton-wheel turbine under low head and heavy-discharge conditions. The modified features provide enough promising opportunities to use this turbine for Mini and Micro hydro power plants.

COMPONENTS OF PELTON WHEEL TURBINE:

The Pelton Wheel Turbine consists of the following construction or parts:

Casing:

The Pelton wheel casing prevents water splashing and facilitates water discharge from the nozzle to the tailrace. Unlike in reaction turbines, the casing surrounding the wheel does not have a hydraulic function to perform.

Spear:

The Needle Spear controls the water flow inside the nozzle, ensuring a smooth flow and minimal energy loss. By moving the spear forward and completely closing the nozzle, the water striking the runner can be reduced to zero while the runner, due to inertia, continues to revolve for a certain time.

Break Nozzle:

A break nozzle is provided to bring the runner to a short stop, which directs the water onto the buckets. This mechanism is known as the breaking jet.

Runner or Rotor:

The Pelton wheel's runner or rotor rotates and possesses kinetic energy, featuring equally spaced hemispherical or double ellipsoidal buckets at its periphery. All the potential energy is converted into kinetic energy before the water jet strikes the rotor blades.

Penstock:

The penstock comprises channels or pipelines that transfer water from a high head source to the actual power station, supplying the Pelton wheel turbine with water for power generation.

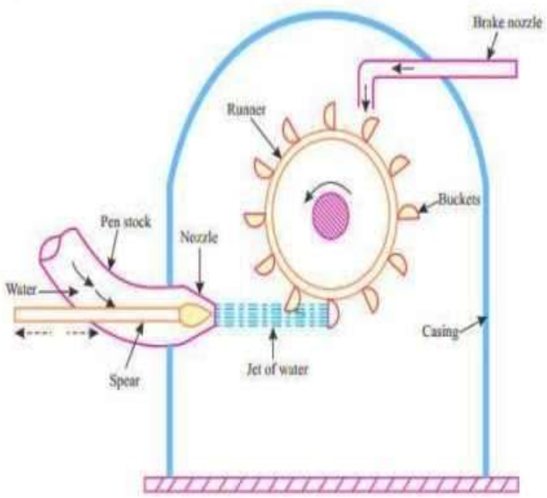

Fig: Line Diagram of Pelton wheel turbine

DETAIL & SPECIFICATION:

Model is dependent on each manufacturer. Each manufacturer should be contacted to verify a turbine will suit a particular site.

The **generator type** associated with micro hydro power is normally either a permanent magnet, a wound-field, or induction. Smaller turbines use permanent magnet generators, some of which have adjustable gaps between the magnets and the windings for tuning the output. Stand-alone synchronous generators have a wound-field that produces its own magnetic excitation, and induction generators receive their magnetic excitation from the stator, either via capacitors or the grid.

Maximum power is determined by the watts produced by the turbine at maximum water flow and net head. This number is used to calculate the size of charge controllers and dump loads necessary to protect turbines and battery banks, adding a safety factor.

Voltage of the type of generator used. Alternating current (AC) generators are used for either standard 60 Hz electricity or to produce “wild” unregulated voltage and frequency electricity, which is rectified to DC to charge batteries. “Wild” indicates that the turbine is not producing steady 60 Hz AC, and the frequency and voltage may vary. High-voltage generation (hundreds of volts instead of dozens of volts) can be useful in overcoming line losses.

AC/DC stands for alternating current and direct current. Smaller (100 to 1,000 W; less than 2 kW; 48 kWh/day) hydro-electric turbines use permanent-magnet, “wild” AC generators. Larger micro hydro systems (2 to 100 kW) use either an induction or synchronous AC generators. Virtually all spinning generators make AC natively, and how it is transferred and conditioned is based on the application. Battery charging turbines end up producing DC. The grid and your home loads are AC systems, so turbines designed to directly interface with them produce AC in the end.

Grid connection is possible with certain makes and models. The grid connection for a smaller (less than 2 kW) hydro system commonly uses a grid-tied inverter, as for PV systems. Larger systems (2 to 100 kW) are connected through switchgear and inductive generators or synchronous generators and governors.

Runner type identifies the turbine wheel used to convert water power to rotational power, and is determined by the head and flow available. Through testing, manufacturers have determined the best runner types for various head and flow conditions. Common types are the Pelton wheel, the turbo, the cross flow, and the propeller. Your turbine supplier and contractor can give good advice about the choices.

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Runner Material. Runners for micro hydro applications are commonly made of an alloy, since these materials resist corrosion and are easily cast and machined into shape. Stainless is most common in larger systems. Stainless steel and various bronze alloys are common, long-lasting materials. Plastics are used for smaller, less expensive runners.

Runner diameter selection is associated with the velocity of water impacting the runner, which is directly related to available head. The higher the head, the smaller the runner diameter for a given/constant shaft speed. Under ideal conditions, the runner velocity is approximately half the water jet velocity. For practicality, runners for smaller turbines are usually limited to just a few. The runner's speed is adjusted by means of the generator field in relation to battery voltage, or using belt pulley ratios in relation to the output frequency of direct AC systems Again; your suppliers are your best resources for helping make this choice.

Number of nozzles is a choice dependent on the range of water flow available to the turbine. Nozzles are opened or closed (manually for most small turbines, and occasionally automatically for larger turbines) to maintain maximum pressure in the turbine pipeline while taking advantage of available flow.

Having multiple nozzles is especially important where stream flow varies widely over the year, so you have the option of using more or less water.

Nozzle size options are associated with available water flow. Smaller-diameter nozzle sizes are used for lower-flow situations. Nozzles are sized by manufacturers based on potential range of flow. Generally, these parts are removable and replaceable. Larger systems sometimes have adjustable "needle nozzles" or "spear valves."

Head range is associated with types of turbine runners that can be used. Higher-head turbines use impact runners, which are generally Pelton or turbo designs. Mid-range turbines (suitable for 20 to 60 feet of head) use reaction runners, which are Submerged fully or partially, and include Francis and propeller runners. Low-head turbines (3 to 20 feet) may also use propeller reaction turbines.

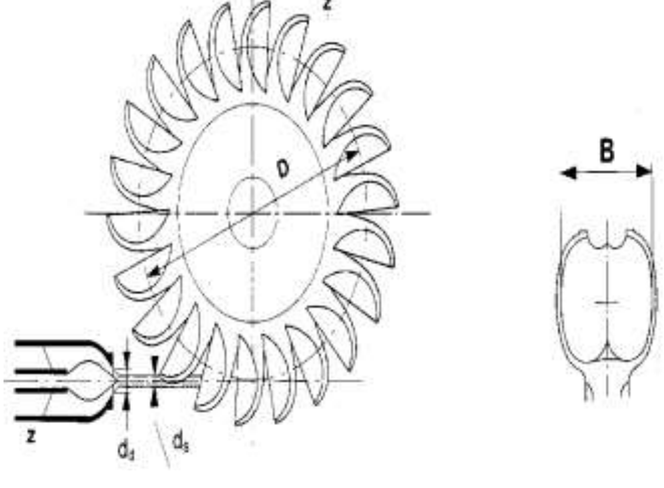
Flow range will vary for every project site. The table shows the actual flow used in the turbine, which may be 10% to 50% of the stream flow.

Controls and over-speed control are necessary for stand-alone AC turbines to maintain 60 cycles per second output under varying load conditions. Electronic load governors usually provide this control for AC units, shunting energy to resistive loads. Control is also necessary for grid-tied systems when utility outages occur. Without the load of the utility grid, a hydro turbine will over-speed, possibly resulting in mechanical and electrical failure.

Controls, dump load, and metering included describes what comes with a turbine and what must be purchased separately.

DESIGN CRITERION OF PELTON WHEEL TURBINE:

Dimensions:



$$u_1 = \frac{c_{1u}}{2} = \frac{1}{2} \cdot \sqrt{2 \cdot g \cdot H_n}$$

For Pelton runner:
For a real Pelton runner there will always be losses.
We will therefore set the hydraulic efficiency to:

$$\eta_h = 0.96$$

The absolute velocity from the nozzle will be:

$$0.99 \le \underline{c}_{1u} < 0.995$$

Circumferential speed:
C_{1u} can be set to 1,0 when dimensioning the turbine.
This gives us:

$$\eta_h = 2(\underline{u}_1 \cdot \underline{c}_{1u} - \underline{u}_2 \cdot \underline{c}_{2u})$$

$$\underline{u}_1 = \frac{\eta_n}{2 \cdot \underline{c}_{1u}} = \frac{0,96}{2 \cdot 1,0} = 0,48$$

From continuity equation:

$$Q = z \cdot \frac{\pi \cdot d_s^2}{4} \cdot c_{1u}$$

$$\Downarrow$$

$$d_s = \sqrt{\frac{4 \cdot Q}{z \cdot \pi \cdot c_{1u}}}$$

Where:
Z = number of nozzles
Q = flow rate
C_{1u} = $\sqrt{2 \cdot g \cdot H_n}$

The size of the bucket and number of nozzles

$$3.1 > \frac{B}{d_s} \ge 3.4$$

Rules of thumb:
B = 3,1 · ds 1 nozzle
B = 3,2 · ds 2 nozzles
B = 3,3 · ds 4-5 nozzles
B > 3,3 · ds 6 nozzles

Number of buckets
$z \ge 17$ **Empirical**

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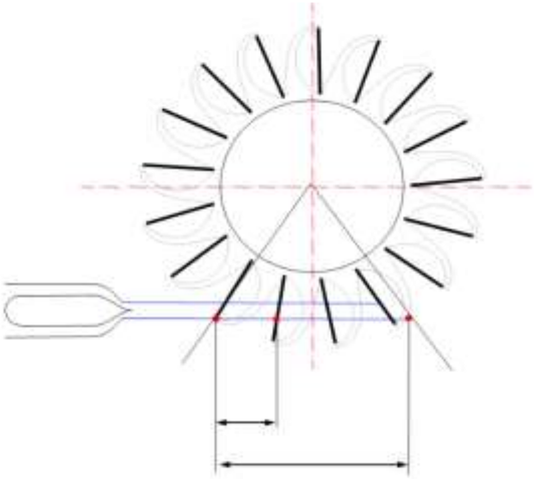
Number of buckets



Runner diameter
Rules of thumb:

D = 10 · ds   Hn < 500 m
D = 15 · ds   Hn = 1300 m
D < 9,5 · ds   must be avoided because water will be lost
D > 15 · ds   is for very high head Pelton

The number of poles on the generator:
The speed of the runner is given by the generator and the net frequency:

Zp = number of poles on the generator
The number of poles will be:

$$Z_p = \frac{3000}{n}$$

APPLICATIONS:
Pelton wheels are the preferred turbine for hydro-power where the available water source has relatively high hydraulic head at low flow rates. Pelton wheels are made in all sizes.
There exist multi-ton Pelton wheels mounted on vertical oil pad bearings in hydroelectric plants. The largest units – the Bieudron Hydroelectric Power Station at the Grande Dixence Dam complex in Switzerland – are over 400 megawatts.
The smallest Pelton wheels are only a few inches across, and can be used to tap power from mountain streams having flows of a few gallons per minute. Some of these systems use household plumbing fixture for water delivery. These small units are recommended for use with 30 metres (100 ft) or more of head, in order to generate significant power levels.
Depending on water flow and design, Pelton wheels operate best with heads from 15–1,800 metres (50–5,910 ft), although there is no theoretical limit.

CONCLUSION:
As a conclusion from the experiment that had been performed, we can conclude that different range of flow rates and rotational speeds influences the performance of Pelton wheel turbine. The combination of flow rate and jet velocity manipulates the power or work input. The bigger the diameter nozzle the faster the flow rates but lower in velocity jet. Therefore, we need the perfect combination of both. In general, impulse turbine is high-head, low flow rate device. So, we can assume that our experiment is successful due to the result we obtained.

REFERENCES:

https://en.wikipedia.org/wiki/Pelton_wheel
https://energyeducation.ca/encyclopedia/Pelton_turbine
https://commons.wikimedia.org/w/index.php?curid=53731013
https://testbook.com/mechanical-engineering/pelton-wheel-turbine
https://i0.wp.com/theconstructor.org/wp-content/uploads/2010/09/PELTON TURBINE.jpg?w=563&ssl=1
https://www.scribd.com/document/376259653/Pelton-Wheel-Project-Report-1