Small Hydro Power (SHP) Module

Students Guidebook

Study materials in Renewable Energy Areas
for ITI students

Ministry of New and Renewable Energy
Government of India

Content Development, Editing, Design and Layout
New Concept Information Systems Pvt. Ltd
E-mail: communication@newconceptinfosys.com
www.newconceptinfo.com

Students Guidebook
for
Small Hydro Power (SHP) Module

Ministry of New and Renewable Energy
Government of India

Contents

Unit 1: Introduction to Renewables

Q1. Write a note on Water Cycle.

Ans: Understanding the water cycle is important to understand the working of a hydro power plant. In the water cycle

- Solar energy heats water on the surface, causing it to evaporate.
- This water vapour condenses into clouds and falls back onto the surface as precipitation.
- The water flows through rivers back into the oceans, where it can evaporate and begin the cycle over again.

Directing, harnessing, or channelling moving water derives mechanical energy. The amount of available energy in moving water is determined by its flow or fall. Swiftly flowing water in a big river, like the Narmada or the Ganges, carries a great deal of energy in its flow. So too, with water descending rapidly from a very high point. In either instance, the water flows through a pipe, or penstock, then pushes against and turns blades in a turbine to spin a generator to produce electricity. In a run-of-the-river system, the force of the current applies the needed pressure, while in a storage system, water is accumulated in reservoirs created by dams, then released when the demand for electricity is high. Meanwhile, the reservoirs or lakes are used for boating and fishing, and often the rivers beyond the dams provide opportunities for whitewater rafting and kayaking.

Q2. Explain Small Hydro Power as a viable option.

Ans: Small and mini hydro projects have the potential to provide energy in remote and hilly areas where extension of an electrical transmission grid system is uneconomical. Realising this fact, the Indian government is encouraging development of Small Yydro Power (SHP) projects in the country. Since 1994, the role of the private sector for setting up of commercial SHP projects has been encouraged. So far, 14 States in India have announced policies for setting up commercial SHP projects through private sector participation. Over 760 sites of about 2,000 MW capacity have already been offered/ allotted.

An estimated potential of about 15,000 MW of SHP projects exist in India. 4,233 potential sites with an aggregate capacity of 10,071 MW for projects up to 25 MW capacities have been identified. In the last 10-12 years, the capacity of Small Hydro projects up to 3 MW has increased 4 fold from 63 MW to 240 MW. 420 small Hydro power projects up to

25 MW station capacity with an aggregate capacity of over 1,423 MW have been set up in the country and over 187 projects in this range with an aggregate capacity of 521 MW are under construction.

The MNES provides various incentives like soft loans for setting up of SHP projects up to 25 MW capacity in the commercial sector, renovation and modernisation of SHP projects, setting up of portable micro hydel sets, development/upgradation of water mills. India has a reasonably well-established manufacturing base for the full range and type of small hydro equipment. There are currently eight manufacturers within India in the field of small hydro manufacturing supplying various types of turbines, generators, control equipment, etc.

Unit 2: Small Hydro Power – Basic Working Principles

Q1. Explain how Micro Hydro power works.

Ans: Hydro power plants capture the energy of falling water to generate electricity. A turbine converts the energy of falling water into mechanical energy. Then an alternator converts the mechanical energy from the turbine into electrical energy. The amount of electricity a hydro power plant produces is a combination of two factors:

i). How far the water falls (Head): Generally, the distance the water falls depends on the steepness of the terrain the water is moving across, or the height of the dam the water is stored behind. The farther the water falls, the more power it has. In fact, the power of falling water is 'directly proportional' to the distance it falls. In other words, water falling twice as far has twice as much energy. It is important to note we are only talking about the vertical distance the water falls – the distance the water travels horizontally is consequential only in calculating the expense of the system and friction losses. 'Head' is usually measured in 'feet'.

ii). Volume of water falling (Flow): More water falling through the turbine will produce more power. The amount of water available depends on the volume of water at the source. Power is also 'directly proportional' to river flow or flow volume.

A river, with twice the amount of flowing water as another river, can produce twice as much energy. Flow volume is usually measured in 'gallons per minute', or 'GPM'.

For Micro Hydro systems, this translates into two categories of turbines:

For high head and low flow volume sites, impulse turbines are the most efficient choice. The power produced by an impulse turbine comes entirely from the momentum of the water hitting the turbine runners. This water creates a direct push or 'impulse' on the blades, and thus such turbines are called 'impulse turbines'.

For low head and high flow volume sites, a reaction turbine is the best choice. The reaction turbine, as the name implies, is turned by reactive force rather than a direct push or impulse. The turbine blades turn in reaction to the pressure of the water falling on them. Reaction turbines can operate on heads as low as 2 feet, but require much higher flow rates than an impulse turbine.

Q2. What are Impulse turbines and Reaction turbines?

Ans: The impulse turbine uses the kinetic energy from the water as it leaves the nozzle rather than the kinetic energy of air. In a system using an impulse turbine, water is diverted upstream of the turbine into a pipeline. The water travels through this pipeline to a nozzle, which constricts the flow to a narrow jet of water. The energy to rotate an impulse turbine is derived from the kinetic energy of the water flowing through the nozzles. The term ‘impulse’ means that the force that turns the turbine comes from the impact of the water on the turbine runner. This causes the attached alternator to turn, and thus the mechanical work of the water is changed into electrical power.

Most sites with a head of at least 25 feet now use impulse turbines. These turbines are very simple and relatively inexpensive. As the stream flow varies, water flow to the turbine can be easily controlled by changing nozzle sizes or by using adjustable nozzles.

Common impulse turbines are the Pelton, Turgo, Cross flow and Waterwheel or Chain turbines.

One major disadvantage of impulse turbine is that they are mostly unsuitable for low head sites.

Unit 3: Working of an SHP

Q1. Expain in brief the main parts of an SHP.

Ans: Small hydro power is not simply a reduced version of a large hydro plant. Specific equipments are necessary to meet fundamental requirements with regard to simplicity, high-energy output and maximum reliability.

Weir and Intake

An SHP must extract water from the river in a reliable and controllable way. A weir can be used to raise the water level and ensure a constant supply to the intake. Sometimes, a weir is not built because natural features of the river are used. The following are required for an intake:

- The desired flow must be diverted,
- The peak flow of the river must be able to pass the weir and intake without causing damage to them,
- Minimum maintenance and repairs, as far as possible,
- It must prevent large quantities of loose material from entering the canal,
- It should have the possibility for more piled up sediments.

Canal

The canal conducts water from the intake to the forebay tank. The length of the canal depends on the local conditions. In one case, a long canal combined with a short penstock can be cheaper or necessary while in other cases, the combination of a short canal with a long penstock is better suited. The canals are sealed with cement, clay or polythene sheets to reduce friction and prevent leakages. The size and shape of a canal is a compromise between cost and reduced head. The following are incorporated in a canal:

- Settling basin – these are basins which allow particles and sediments, which have come from the river flow, and which will settle on the basin floor. The deposits are periodically flushed.
- Spillways – these divert excess flow at certain points along the canal. The excess flow can be due to floods.

Forebay tank

The fore bay tank forms the connection between the canal and the penstock. The main purpose is to allow the particles to settle down, before the water enters the penstock.

Penstock

In front of the penstock, a trashrack is installed to prevent large particles from entering the penstock. Penstock is a pipe, which conveys water under pressure from the forebay tank to the turbine. Usually unplastified polyvinyl chloride (uPVC) is used to make penstock pipes. uPVC can reduce a lot of friction in the pipe, it is cheap and it can withstand pressure when compared to other materials that can be used to make penstock pipes.

Pipes are generally made and supplied in standard lengths and have to be joined together on site. There are several ways to join the pipe; flanged, spigot and socket, mechanical and welded. Expansion joints are used to compensate for maximum possible change in length.

Penstock pipes can be either be buried or surface mounted. This depends on the nature of the terrain and environment considerations. Buried pipelines should be 0.75 m below the surface so that vehicles do not damage it. However, one disadvantage can be, that if leaks occur in the pipes, it would be difficult to detect and rectify. When pipes are run above ground, anchors or thrust blocks are needed to counteract the forces which can cause undesired pipeline movement.

The pressure rating of the penstock is critical because the pipe wall must be thick enough to withstand the maximum water pressure. This pressure depends on the head; the higher the head the greater will be the pressure.

Powerhouse and trailrace

Powerhouse is a building that contains the turbine generator and the control units. Although the powerhouse can be a simple structure, its foundation must be solid. The tailrace is a channel that allows the water to flow back to the stream, after it has passed through the turbine.

Unit 4: Electrical and Mechanical Equipment in a small Hydro power Plant

Q1. What are the types of Reaction turbines? Explain them in brief.

Ans: There are four types of Reaction turbines:

I. Francis Turbine

This is either volute cased or an open flume machine. The runner blades are profiled in a complex manner and direct the water so that it exits axially from the centre of the runner. In doing so, the water imparts most of its pressure energy to the runner before leaving the turbine via a draft tube.

II. Propeller Turbine

This consists of a propeller fitted inside a continuation of the penstock pipe. The turbine shaft passes out of the pipe at the point where the pipe changes direction. A propeller turbine is known as a fixed blade axial flow turbine because the pitch angle of the rotor cannot be changed.

III. Kaplan Turbine

This is a propeller type turbine with adjustable blades.

IV. Reverse Pump Turbine

Centrifugal pumps can be used as turbines by passing water through them in reverse. Research is currently being done to enable the performance of pumps as turbines. The advantage is that it is low cost and spare parts are readily available.

Q2. What are the parts of an SHP drive systems?

Ans: The drive system transmits power from the turbine shaft to the generator shaft. It also has the function of changing the rotational speed from one shaft to the other, when the turbine speed is different to the required speed of the generator. The part of an SHP drive system are:

- Direct drive
- Flat belt and pulley
- V or wedge belt and pulleys
- Chain and sprocket
- Gearbox

Q3. What are the types of generators? Explain them in brief.

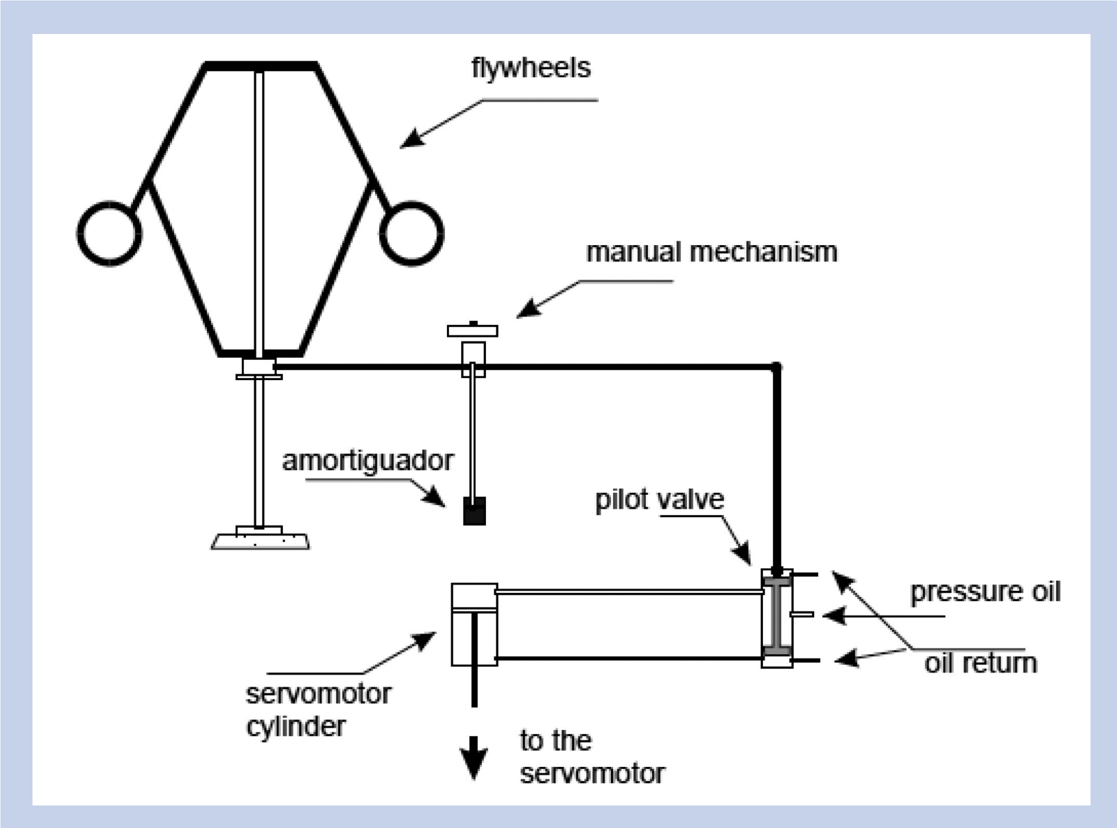
Ans: There are two types of generators and depending on the characteristics of the network supplied there can be a choice between:

- **Synchronous generators:** They are equipped with a DC electric or permanent magnet excitation system (rotating or static) associated with a voltage regulator to control the output voltage before the generator is connected to the grid. They supply the reactive energy required by the power system when the generator is connected to the grid. Synchronous generators can run isolated from the grid and produce power since excitation is not grid-dependent.
- **Asynchronous generators:** They are simple squirrel-cage induction motors with no possibility of voltage regulation and running at a speed directly related to system frequency. They draw their excitation current from the grid, absorbing reactive energy by their own magnetism. Adding a bank of capacitors can compensate for the absorbed reactive energy. They cannot generate when disconnected from the grid because are incapable of providing their own excitation current. However, they are used in very small stand-alone applications as a cheap solution, when the required quality of the electricity supply is not very high.

Q4. What is a speed governor?

Ans: A speed governor is a combination of devices and mechanisms, which detect speed deviation and convert it into a change in servomotor position. A speed-sensing element detects the deviation from the set point; this deviation signal is converted and amplified to excite an actuator, hydraulic or electric, that controls the water flow to the turbine. In a Francis turbine, where there is a reduction in water flow, you need to rotate the wicket-gates. For this, a powerful governor is required to overcome the hydraulic and frictional forces and to maintain the wicket-gates in a partially closed position or to close them completely.

Several types of governors are available, varying from old fashioned purely mechanical to mechanical-hydraulic to electrical-hydraulic and mechanical-electrical. The purely mechanical governor is used with fairly small turbines, because its control valve is easy to operate and does not require a big effort. These governors use a flyball mass mechanism driven by the turbine shaft. The output from this device - the flyball axis descends or ascends according to the turbine speed - directly drives the valve located at the entrance to the turbine.



Q5. Why is a speed increaser required?

Ans: When the turbine and the generator operate at the same speed and can be placed so that their shafts are in line, direct coupling is the right solution; virtually no power losses are incurred and maintenance is minimal. Turbine manufacture's recommend the type of coupling to be used, either rigid or flexible, although a flexible coupling that can tolerate certain misalignment, is usually recommended.

In many instances, particularly in low head schemes, turbines run at less than 400 rpm, requiring a speed increaser to meet the 750-1000 rpm of standard alternators. In the range of powers contemplated in small hydro schemes, this solution is often more economical than the use of a custom made alternator.

Nowadays, alternator manufacturers also propose low speed machines that allow direct coupling.

Unit 5: Measuring Head and Flow

Q1. How would you select the best water source site?

Ans: There may be several potential water source points, particularly if the water source is a river or stream. Each one will have a different elevation and linear distance from the hydro turbine. In selecting the best site, several factors that one should consider are water availability, site access, topography of the site, elevation (potential static head), linear distance from the turbine, head pressure required for the turbine, and the volume of water required for the turbine. The best site will usually be the one that has the best cost-benefit ratio (the least cost per KWh of electricity produced). The site with the highest elevation may not be the best, as that site may also have the highest incremental cost of diverting and transporting the water to the turbine.

Q2. List the different methods of measuring the head for a closed diversion system. Explain them in brief.

Ans: There are a couple of commonly used methods of measuring head for a closed diversion system:

- Use a transit or level and a measuring stick of known length to measure the vertical elevation change in successive steps down the slope. The cumulative total of the vertical measurements is the head in feet.
- Assemble a temporary piping system (a series of connected garden hoses works well for this) and with a water pressure gauge, measure the static pressure (in pounds per square inch or PSI) at the lower end of the hose system, with the hose filled with water.

Convert the static pressure to vertical feet of head, using the formula 0.43 PSI = 1.0 foot of head. This method can also be done in successive steps to measure total head over a longer distance. This method is quite accurate.

Several methods exist for measurement of the available head. Some measurement methods are more suitable on low-head sites, but are too tedious and inaccurate on high-heads. If possible, it is wise to take several separate measurements of the head at each site. One should always plan for enough time to allow on-site comparison of survey results. It is best not to leave the site before analysing the results, as any possible mistakes will be easier to check on site.

A further very important factor to be aware of is that the gross head is not strictly a constant but varies with the river flow. As the river fills up, the tailwater level often rises faster then the headwater level, thus reducing the total head available. Although this head variation is much less than the variation in flow, it can significantly affect the power available, especially in low-head schemes where every half metre is essential. To assess the available gross head accurately, headwater and tailwater levels need to be measured for the full range of river flows.

Unit 6: Generating Power

Q1. What is the benefit of a draft tube?

Ans: A water discharge tube is called a 'draft tube' it can increase the head by producing a vacuum between the turbine runner blades and the level of the exit water. This is called the 'suction head' and can increase power output of the turbine by up to 20 percent, if it is set up properly. It is important that it is completely submerged in the tail water with no air leaks, maintaining a closed system and thus, the vacuum suction. With this system, the total head is a combination of the pressure head and the suction head.

Q2. Write down the causes of head loss.

Ans: Head losses occur when water flows from the intake to the turbines through canals and penstock. Water loses energy (head loss) as it flows through a pipe. Net head is the gross head mines the head loss which occurs due to:

i. Friction against the wall.

The friction against the pipe wall depends on the wall material roughness and the velocity gradient which is near the wall. The friction in the pipe walls can be reduced by increasing the pipe diameter. However, increasing the diameter increases the cost, so a compromise should be reached between the cost and diameter.

ii. Flow turbulence

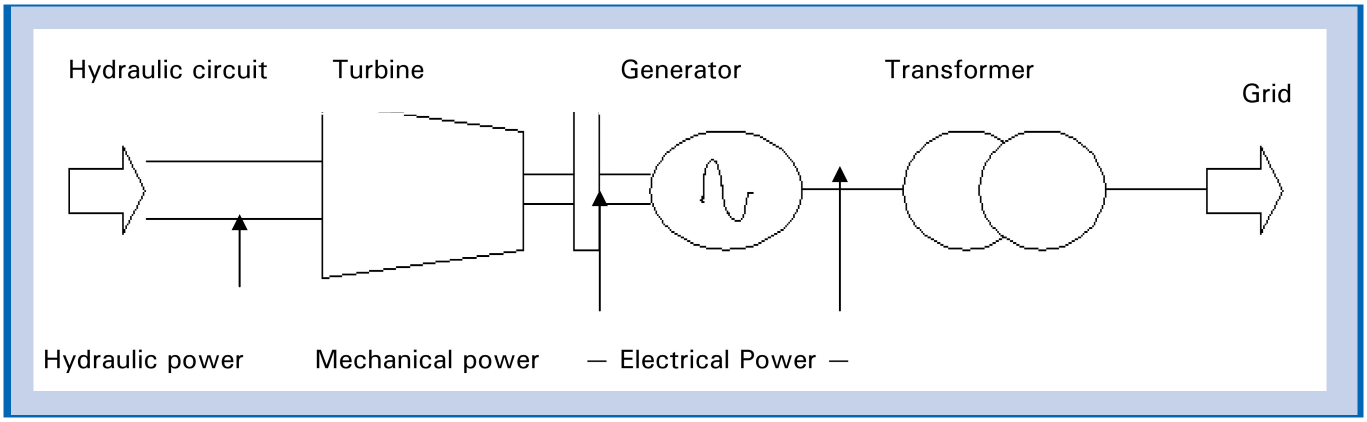
Water flowing through a pipe system with bends, sudden contractions and enlargement of pipes, racks, valves and other accessories, experience, in addition to the friction loss, a loss due to inner viscosity. This loss depends on the velocity and is expressed by an experimental K multiplied with the kinetic energy $\frac{v^2}{g2}$. Water flow in a pipe bend, experiences an increase of pressure along the outer wall and a decrease of pressure along the inner wall. This pressure inbalance causes a secondary current. Both movements together (the longitudinal flow and the secondary current) produces a spiral flow, at a length of around 100m and is dissipated by viscous friction. The head loss produced depends on the radius of the bend and the diameter of the pipe.

The loss of head produced by water flowing through an open valve depends on the type and manufacture of the valve.

Q3. How would you calculate the overall efficiency of an SHP?

Ans: The figure below shows the power conversion scheme.

Figure : Power conversion scheme (15)



The final power (P_f) output from SHP is smaller than available hydraulic power (P_i)

$P_f = \eta P_i$

That is, $P_f(KW)=(9.81).n.Q.H$ ....(3)

Where η is the overall efficiency.

This results from multiplication of partial efficiencies.

$$\eta = \eta_{turbine} . \eta_{generator} . \eta_{transformer}$$

$\eta_{turbine}$ => This depends on the type of turbine used.

$\eta_{generator}$ => This depends on the size of the generator.

$\eta_{transformer}$ => This depends on the size of the transformer.

Unit 7: Economics of using an SHP

Q1. Write down the advantages and shortcomings of an SHP.

Ans: Some of the key advantages of an SHP are:

- Environmental protection through CO_2 emission reduction – CO_2 emission is reduced because electricity production from an SHP does not release CO_2 in the process
- Proven and reliable technology
- Improves the diversity of energy supplies – this is the one of many alternatives of producing electricity
- Grid stability
- Reduced land requirements – unlike in wind energy, where a fair bit of land is required to install a wind turbine
- Local and regional development – leads the community to be independent of fossil fuel
- Assists in the maintenance of river basins
- Technology suitable for rural electrification in developing countries
- High energy payback ratio

Shortcomings of an SHP

Some of the shortcomings are:

- SHP is a site specific technology and usually the site is faraway from the place where the electricity is required
- Run-of-the river plants experience significant fluctuations in output power

Unit 8: Water Mills

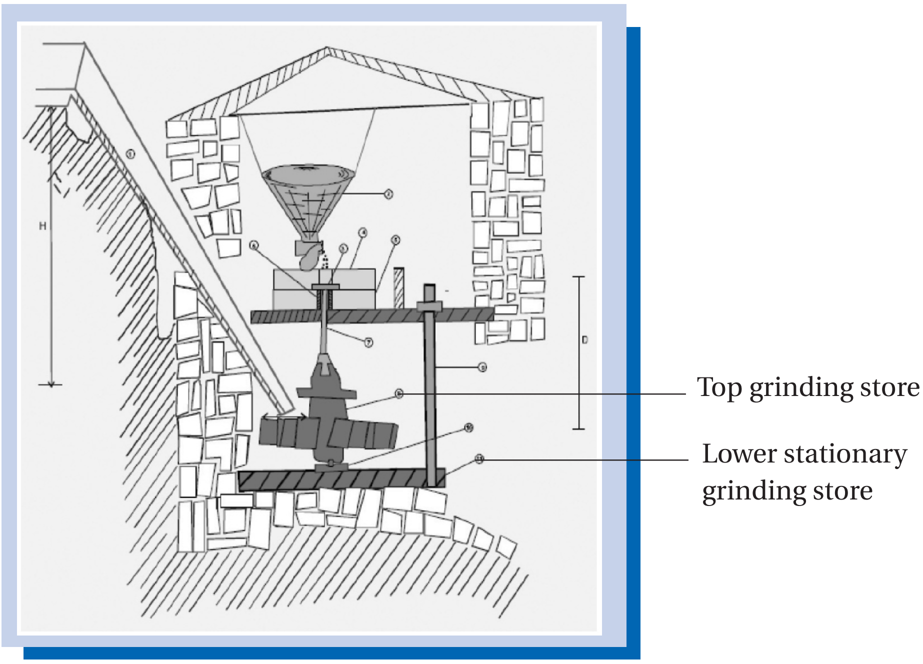
Q1. Write a short note on water Mills.

Ans: The idea of using energy in water and converting it into mechanical energy has been known to mankind for a long time. In ancient times, mechanical power was developed by passing flowing water through wheels and such wheels, known as water wheels, were used in China, India, Egypt and later in Europe. Vertical shaft wooden water mills generally used only for grinding grains and are called *"Gharats"*. These gharats operate under a head of 2 to 5 metres to produce on an average of 1.0 KW mechanical output.

Traditional Water Mill

A traditional water mill consists of a wooden turbine with straight wooden blades, fitted at an incline to a thick vertical wooden shaft, tapering at both ends. The water chute consists of an open channel, either made from wooden planks or carved from a large tree trunk. The chute is narrowed down toward the lower end, to form a nozzle. The wooden shaft of the turbine is supported on a stone pivot through a steel pin and held in the sliding bearing at the top. The sliding bearing is a wooden bush fixed in the lower stationary grinding stone. The top grinding wheel rests on the lower stone and is rotated by the turbine shaft through a straight slot coupling. The gap between the stone is adjusted by lifting the upper stone with the help of a lift mechanism.

Figure : Label Parts



The parts of the machines are very simple and are easy to understand by local people. The newly designed water mill consists of the following components:

Runner

The diameter of the runner is about 750 mm having 16 blades. The complete runner is cast in single-piece and weighs about 50 kg.

Drive Shaft

A steel shaft of 50 mm diameter has been used as a drive shaft. The upper end of the shaft is cut in rectangular form to fit the rynd/cam for the upper stone attachment.

Bottom Bearing

A very simple bottom bearing which has a ball is press fitted at the lower end of the shaft, which in turn rests on a piece of hard steel.

Wooden Bush

A simple oil soaked wooden bush made of hard wood is used in the upper stone hole to hold the shaft straight and aligned vertically.

Rynd or Cam

Cam is used for revolving the upper stone over the bottom stone which is fitted with a driving shaft.

Q2. Write down the installation procedure for new Improved water Mills.

Ans: Step I: Ensure the Tools

To enable the installation of the improved system, well maintained and good quality tools are essential. First of all, check all the tools such as; hammer, sheet cutter, file, grease gun, hacksaw, plumb, screw driver, draw bar, spirit level, spanner, wood saw, chisels.

Step II: Dismantling of Traditional Water Mill Components

The components of a traditional water mill should be dismantled in order to fit the improved components.

Step III: Fitting of Bottom Bearing

To ensure the shaft alignment in a proper vertical position with respect to the cross bar over foot bearing at the lower end and the upper grinding stone at the upper end, a centre mark should be made on the cross bar. Taking this mark as the centre of bottom bearing spindle, the plate of the bearing is fixed by putting nails on the cross bar.

Step IV: Shaft Fixing with Runner

After placing the runner over the bottom bearing from the downstream side place the shaft through the hole of the lower grinding stone from the upstream side. After, the alignment of the shaft with the runner, put the pin through the holes of the runner hub and the shaft in order to fit the runner with the shaft. Now put the wooden bush inside the hole of the lower grinding stone over the shaft.

Step V: Fitting the Remaining Components

After fitting the runner with the shaft, fix the rynd at the upper end of the shaft and place the upper grinding stone over the lower grinding stone. Fix all the remaining components.

Step VI: Alignment of the Water Jet

Alignment of the chute is one of the essential requirements of the water mill installation. In case of the new runner the water jet must strike 3 blades on the inside of the runner. The water flow is from the inside to the outside direction, as the runner is the 'outward' flow type.

Q3. Write a note on Maintenance of Water Mills.

Ans: Maintenance of Chute Inlet

For a smooth flow, from the power channel to the chute, the joint should be maintained properly.

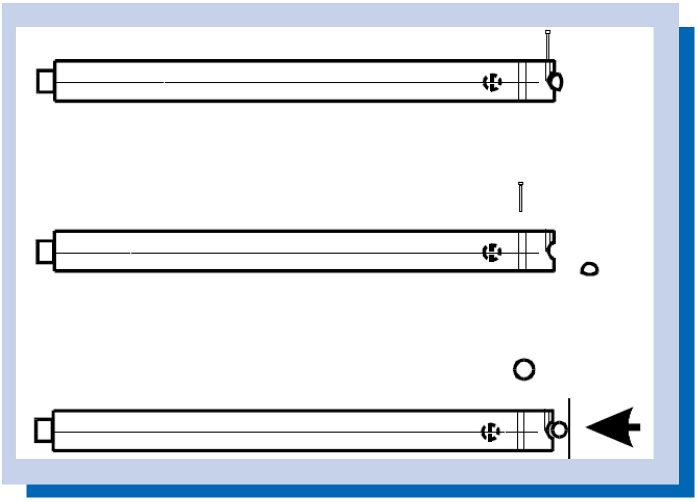
Maintenance of Water Chute

With use, the surface of the water chute gets worn out and the surface in contact with the water becomes rough, causing loss of head due to friction. Try to make this surface smooth by maintaining it properly.

Bottom Bearing Ball

Sometimes the alignment of the shaft gets disturbed due to the thrust of the water jet through the chute. This misalignment resluts in wobbling in the runner. This may damage the foot bearing and the hub of the runner. It is suggested to the owner/operator that he should check the alignment of the shaft regularly, if there is any misalignment then find out what the cause is and get it rectified immediately.

Figure : Alignment of the shaft



Alignment of the Shaft

The bottom bearing ball fitted with the shaft revolves over the foot bearing spindle. This ball gets worn out over a period of time. The ball should be replaced with a new one however, the life of the ball may be increased by providing proper lubrication. The owner/operator must ensure the lubrication before starting the system.

There is a hole embedded at the end of the shaft. By striking a nail with a hammering device, the ball inside the hole in the shaft is drawn outside. For inserting the new ball in the given hole of the shaft the wooden batten is stroked on the outer surface of the shaft.

Q4. List in detail the impacts of water mill upgrades.

Ans: Improved water mills have helped the water milling community in various ways.

Improved revenue and position

The increased processing capacity of the improved water mills has helped the owner to process more, by attracting more customers from distant villages, which has resulted in increased income. Income has also been high due to the willingness of customers to pay more service charges for efficient processing. The pay back period for the additional investment made on the water mill upgradation is about 4 years. The improved water mill owners now have a respectable status in the village and the enterprise is considered as one of the prestigious ones. There has been upliftment of the social status of the owners. The upgradation also has resulted in increased inflow of ground flour to the families of water mill operators, which is given as a fee for the grinding work. In some cases, the millers are able to sell in the local market, The additional flour obtained.

Variety of end-use possibilities

Although the upgraded water mill has potential for many end use applications, the main application of the improved mill at present is mainly limited to grinding and hulling only. Attempts are being made to extend the end usage applications for oil expelling, spice grinding, juice extraction, alternator, wool carding and welding.

Ease of Maintenance

The mill owners had to replace the wooden runner every 2 years while the improved mill runner can be used for more than 10 years. The owners had to tighten the wooden blades of the runner every 2 to 3 days. In improved mill, only the repair of the pin bearing is required every 2-3 months.

Time of grinding

Because of increased processing capacity of the upgraded mills, the processing/waiting time of the village customers has been reduced drastically. The time thus saved is utilised in fodder/fuelwood collection, household sanitation, childcare etc.

Quality of processed grain

The flour from improved mills is finer than that of the traditional mills. The quality is also better than that of the diesel mills, as the rotational speed in diesel mills is much more (about 700 rpm) than that of upgraded mill, which in turn deteriorates the taste and quality of the ground flour due to generation of more heat.

Environment

The improved mill has reduced installation of diesel mills to some extent and the consumption of diesel oil, subsequently reducing the money outflow from local village communities. As compared to diesel mills and any other micro-hydro scheme, the improved mill installation has very negligible environmental effects.

Socio-economic development

In times to come, the village information centre powered by upgraded water mills will provide basic computing facilities including internet connectivity for the local community. The people will have accessibility to a wide range of information on education, health, employment, finances etc. through software, information kits, CDs, and internet. Through the local browser, the local community will be able to produce the local content, and to access the internet without language barriers. The Information centre will result in dissemination of information obtained from the internet among the local community for developmental requirements. The idle time of the water millers will be utilised for developmental activities of the community as a whole, and also help in building capacity of the youth and the unemployed, in terms of computer literacy and employment generation.

Employment and income generation

Local blacksmiths, carpenters and technicians will get more job opportunities as their technical capabilities are enhanced and the market for water mill upgrades develop.