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Research Article

Suitability of Archimedes Screws for Micro Hydro Power Generation in India

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Abstract

Micro-hydro power plant At Kabitkhedi, Indore, India is based on Archimedes Screw turbine is a type of renewable energy power plant that is environment friendly, easy to be functioned and operates on low costs, etc. The outcome of initial survey shows that the seepage water has hydraulic potency about 29.43 kW. According to the result, micro-hydro power plant based on Archimedes Screw turbine has been planned to this location. The power plant having19.5 kW of its practical power based on flow rate 0.6 m3/s and head height 5 m. Turbine for the power plant is mixed flow Archimedean turbine. The results show that significant potential exists for energy recovery in the water industry. However, several previous studies have not considered key complexities such as dissimilarities in flows or turbine efficiency. Correspondingly, precise costing and return on speculation data are often absent or deficient sensitivity analysis. Further research is essential to report the risks and long-term reliability of installations, accompanied by the development of firm policy to direct and incentivize sustainability gains in this area.(Jash Engineering Limited, 2012-2013)Micro-hydro-electric power is both an efficient and reliable form of clean source of renewable energy. It can be an excellent method of harnessing renewable energy from small rivers and streams. The micro-hydro project designed to be a run-of-river type, because it requires no reservoir in order to power the turbine. The water will run straight through the turbine and back into the river or stream to use it for the other purposes. This has a minimal environmental impact on the local ecosystem. The choice of the turbine type depends mainly on the site head and flow rate. The turbine power and speed were directly proportional with the site head, but there were specific points for maximum turbine power and speed with the variation of the site water flow rate. The turbine efficiency could range from 80 to 95 percent and the generator efficiency about 90 percent. A feasibility study has been carried ready for a micro hydroelectric installation in India.(Nasir Bilal Abdullah, 2013)

Keywords: *micro-hydro power plant based on Archimedes Screw turbine at Kabitkhedi, Indor e(MP), India*

1. Introduction

Micro hydropower is an eco-friendly, fish friendly, non-polluting renewable source of energy. It is the oldest renewable energy method for production of electricity known to mankind mechanically. According to Kyoto protocol of 1997, most of industrialized countries agreed to set some emission reduction target in order to maintain environmental & climatic equilibrium of the world exposed by greenhouse effect, ozone depletion etc. To overcome these problems, renewable energy can be utilized to meet those international targets. In current scenario, India is blessed with half a million locations where water mills are serving for centuries. (University College London, 2012). Under the Prime Minister's "Reconstruction Plan for J&K", it was decided toset up 1000 micro hydro projects in Jammu & Kashmir. A total of 948 micro hydro projects of 3-5 KW each have been installed in Jammu & Kashmir. of these 550 projects are in Kashmir region, 339 in Jammu region and 59 in Ladakh region.If micro hydro power plants are installed there, an energy equivalent of 15000MW can be generated & 20 million Indians may get employed. There are nearly 5lac (approx.) potential sites over the entire Himalayan region from Jammu & Kashmir to north eastern states and can generate power as much as of 25000 MW i.e. each can generate at least 5KW. Till date only 25% (approx.) of the total hydro power potential has been tapped to generate power. Water mills are enough to run TV, refrigerator, cooler, fan & light bulbs etc. Small scale hydropower constitutes a cost effective technology for rural areas in developing countries and, on the other hand, is a quiet growing sector in India. (Jindal Alok Kumar, 2007) In the last decade, problems related to energy crisis such as oil crisis, climatic change, electrical demand and restrictions of whole

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sale markets have risen world-wide. These difficulties are continuously increasing, which suggest the need of technological alternatives to assure their solution. One of these technological alternatives is generating electricity as near as possible of the consumption site, using the renewable energy sources, that do not cause environmental pollutions, such as wind, solar, tidal and micro hydro-electric power plants. (Ministry of New and Renewable Energy, 2014)

1.1 History of screw turbine

The screw turbine is a water turbine which uses the principle of the Archimedean screw to convert the potential energy of water on an upstream level into kinetic energy. It may be compared to the water wheel, though the screw turbine has a much higher efficiency.

The invention of the water screw is credited to the Greek polymath Archimedes of Syracuse in the 3rd century BC. A cuneiform inscription of the Assyrian king Sennacherib (704 - 681BC) has been interpreted by Dalley to describe the casting of water screws in bronze some 350 years earlier (Berkeley University, 2007). This is consistent with the classical author Strabo who describes the Hanging Gardens as watered by screws. A contrary view is expressed by Dalley and Oleson in an earlier review. The German engineer Konrad Kyeser, in his Bellifortis (1405), equips the Archimedes' screw with a crank mechanism. The Archimedean screw is an ancient invention; attributed to Archimedes of Syracuse (287–212 BC.), and commonly used to raise water from a watercourse for irrigation purposes. (P. J. Kantert, 2008) In 1819 the French engineer Claude Louis Marie Henri Navier (1785–1836) suggested using the Archimedean screw as a type of water wheel. In 1922 William Moerscher patented the hydrodynamic screw turbine in America. (Renewable First, 2015)

1.2 History of Micro Hydro Power Plant

The first hydroelectric scheme was installed in Wisconsin in 1882; three years after Thomas Edison invented the light bulb. Soon after, hydropower became an important resource for electricity generation. 20% of total electricity consumed worldwide comes from hydro electrical plants. In some countries hydropower supplies 80% of electricity. This has generally been supplied by larger hydroelectric schemes. Interest in small hydro declined from its historical roots due to the success of these large hydropower plants in bringing down costs and the success of other technologies such as nuclear and diesel generation. However concern about climate change, air quality and nuclear generation and increasing costs of fossil fuel based generation has renewed interest in small hydro and other renewable forms of generation. (Green Bug Energy Inc., 2015) The use of falling water as a source of energy is known for a long time. In the ancient times waterwheels were used already, but only at the beginning of the nineteenth century with the invention of the hydro turbine the use of hydropower got a new impulse. Small-scale hydropower was the most common way of electricity generating in the early 20th century. In 1924 for example in Switzerland nearly 7000 small scale hydropower stations were in use. The improvement of distribution possibilities of electricity by means of high voltage transmission lines caused fainted interest in small scale hydropower. Renewed interest in the technology of small scale hydropower started in China. Estimates say that between 1970 and 1985 nearly 76,000 small scale hydro stations have been built there. (Berkeley University, 2007) In 1995, the micro-hydro capacity in the world was estimated at 28 GW, supplying about 115 TWh of electricity. About 60% of this capacity was in the developed world, with 40% in developing areas. Micro hydro plants that are found in the developing world are mostly in mountainous regions for instance in some places in the Himalayas as well as in Nepal where there are around 2,000 schemes, including both mechanical and electrical power generation. In South America, there are micro-hydro programs in the countries along the Andes, such as Peru and Bolivia. Smaller programs have also been set up in the hilly areas of Sri Lanka, Philippines and some parts of China (Energypedia, 2015)

1.3 Working of screw turbine based plant

The screw turbine is a water turbine which uses the principle of the Archimedean screw to convert the potential energy of water on an upstream level into kinetic energy. It may be compared to the water wheel, though the screw turbine has a much higher efficiency. The turbine consists of a rotor in the shape of an Archimedean screw which rotates in a semicircular trough. Water flows into the turbine and its weights presses down onto the blades of the turbine, which in turn forces the turbine to turn. Water flows freely off the end of the turbine into the river. The upper end of the screw is connected to a generator through a gearbox. (P. J. Kantert, 2008)

The Archimedean screw turbine is applied on rivers with a relatively low head (from 1 m to 10 m) and on low flows (up to around 10 m3/s on one turbine). Due to the construction and slow movement of the blades of the turbine, the turbine is considered to be friendly to aquatic wildlife. It is often labelled as "fish friendly". The Archimedean turbine may be used in situations where there is a stipulation for the preservation and care of the environment and wildlife. (P. J. Kantert, 2008)

The low rotational speed and large flow-passage dimensions of Archimedean screws also allow fish to pass downstream through the screw relatively safely. Archimedean screws are often touted as 'fish friendly' hydro turbines, which they undoubtedly are, though we at Renewables First would say that all hydro systems should be fish friendly, regardless of turbine type. In non-screw hydro systems this just means well designed intake screens and fish passes / by passes would be required. Note that if upstream fish passage is required at an Archimedean screw site, a fish pass will be required. The final advantage of the Archimedean screw is simplified civil engineering works and foundations. Because screws don't have draft tubes or discharge sumps, it means that the depth of any concrete works on the downstream-side of the screw is relatively shallow, which reduces construction costs. The civils works are also relatively simple, the main part being the load-bearing foundations underneath the upper and lower bearings. In softer ground conditions the load-bearing foundations can be piled. (Renewable First, 2015)

2. Experimental Setup: (Jash Engineering Limited, 2012-2013)

Figure: 2.1

2.1Technical Specification of Plant: (Jash Engineering Limited, 2012-2013)

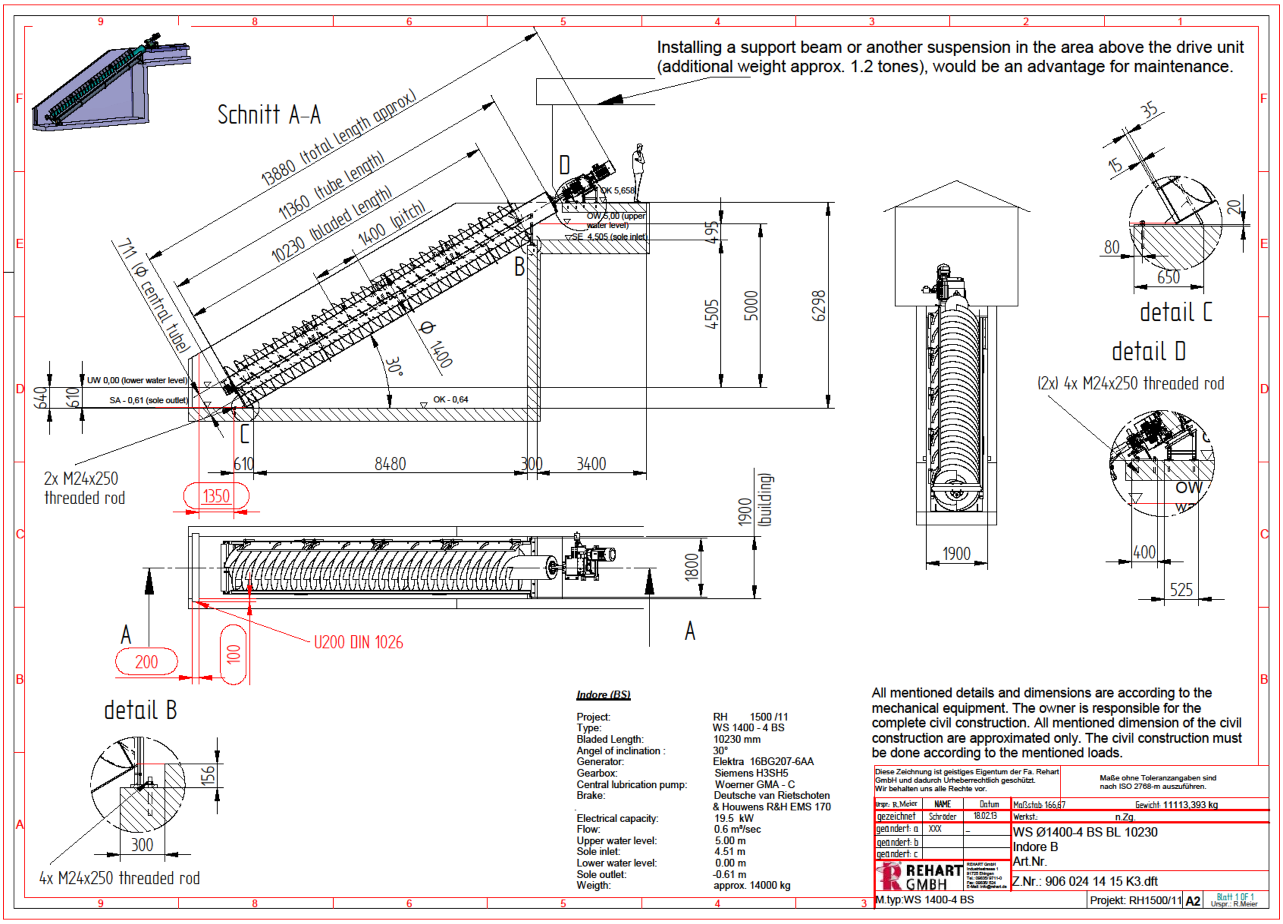

Figure: 2.2

2.2 Comparison Between various turbines: (Jash Engineering Limited, 2012-2013)

Turbine Type→	Screw Turbine	Cross Flow Turbine	Kaplan Turbine	Francis Turbine
Efficiency	Up to 90%.Remains constant with varying load.	Up to 85%.Remains constant with varying load.	Above 90%.Comes down drastically at varying load.	Above 90%.Comes down changes at varying load.
Output	Varies proportionally to inlet flow conditions and there is no risk of damage from running dry.	Varies proportionally to inlet flow conditions.	Requires a constant flow & Head to generate power. Output comes down exponentially at part inlet flow condition. Generally does not perform at low flow in summer season.	Requires a constant flow & Head to generate power.
Generation Capacity	Good for 5 KW to 500 KW	Good for 5 KW to 100 KW	Good for 75 KW to 5 MW	Up to 1000MW
Head	Best for ranges from 1 m to 10 m	Best for ranges from 1.75 m to 40m	Best for ranges from 2 m to 50 m	Best for ranges from 30 m to 800 m
Discharge	Can work efficiently from 0.2 m^3/s to 10 m^3/s	Can work efficiently from 0.04 m^3/s to 5 m^3/s	Can work efficiently from 3 m^3/s to 30 m^3/s	Approx. more than 1m
Ease Of Installations	Factory pre-assembled, less civil work.	Requires Penstock & Draft tube.	Requires Penstock & Draft tube. Very expensive civil work.	Requires Penstock & Draft tube. Very expensive civil work.
Installation Period	2-3 months	5-6 months	10-12 months	More than 1 years
Durability	Only Water required	Only clear water required	Only clear water required	Only clear water required
Wear & Tear	Negligible	High	Very high	Very high
Reliability	Excellent	Good	Good	Good
Maintenance	Negligible	Regular	Regular	Regular
Environment Compatibility	Fish compatible	Fish incompatible	Fish incompatible	Fish incompatible

Figure: 2.3

2.3 Objectives and advantages of Micro hydro power plant with Screw turbine: (Jash Engineering Limited, 2012-2013)

- Eco friendly in nature and has zero polluting effect on environment.
- Cutting of trees & displacement of people are not needed.
- Suitable for power consumption of small villages or one or more than one families.
- Sources – Renewable energy resources
- Small canals, ponds & rivers etc. can be utilized as resources.
- Negligible maintenance & operational cost.
- Fish friendly.
- Easy & fast installation.
- Less civil work required.
- High reliability.
- Efficient for low & variable water heads (min. 1m head).
- Durability (mode of operation).
- Low wear & tear.
- Cavitation & erosion can't affect the turbine.
- Efficiency will remain same with respect to varying loads.
- No control system necessary.
- Efficiency is more as compared to water wheels & small turbines.
- Ultra long life at least 30 years.
- Insensitive to clogging.
- CO2 reduction.
- Natural flow of water i.e., no pressure built up
- Wild life habitat will not be affected.

3. Results

The mechanical power produced by an Archimedean Screw Turbine power plant is $P = \omega T$, where, ω is the rotational speed of the turbine in rad/s and T is the torque in Nm. A typical test involved setting operating parameters (flow Q, Water Head H, etc.) at angle 300 and varying braking load to produce a torque/speed with respect to discharge. Since power is the product of torque and rotation speed, each operating condition will have an optimal point on the torque speed curve that maximizes power production. During testing, a nominal flow rate of 0.6 m3/s and head of 5 m was used, giving a typical P_{max} of 19.5 KW & $P_{theoritical}$ is 29.43 KW with overall efficiency of 66.2589%.

Graph between Power & Discharge

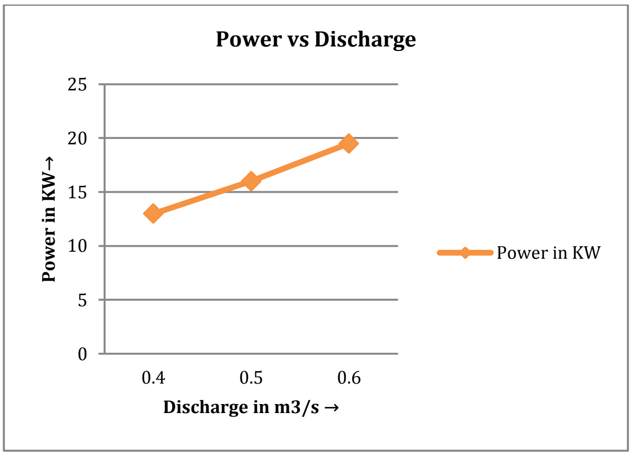

Figure: 3.1

Interpretation: In Figure:-3.1 Power is increasing with respect to increasing in Discharge.

Graph between Power & Speed

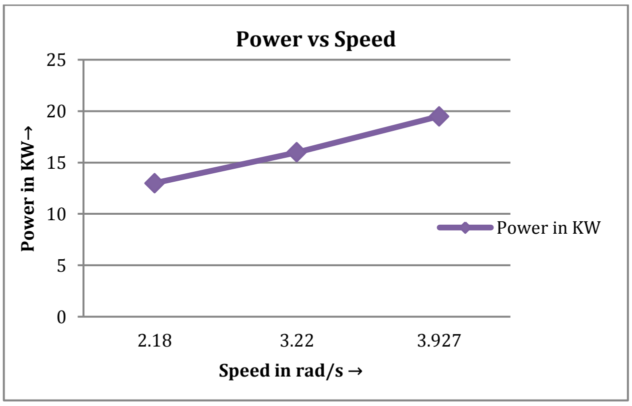

Figure: 3.2

Interpretation: In Figure:-3.2 Power is increasing with respect to increasing in Speed.

Graph between Speed & Discharge

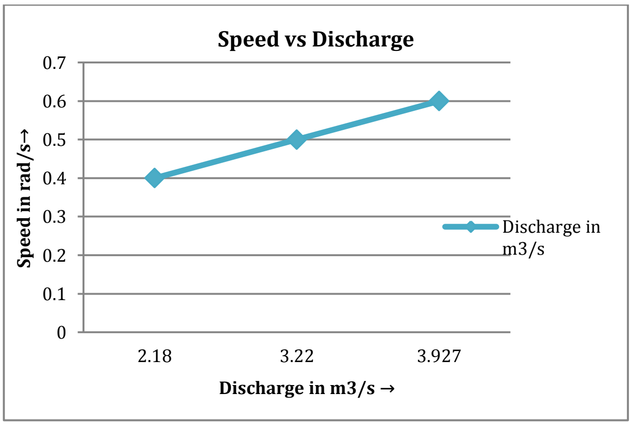

Figure: 3.3

Interpretation: In Figure:-3.3 Speed is increasing with respect to increasing in Discharge.

Comparison between Power, Speed & Discharge

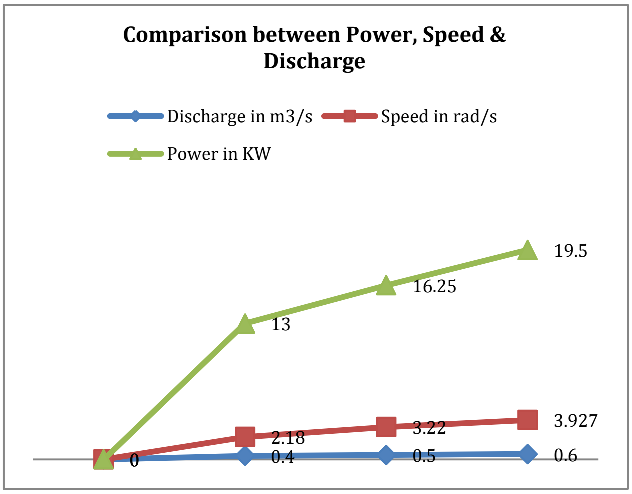

Figure: 3.4

Interpretation: In Figure:-3.4 Power as well as Speed depend on Discharge at same Head because all the parameter depend two main parameter viz., Head & Discharge. At this condition all the parameters only depend on Discharge. Hence Power as well as Speed increased with increased in Discharge.

4. Discussion

Table No.4.1

S.No.	Power in KW	Speed in rad/s	Discharge in m³/s
1	19.50	3.927	0.60
2	16.25	3.220	0.50
3	13.00	2.180	0.40

The efficiency of plant does not vary with load but Power output & Speed of this plant vary with discharge at same Head condition. Total cost of generation of plant is lesser than the other hydel plant. This performance analysis determined at KABITKHEDI based Screw Archimedean Turbine micro hydro power plant at INDORE (M.P.). This plant is established by Jash Engineering Limited Indore.

Conclusion

Dam having higher water holding capacity for large scale hydro power plants leads to many drastic problems including people displacement, deforestation, loss of agriculture land & earthquakes. Viz., they are some examples, an earthquake occurred at Latur & Ushmanabad (Maharashtra) due to KOENA dam and at Jabalpur (MP) due to BARGI dam. Due to INDRA SAGAR dam the Harshood place was completely displaced & new Harshood was established known as Chhannera. Only Due to Sardar Sarovar dam at Narmada River (Gujrat) more than 2 lakhs people were displaced, 37 thousands hectares agriculture lands & 10713 hectares deforestation took place etc. There are several other examples of these kinds of dams due to which the mentioned problems are occurring.

However Micro hydropower based on Archimedean turbine is an eco-friendly, fish friendly & there is no requirement of deforestation as well as people displacement and other harassments. In these types of plant there are no requirements of big dam, high Discharge, high Head & penstock etc. So there is very less civil work requirement as compare to other plants which is based on conventional turbine like Pelton, Kaplan & Francis etc. Micro hydropower based on Archimedean turbine plant has less total cost of generation, operation cost, other cost & more overall efficiency at same conditions as compare to other plants etc. The efficiency of plant does not vary with load, but Power output & Speed of this plant vary with discharge at same Head condition. This performance analysis determined at KABITKHEDI based Screw Archimedean Turbine micro hydro power plant at INDORE (M.P.).This plant established by JASH ENGINEERING LIMITED INDORE.In relation to rural development, the ease& low relative cost of micro hydro based on Archimedes Screw systems open up new prospects for some isolated communities to fulfil the requirement of electricity in India. With only a small stream desired, remote areas can access power easily for numerous domestic day today uses and it can even run small power consuming machineries for supporting small businesses. Hence this type of power plant is most suitable hydro power plant in the present as well as future.

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