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Testing and Performance Evaluation of Improved Water Mill (Improved Ghatta) Runners

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Abstract

Improved Water Mill (IWM) runner is an impulse type, vertical shaft, mechanical device used for converting hydrological power into the useful mechanical output. The traditional water mills have low output with primarily use of grinding. The upgradation and improvement of these water mills is an effective and sustainable way of improving the efficiency of water mill. Improved Water mills are locally manufactured in our country. The most of the IWM models are fabricated on the basis of design guidelines provided by Center for Rural Technology, Nepal (CRT/N). Commonly adopted IWM models by local manufactures are Nepal Yantra Shala (NYS) model, Bhagwati model and Banepa model. The Banepa model is claimed to be highly efficient among these models.

This paper included the testing of five different IWM runners fabricated on the basis of design guideline for Banepa model. The testing is done on Test Rig setup at Center for Energy Studies (CES) lab, Pulchowk Campus. The test shows the sample 1 (orange) has maximum average efficiency 72.24%. Similarly, sample 2 (dark blue) 70.77%, sample 3 (sky blue) 71.17%, sample 4 (red) 71.19% and sample 5 (green) 68.88% mechanical efficiency. The study shows that sample 1 can be best implemented as Improved Water Mill. Although all the runners were fabricated on the basis of Banepa model, but they possess difference in their efficiencies this is due to the variation in the bucket inclination.

Keywords

IWM testing – Water Mill – Efficiency – Banepa model – Test Rig

1. Introduction

Agro-processing has become one of the important activities for the farm communities in rural Nepal. Pani Ghatta, a traditional water mill that uses water wheels to convert kinetic energy of running water into mechanical power for grinding, husking, etc of grains, has a long history in Nepal. In the hills, these traditional water mills, usually located at the bank of streams, have been a part of villagers' life and are being used as an important source of energy. The rural communities often require food-processing services, in the form of cereal grinding, paddy hulling, oil extraction, etc. Mere availability of these services further reduces the waiting for longer time and the burden of carrying loads over a long distance, a task often performed mostly by women. This in turn stimulates and diversifies local agricultural production.

It is estimated that over 25,000 to 30000 operational mills are in operation throughout the country one mill typically servicing 20-50 households. However, the efficiency of these ghattas in the form of milling services has not been improved due to its low power. The ghattas with less than 1 kW output are mostly prevalent throughout rural Nepal, which have not been able to meet the increasing processing demand and other energy requirements of the rural community. [1] On the other hand, diesel mills are swiftly penetrating in high agro-processing demand areas replacing the traditional ones, despite having its negative consequences on local environment. Further, these diesel mills have not only disturbed the self-reliant set up of the villages but have also increased the dependency on imported machinery and diesel. Furthermore, the villagers will suffer more for processing their grains in time of no diesel available, as the traditional ghattas have already been replaced.

Improved Water Mill (IWM) is basically an improved version of traditional water mill with increased power output. Operational output and efficiency have increased at varying range depending on the power output of 2-5 kW, which in turn depends upon the flow and head availability. IWM can be used for a longer period even in the dry season – and through their increased energy output - the quality of the milling service offered to the local community can be improved. However, since its threshold supply of grains has enlarged for sustainable running, the commuting distance of the villagers has also increased.

Available studies reveal that the introduction of IWM has induced positive changes in the socio-economic conditions of both rural communities and local mill-owners. For the communities, benefits include time saving on grinding, reduction of workloads of women, reduce frequency of visits for the mills, employment generation, and market development. Thus IWM has undoubtedly become one of the most efficient options for remote rural areas to assist the communities in improving their livelihood and the time saved can be used in productive works. [2]

2. Objectives

The main objective of this research work is to test and performance evaluation of the number of water mill runners.

The specific objectives are:

- Testing of existing IWM runner samples from different AEPC's pre-qualified companies
- Performance evaluation of the IWM runners

3. IWM Test Rig Description

Improved Water Mill (IWM) Test Rig consists of the mechanism to test the efficiency of the Improved Water Mill in the standard lab condition. The Improved Water Mill (IWM) runner is flexibly coupled to a disc brake dynamometer by which the output torque of the IWM runner is measured. The shaft speed of the IWM runner is directly indicated on a photosensitive type tachometer.

The discharge and head of water flowing to the IWM runner is being controlled by operating the three 3 hp DC centrifugal pumps in different combinations (one, two or three pumps) and operating the discharge diversion valve (DDV) located at the surge pressure chamber. By operating the combinations of the three pumps and DDV different discharge and head can be simulated in the laboratory for testing the performance of the sample IWM runner.

The water pressure in the inlet pipe is indicated on a Bourdon type gauge mounted on the inlet of the supply pipe. The disk brake type dynamometer has been used to measure the output power produced from the runner at specific pressure head and discharge. The dynamometer consists of the brake disk of 250 mm diameter and mechanism to measure force of brake through spring weight meter. The complete IWM runner assembly housing is mounted on a substantial steel bed plate, which in turn is bolted to the steel tank.

The sets of electrically driven DC centrifugal pumps floor mounted alongside the water storage tank draws water from the tank through a suction pipe and delivers it to the Ghatta via a non-return valve, surge tank, pipe work system and nozzle. A flow measurement device with Vee-notch plate and water level indicator has been incorporated to measure the flow rate of the discharge. Water discharging from the IWM runner falls into the tank partition passes through a netted plate to check the turbulence produced and then it flows over the rectangular notch. The height of the water over the notch is measured by means of side mounted water level indicator. The control panel used for control of the electromechanical systems incorporates a series of push button starter for operating centrifugal pumps. [3]

Mechanical Power P_m is given by,

$$P_m = \frac{2\pi NT}{60} \text{ watts} \tag{1}$$

Where, T = Torque = F.r = 0.25 F Nm So, $P = 2.62NF \times 10^{-2}$ watts Water Power P_w is given by,

$$\begin{aligned} P_w &= \rho g H Q \text{ watts} \\ &= 9.81 HQx10^3 \text{watts} \end{aligned} \tag{2}$$

Ghatta runner Efficiency η_g is given by,

$$\eta_g = \frac{\text{Mechanical Power}}{\text{Water Power}} \times 100\% \tag{3}$$

3.1 Technical Data

Turbine type:	IWM (Impulse)
Water flow:	up to 60 lps
Penstock Diameter:	160mm
Nozzle Angle of strike:	45 deg.
Service pump rating:	3 x 3 hp

4. Testing Procedure

While going through the test procedure following steps were followed :

1. Check that the tank is filled to the correct level-just below the apex of the Vee-notch.
2. If necessary, add water to the upstream side of the Vee-notch plate until the water level coincides with the apex of the Vee-notch. Note the reference level of the water level indicator.
3. Check that discharge diversion valve is closed and set to the closed position if opened.
4. Switch on the pump sets.
5. Gradually open the discharge diversion valve to get the desired head and discharge.
6. Slowly apply load to the disc brake by turning the hand wheel in a clockwise direction until the tachometer indicates a speed of required rpm.
7. Keeping the speed steady at specified rpm (by re adjusting the brake load if necessary), take readings of flow rate, pressure head, brake spring balance load and head over the Vee notch (measured by the water level indicator) and record on test sheet (A typical test sheet is given).
8. Operate the required number of the pump sets and DDV as per the required head and discharge and record the readings in the test sheet.
9. After completion of test, close DDV and Switch off pumps.

4.1 Tools and Instruments Used

- Tachometer
- Pressure Gauge
- Digital force measuring device
- Measuring scale, Protractor
- Measuring tape
- Vernier Caliper
- Slide wrench, Spanners, Hammer etc

5. Components of IWM

The samples collected from different manufactures consist of following components [4]:

- Fali: a device to hold the upper grinding stone and to transmit mechanical power
- Short shaft: transmit power from runner to upper grinding stone
- Takkar (ball model): device to act as a pivot for the shaft for efficient rotation
- Chakati (ball model): base plate for the takkar
- Runner:
  - Hub
  - Bucket
  - Hub ring
  - Runner Strip
  - Guide ring
  - Slide plate for the hub

5.1 Description of Runner Sample

The IWM runner samples are fabricated on the basis of design guideline for Banepa model. This model of IWM is mostly used in rural areas because of its higher efficiency than other models. The runner samples are from five different manufacturers which are listed in table 1.

Table 1: Sample arrived from different manufacturers

SN	Manufacturer	Color	Runner Dia (mm)
1	Banepa Metal Udhyog	Orange	680
2	D L Energy Limited	Dark Blue	660
3	Prabidhi Utthan Pvt. Ltd.	Sky Blue	665
4	Malika Engineering	Red	670
5	Asian Metal	Green	685

6. Test Remarks

Following remarks have been drawn after the testing of five Improved Water Mill runner samples provided by Center for Rural Technology/ Nepal.

1. Sample No.1 (Orange, ϕ 680 mm) At the effective head of 4.57m and discharge of 21.7 lps

- Average Runner Efficiency (150 -250 RPM) 72.24%
- Preferable Runner Efficiency range from test 150 to 250 RPM

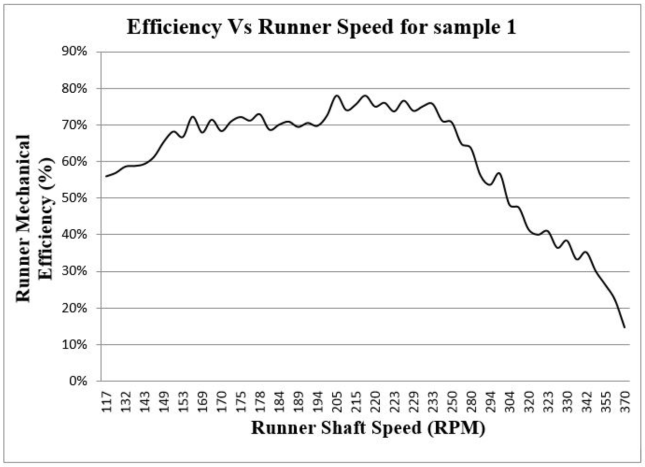

Figure 1: Efficiency vs Runner speed curve

2. Sample No.2 (Dark Blue, ϕ 660 mm) At the effective head of 4.92m and discharge of 21.7 lps
   - Average Runner Efficiency (150 -250 RPM) 70.77%
   - Preferable Runner Efficiency range from test 115 to 300 RPM

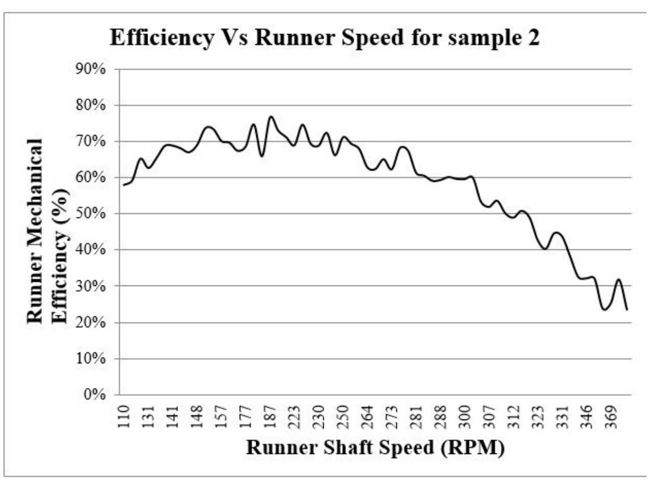

Figure 2: Efficiency vs Runner speed curve

3. Sample No.3 (Sky Blue, ϕ 665 mm) At the effective head of 5.62m and discharge of 22 lps
   - Average Runner Efficiency (150 -250 RPM) 71.17%
   - Preferable Runner Efficiency range from test 135 to 290 RPM

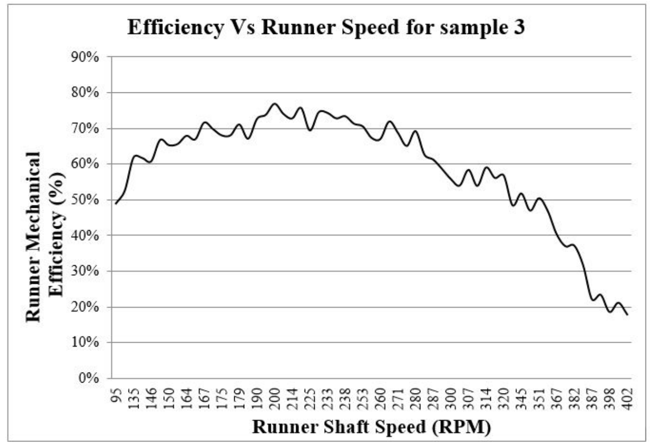

Figure 3: Efficiency vs Runner speed curve

4. Sample No.4 (Red, ϕ 670 mm) At the effective head of 4.92m and discharge of 23.2 lps
   - Average Runner Efficiency (150-250 RPM) 71.19%
   - Preferable Runner Efficiency range from test 170 to 350 RPM

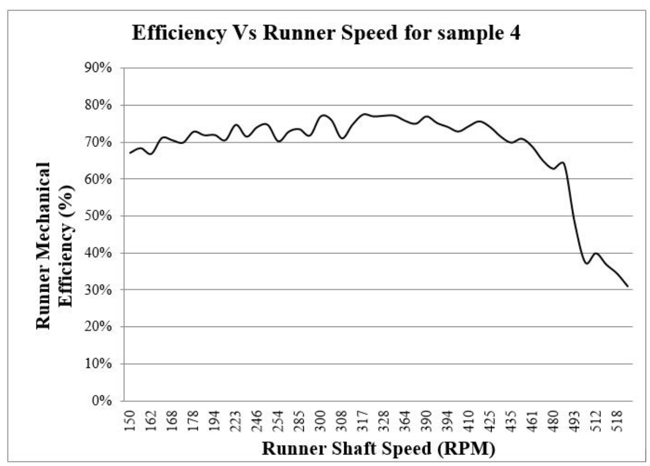

Figure 4: Efficiency vs Runner speed curve

5. Sample No.5 (Green, ϕ 685 mm) At the effective head of 4.57m and discharge of 21.7 lps
   - Average Runner Efficiency (150-250 RPM) 68.88%
   - Preferable Runner Efficiency range from test 150 to 400 RPM

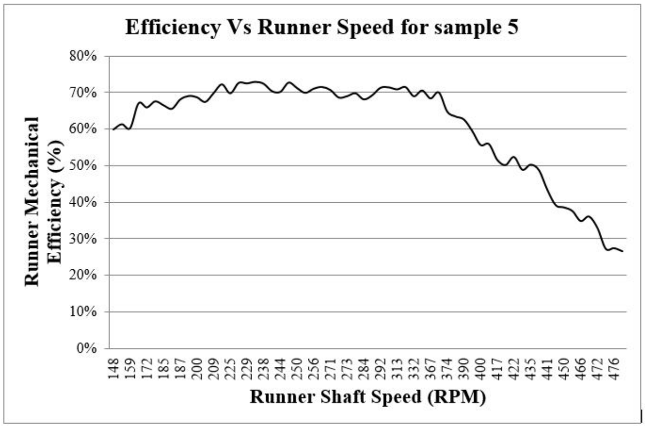

Figure 5: Efficiency vs Runner speed curve

7. Conclusions and Recommendations

7.1 Conclusions

From the test of five samples of IWM the following conclusions are drawn:

- From the test of five IWM runners we found that the sample 1 has the higher efficiency 72.24% than the other samples within the preferable range of speed (150-250 RPM).
- The variations in the efficiency lies between 68–72% for preferable range of speed.
- Although, all the samples are fabricated based on same Banepa model, the variation in the IWM runner efficiency observed during the standard laboratory testing condition may be due to the fact that angle of the nozzle is fixed at 45° but the bucket inclination angle is different for all five samples.
- When the RPM is less than 100, water started to splash highly which decreases the efficiency.

7.2 Recommendations

Following recommendations are highly desirable to be incorporated for the efficient design and operation of the Improved Water Mill.

- During system design of Improved Water Mill, the shaft speed of the IWM runner should be maintained from 150 to 400 RPM for better efficiency.
- As there has not been any theoretical analysis of the existing design of the IWM runner, there should be hydrodynamic analysis of the runner for getting the most effective parameters such as bucket angle, curvature angle, notch profile etc. of the runner for better design of the runner.
- There should be uniformity in the inclination angle of nozzle so that the bucket angle and curvature angle of the runner can be fixed during runner design. It is highly recommendable to fix the angle of the nozzle as 45 for future installation.
- It is recommendable to perform the end use operation performance testing of the electro-mechanical machines by upgrading the existing test rig if possible.
- To manufacturer
  - Strictly follow the standard design.
  - Maintain uniformity in blade angle.
  - Holes in a hub must be concentric.
  - Runner weight must be as standard.
  - Shaft and runner fit must be interference or transition.

References

[1] Micro-Enterprise Development Programme (MEDEP)/ UNDP. *Micro-Enterprises, Development for Poverty Alleviation*. MEDEP)/UNDP, Ministry of Industry (MOI), 1st edition, 2010.

[2] Nepal Centre for Rural Technology. Improved Water Mill Development in Nepal, A Status Review. Technical report.

[3] Nepal Centre for Rural Technology. Test result analysis of improved water mill (improved ghatta) runners. Technical report, Department of Mechanical Engineering, 2006.

[4] Nepal Centre for Rural Technology. Quality Standard for IWM Components. Technical report, Centre for Rural Technology, Nepal, 2006.

[5] M K Marita. Study on a theoretical design of improved water mill runner through performance testing. Master's thesis, Department of Mechanical Engineering, Tribhuvan University Nepal, Pulchowk Campus, 2007.

[6] Bajracharya T.R, Nakarmi K.B, and Chaulagain R.K. Performance and Capacity Improvement of Existing IWM in Nepal. *RETSUD-09*, 2009.