Experimental Investigation of Centrifugal Pump Regular and Reverse Mode

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Abstract— Pumps as turbines have been successfully applied in a wide range of small hydro sites in the world. Since the overall efficiency of these machines is lower than the overall efficiency of conventional turbines, their application in larger hydro sites is not economical. Therefore, the efficiency improvement of reverse pumps is essential. In this study, by focusing on a pump impeller, the shape of blades was redesigned to reach a higher efficiency in turbine mode. After each modification, a new impeller was tested in the test rig. The efficiency was improved in all measured points by the optimal design of the blade and additional modification as the rounding of the blade's profile in the impeller inlet and hub/shroud inlet edges in turbine mode. Experimental results confirmed the numerical efficiency improvement in all measured points. This study illustrated that the efficiency of the pump in reverse operation can be improved just by impeller modification the effects of impeller rounding on a combination of radial flow and mixed flow pumps as turbines using experimental data. The impeller rounding is seen to have positive impact on the overall efficiency in different operating regions with an improvement in the range of 1–3%. The behavior of the two control variables have been elaborately studied in which it is found that the system loss coefficient has reduced drastically due to rounding effects, while the extent of changes to the exit relative flow direction seems to be limited in comparison. The larger picture of impeller rounding has been discussed in comparison with performance prediction models in pumps as turbines. The impeller rounding technique is very important for performance optimization and recommends its application on all pump as turbine projects.
Key words: PAT and modification in the geometry, Micro-hydropower, hydraulic energy of water

I. INTRODUCTION

The current energy crisis - with rising fuel prices - might be enough to boost the world's appetite for renewable energy. Renewable energy technologies produce profitable energy converting natural phenomenon into useful energy forms. One of renewable energy technology is hydropower. Hydropower systems convert hydraulic energy of water, potential and kinetic energy of water into mechanical or electrical work. However, the possibility for the implementation of large scale hydro electric power generation, whilst benefiting from the economies of scale, is not always technologically, economically, politically or environmentally feasible. Consequently, interest in small scale hydro electric power generation is increasing. However, construction costs for such plant are relatively high when compared with the small amount of power generation possible. If the construction costs could be reduced small scale hydro electric power production could be become more widespread especially in the third world.

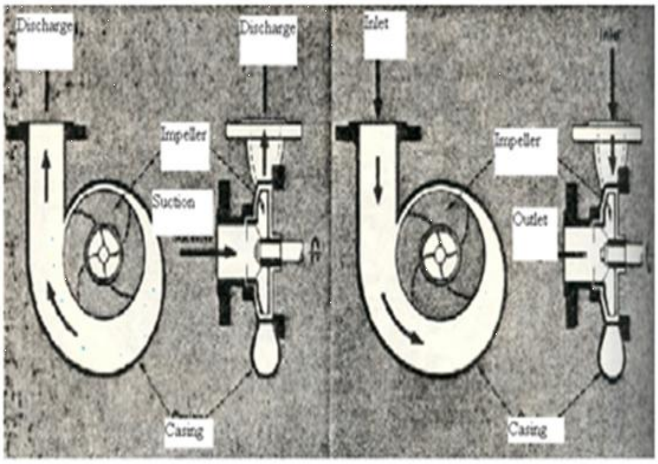
Micro-hydropower is a practical and potentially low-cost option for generating electricity at remote sites, particularly for small villages in hilly areas. Running costs for such schemes are very low, but the initial capital cost can be relatively high and any reduction in equipment costs will make the technology more accessible. One way to reduce the equipment cost is to use a standard pump unit as an alternative to a conventional turbine.

Pumps are mass-produced, and as a result, have the following advantages for micro-hydro compared with purpose-made turbines:

1. (1) Integral pump and motor can be used as a turbine and generator set
2. (2) Available for a wide range of heads and flows
3. (3) Available in a large number of standard sizes
4. (4) Short delivery time
5. (5) Spare parts such as seals and bearings are easily available
6. (6) Easy installation - uses standard pipe fittings

A. *PAT Working Principal:*

Pumps are designed for particular head and flow rate. In pumps fluid enters from suction side at low pressure side and discharge to high pressure side. It takes energy from impeller to convert fluid low pressure to high pressure.



Pump in pumping and turbine mode

Fig. 1: PAT Working Principal

In case of pump as turbine (PAT) pump operates in reverse mode. In PAT mode water enters in casing at high pressure and transfer convert pressure and kinetic energy in to mechanical energy and fluid exit from pump the eye at low pressure. And fluid exit from pump the eye at low pressure. In the reverse operation of pump it may be less efficient because the direction of flow is reverse and hydraulic and frictional losses increase sharply. When fluid enters in to impeller because of Sharpe edges of impeller at the end flow separation occurs at inlet of PAT due to that separation losses occurs.

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B. PAT and Modification in the Geometry:

The main difference in the pump and turbine design is that, conventional turbines having flow control mechanism to increase its part load efficiency but the standard pumps are not having any flow control mechanism to increase its part load efficiency.

Pumps are generally operated with constant speed, head and flow. A pump is therefore designed for one particular of operation (duty point) for maximum efficiency and it not required any regulating flow control device. Turbine operates under variable head and flow condition. In various seasonal variations of the available water so to adjust the power output and consumer requirement regulate the flow regulator are required.

Also in the reverse operation of pump it may be less efficient because the direction of flow is reverse and hydraulic and frictional losses increase sharply. When fluid enters in to impeller because of Sharpe edges of impeller at the end flow separation occurs at inlet of PAT due to that separation losses occurs. In order to improve the PAT performance by reducing the losses at various sections, geometry modification in the PAT has become an interesting area of the research.

C. Nomenclature:

- $P_{hyd.shaft}$ Hydraulic shaft power
- P_{out} Power output
- V_m Flow velocity
- V_u Tangential velocity
- BEP Best efficiency point
- H Total Head
- N Rotational speed
- Q Discharge
- U Tangential speed
- V Absolute velocity
- η Efficiency

II. EXPERIMENTAL TEST-RIG AND INSTRUMENTATION

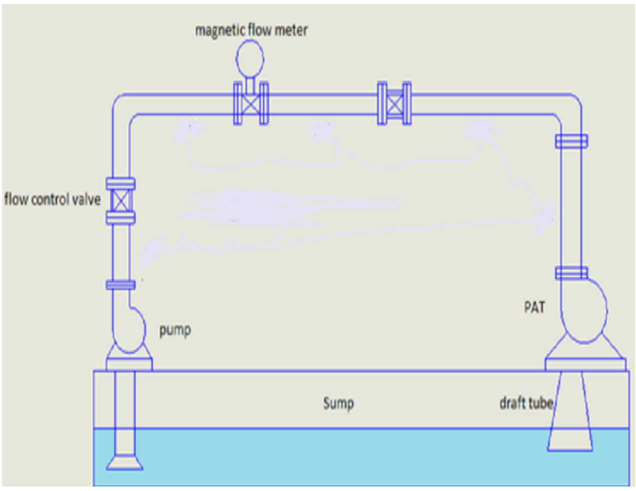

Fig. 2: Experimental Test-Rig and Instrumentation

A compact open loop-test rig was used for testing the pump in turbine mode. Schematic diagram of test-rig is shown in Figure. The test rig consists of one feed pump of radial flow type for pumping water at high pressure to provide the necessary head and flow. The pump has been connected with the motor. The motor connects with VFD (variable frequency drives) drive. The motor speed can be easily varied and controlled with PLC (Programmable logic controller). Thus it improves the efficiency of motor and also it matches the speed according to changing load requirements and gives accurate and continuous process control over a wide range of speeds. From the sump the water supplied with high pressure in the centrifugal pump being used as a turbine. After imparting motion to the pump impeller, water is discharged through the conical draft tube connected to the pump outlet. Water goes back through the same sump channel, from which the radial flow pump again pumps the same water back to the PAT. The pressure gauge and vacuum gauge along with the pressure transmitter were connected to the PAT inlet and outlet to measure the head.

A. Objectives and Problem Outline:

- To obtain the performance of the pump in the reverse mode with non-modified impeller.
- To modified the impeller as per the method / procedure available in the literature.
- To test the pump with modified impeller in the same test rig.
- To compare the performance of pump in the reverse mode with modified and non-modified impeller.

III. RESULTS AND DISCUSSION

The experiments were conducted on PAT with impeller in modified and non-modified condition. The experiments are carried out on the PAT to find out the performance at constant speed. The specification and the dimensions of the PAT used in the experiment is given below.

Pump parameters given by manufacturer	**Value**	**Geometrical parameters measured**	**Value**
Type	KDS 1030++	Outer diameter	158 mm
Head	25 m	Eye diameter	94 mm
Flow	22 lps	Hub diameter	68 mm
IPKW	8.42	Eye width	45mm
RPM	2900	Width of exit	20mm
Efficiency	64%	Inlet blade angle	19°
Head range	10 to 29 m	Outlet blade angle	23°
Flow range	33.5 to 151 lps	No of blade	6
Pump suction dia.	3 inch	Thickness of the blade	4.5 mm
Pump discharge dia.	4 inch		
Motor	3 phase ,50HZ,415 V		

PAT (KDS 1030^{++}) was tested on Test rig. The experiments were conducted on test rig by the application of different load at constant speed of 1100 rpm. Readings were

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recorded of Head, flow rate and power output at different loads using SCADA (Automation software). The result data from the test is tabulated and non-dimensional parameters are found out. The data graph.

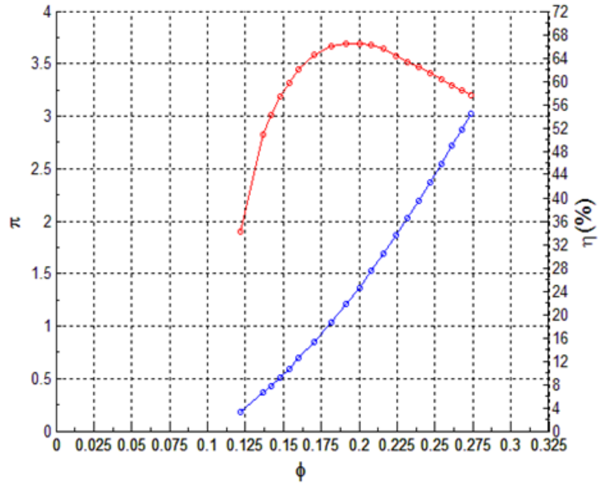

Fig. 3: Power number and efficiency vs flow number characteristic of PAT without modified impeller

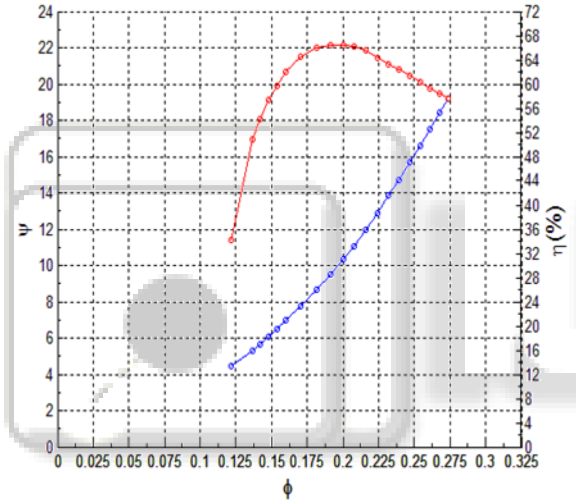

Fig. 4: Head number and efficiency vs flow number characteristic of PAT without modified impeller

A. Modified Impeller:

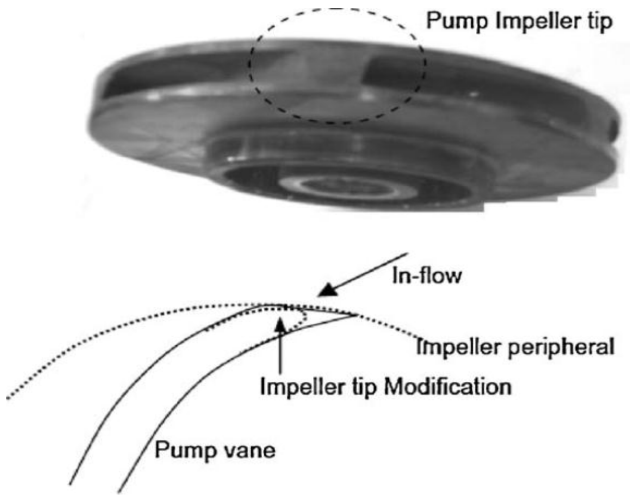

Fig. 5: Modified Impeller

Three modifications are performed on impeller as follows

(1) Impeller edges are rounded.

(2) Front and back portion of shroud are also rounded.

(3) Removal of material at Exit area of PAT impeller face.

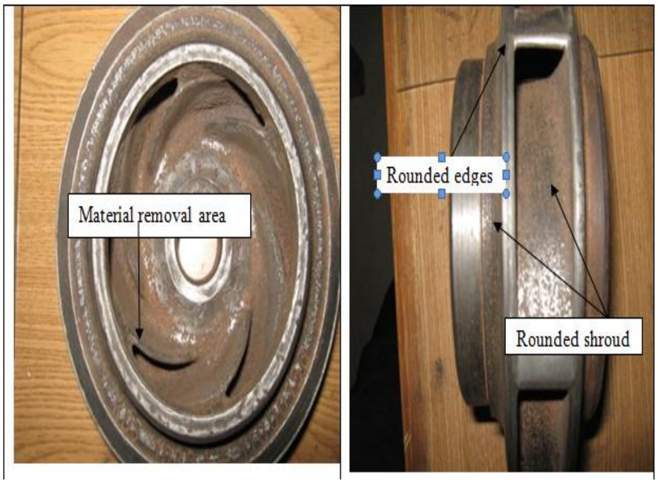

Fig. 6: PAT Impeller with modification

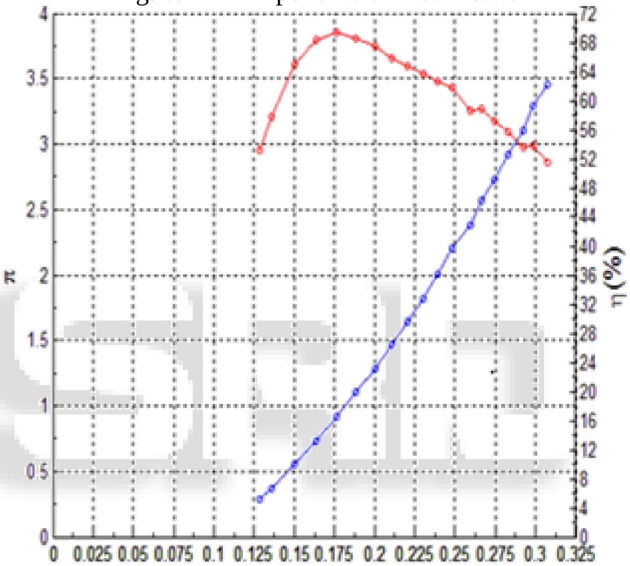

Fig. 7: Power number and efficiency Vs flow number characteristic of PAT with modified impeller

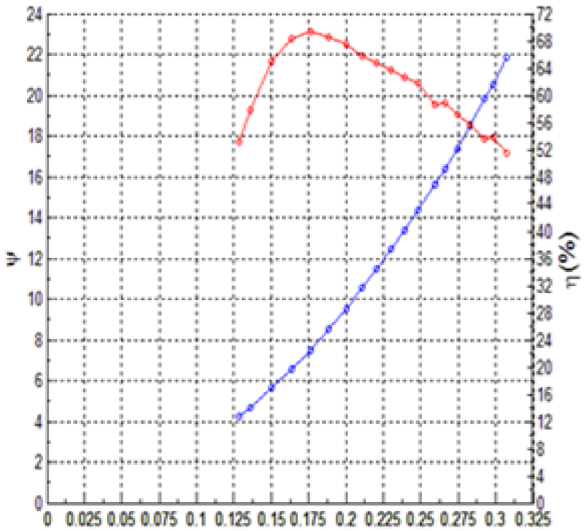

Fig. 8: Head number and efficiency Vs flow number characteristic of PAT with modified impeller

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B. Comparison between Performa of PAT by Using Impeller with and Without Modification:

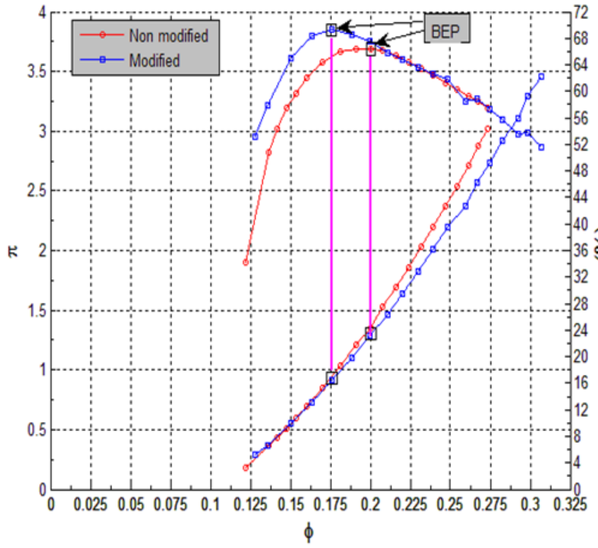

Fig. 9: Comparison of power number and efficiency of PAT with and without modified impeller

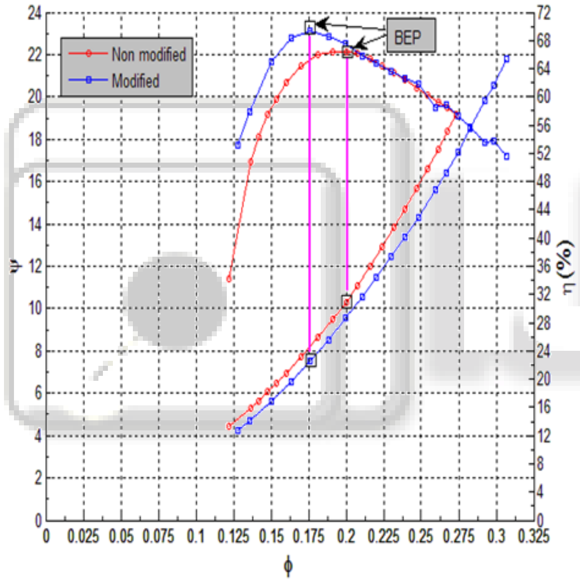

Fig. 10: Comparison of Head number and efficiency of PAT with and without modified impeller

Above Fig shows the comparison of the performance of the PAT by using impeller with and without modification. First graph shows the power co efficient and efficiency versus the flow number at 1100 rpm.

Fig -2 shows the best efficiency point the mechanical power generated by the PAT after modification is almost same as the power generated by PAT before modification. But the best efficiency point is changed. Graph shows that the efficiency increases with the modification of the impeller. And also the flow required by the PAT for the best efficiency is lower than the flow required before modification of the impeller, in other word PAT can give more efficiency at lower flow rate by modifying the impeller.

Fig -2 shows the head number and flow number characteristic of the PAT at 1100 rpm. From the graph we can say that the efficiency increases with the modification of the impeller. Also the head required for the best efficiency is reduces. In the part load region the efficiency of the PAT with modification is more than without modification. But in the overload region efficiency remains almost same. Head number changes totally from the part load region to the overload region.

IV. CONCLUSION AND FUTURE SCOPE OF WORK

A. Conclusions:

These are the conclusions are made from the experiment on the PAT at 1100 rpm speed.

(1) The results are compared before and after modification of the impeller which suggests that at constant speed of 1100 rpm, the efficiency has increased and the required head has been decreased.

(2) Power generated by the PAT is same in the part load region, but in overload region PAT generates more power by using non modified impeller than by modified impeller and also at the best efficiency point it is remains same in both the condition.

B. Future Scope:

(1) Computational Fluid Dynamics (CFD) can be used for numerical investigation of PAT and to compare and validate the experimental results.

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