Chapter 7

Conclusions and Scope for Future Work

7.1 Conclusions

The major limitations of mini/micro hydropower schemes is the higher cost of small capacity hydro turbines. Also, it is very cumbersome, time consuming and expensive to develop the site specific turbines corresponding to local site conditions in mini/micro hydro range. In such plants, small centrifugal pumps can be used in turbine mode by running in the reverse direction. The efficiency of PAT is usually lower than that of conventional hydro turbines; however, it offers various advantages like lower initial cost and easy availability in the wider range of head and flow rates. The scope of application of PAT can be widened by improving its part load
and/or maximum efficiency by optimizing its geometric/operational parameters viz. impeller diameter and rotational speed or with some low cost modifications viz. blade rounding, provision of flow controlling mechanism etc.

**Conclusions based on parametric studies**

In the present study, experimental investigations were carried out to improve the PAT performance by optimizing its geometric and operational parameters e.g. impeller diameter and rotational speed. The experiments were performed in the wide range of rotational speeds varying from 900-1500 rpm with original (φ250 mm), 10% trimmed (φ225 mm) and 20% trimmed (φ200 mm) impellers before and after blade rounding. The major conclusions made from the study are as under:

- The power output and efficiency of original impeller at rated speed were found as 2.02 kW and 58.87% respectively.
- With 10% trimmed impeller, the power output and efficiency were increased by 5-10% at part load. However, further trimming resulted in sudden drop in performance.
- The performance of PAT was found better in the speed range of 1000 to 1200 rpm with all three impellers.
- The blade rounding resulted in 3-4% rise in efficiency at rated speed with the existing impeller. Also, it was found more advantageous around rated speed.
- The maximum power and efficiency were found as 2.09 kW and 76.93% with 10% trimmed-blade rounded impeller at 1100 rpm. The value is very close to the maximum efficiency in pump mode i.e. 77.5%.
- The empirical correlation was developed between $\eta_{BEP}$, D/Dr (range: 0.8-1) and N/Nr (range: 0.64-1.07) and applied for the present analysis. The predicted $\eta_{BEP}$ was found within ±10% range of the experimental results.

**Conclusions based on guide vane analysis**

To study the effects of guide vanes on PAT performance, five numbers of NACA 6520 profile guide vanes were provided with 10% trimmed (φ225 mm) impeller in the casing. The experiments were performed in the speed range of 1000-1400 rpm. To find out the optimum
position of guide vane, its angle was varied in the range of $10^\circ-21^\circ$ in five steps viz. $10^\circ, 13^\circ, 15^\circ, 18^\circ$ and $21^\circ$. The major conclusions drawn are as under:

- The performance of PAT was found better in the guide vanes angle range of $13^\circ-15^\circ$ at all the speeds in context of higher power output and efficiency.
- After provision of guide vanes, the maximum power output and efficiency were found as 2.13 kW and 78.04% at 1100 rpm at an angle of $15^\circ$ which showed 1.70% and 1.44% further rise in power output and efficiency compared to previous modifications in the current study.
- The part load efficiency was improved by 24.81%, 10.87% and 4.77% at $0.7Q_{BEP}$, $0.8Q_{BEP}$ and $0.9Q_{BEP}$ respectively in comparison with best efficiency obtained before installation of guide vanes.

The comparison of efficiency obtained with various modifications is shown in Figure 7.1. At BEP, the efficiency was improved by 32.56% after installing five guide vanes with 10% trimmed ($\varphi 225$ mm) blade rounded impeller at 1100 rpm in comparison with the original ($\varphi 250$ mm) unrounded impeller at rated speed of 1400 rpm.

Figure 7.1. Variation of efficiency with discharge with different modifications.
Conclusions based on cavitation analysis

To study the cavitation behavior of PAT, numerical and experimental investigations were carried out. For experimental study, additional suction creation system was installed. Different techniques were applied for cavitation detection viz. pressure measurement, visual inspection, vibration analysis and acoustic emissions. The major conclusions drawn are as under:

- Numerical investigations were carried out with four different turbulence models viz. standard k-ε, RNG-k-ε, standard k-ω and SST k-ω. Among them, the results obtained with RNG k-ε model were found closest to the experimental results.
- The average difference in η obtained with CFD and experiments was found as 10.14%, which showed reasonably good agreement between the two approaches.
- From the sigma test, the critical value of Thoma’s cavitation factor (σ_{cr}) was found as 0.595.
- In draft tube and bearing, higher accelerations were observed in radial direction; whereas, in casing higher vibrations were found in axial direction.
- At higher speeds (above 1300 rpm), the vibration amplitudes were found higher and σ was found below σ_{cr}; which showed higher risk of cavitation. Moreover, lowest vibrations were detected at 1200 rpm in all the components.
- The study of vibration peaks at f_f and f_b revealed that, PAT might be suffering from travelling bubble cavitation on blade suction sides, von Karman vortex cavitation on blade trailing edges and vortex rope cavitation near draft tube inlet; at different operating points. Similar types of cavitation were also predicted with numerical simulations.

It was recommended to operate PAT in the speed range of 1000-1200 rpm with 10% trimmed-blade rounded impeller after installation of five numbers of NACA 6520 profile guide vanes to obtain better performance and lesser possibility of cavitation. It was concluded that PAT can give acceptable efficiencies in mini/micro hydro range which may compensate the higher manufacturing costs of specially designed hydro turbines.
7.2 Usefulness of the Present Study for Actual Micro Hydropower Plants

The findings of the present study may be helpful to the small hydro researchers and developers of mini/micro hydropower plants in proper selection of geometric and operational parameters as well as proper installation of PAT and hence to obtain better performance with lesser maintenance issues due to cavitation. PAT may lead to socio-economic development of the people living in rural, remote and hilly areas where such plants are most favorable.

There may be some deviations in the performance of PAT installed in the micro hydropower plants in comparison with laboratory scale model used in the current study due to following reasons:

- In the current experimental test rig, service pump was used for the artificial head generation. Hence, while performing the experiments some variation in head was observed. In actual micro hydropower plants, water may come from natural stream, canal or reservoir. Hence, there may not be significant variation in head.

- In the cavitation study, artificial suction creation system (ASCS) was used for varying the head and hence cavitation factor (σ). However, in actual micro hydropower plant the possibility of cavitation will depend on the PAT setting level, design of draft tube, location of the plant, operating condition etc.

- In the present study, the experiments were performed on small scale PAT with rated impeller diameter of φ250 mm. But, actual micro hydropower plant may deal with large capacity PAT with bigger impeller diameter. Hence, in actual systems the hydraulic losses and efficiency may be different from that obtained in the current study.
7.3 Scope for Future Work

Many aspects of PAT still deserve considerations for wider acceptability of PAT which are mentioned below to encourage further research:

- The empirical correlation developed in the present study is applicable in the specific range of diameter and rotational speed. More detailed investigations may be carried out to apply the correlation in the wider range.
- Majority of the research on PAT focuses on water as the working fluid. But, PAT also found applications for energy recovery in petroleum industries, gas scrubbing, sewage treatment plants etc. Hence, the effects of viscosity and density of fluid on PAT performance may be studied.
- More detailed cavitation and vibration analysis may be carried out.
- Mathematical modeling of PAT working under different operating conditions may be carried out.