Abstract

Among various renewable energy sources, hydropower is probably the oldest and most reliable source of energy on the earth. In remote communities where it is not economical and practically possible to take the grid connection, stand-alone small hydro systems can be used to fulfill the energy requirement of the local community. Small-scale hydroelectric power systems are emerging as a promising source of renewable energy generation, but they require low cost hydraulic and electric equipments to make them economically feasible. In such plants, pumps can be used in turbine mode considering various advantages associated with the pump e.g. low initial and maintenance cost, ease of availability, proven technology, availability for a wide range of heads and flows etc.

The efficiency of pump as turbines (PATs) is usually lower than the conventional hydro turbines; however, there is substantial decrease in the capital cost of the plant as the pump costs less than one sixth of an equivalent hydro turbine cost. Hydropower plants usually runs at part load for several months in a year due to insufficient water availability for the power generation. Whether power can be generated or not during rest of the months depends on the part load performance of the turbine. The scope of application of PAT can be widened by improving its part load and/or maximum efficiency as well as by improving the life of PAT by cavitation free operation.

In the present study, experimental investigations were carried out on single stage end suction centrifugal pump (rated head: 14 m, rated discharge 1700 LPM) running in turbine mode to optimize its geometric and operational parameters viz. impeller diameter and rotational speed. The experiments were performed in the wide range of speeds varying from 900-1500 rpm with original (φ250 mm), 10% trimmed (φ225 mm) and 20% trimmed (φ200 mm) impellers. The effects of blade rounding were studied in all the cases. Impeller trimming led to improvement in efficiency at part load conditions. The PAT performance was found better in the speed range of 1000-1200 rpm. The blade rounding resulted in 3-4% rise in efficiency at rated speed with the original impeller. The maximum PAT efficiency was obtained as 76.93% with 10% trimmed-blade rounded impeller at 1100 rpm. The efficiency predicted from the empirical
correlation developed based on impeller diameter and rotational speed was found within ±10% range of the experimental results.

To study the effects of guide vanes on PAT performance, five numbers of NACA 6520 profile guide vanes were installed with 10% trimmed impeller. The experiments were performed between 1000-1400 rpm by varying the guide vane angle in the range of 10°-21°. The performance of PAT was found better in the guide vane angle range of 13°-15° at all the speeds. It led to 1.70% and 1.44% further rise in power output and efficiency at best efficiency point compared to previous modifications done in the present study. The part load efficiency was also improved by 5-25% at different flow rates.

When pump is running in turbine mode, susceptibility to cavitation increases and it may be more severe than that in the conventional hydro turbines. In this study, numerical and experimental investigations were carried out on cavitation characteristics of PAT at different speeds. For cavitation analysis, additional suction creation system was installed and different techniques were applied for cavitation detection viz. numerical simulation, pressure measurement, visual inspection, vibration analysis and acoustic emissions. From the sigma test, the critical cavitation factor was found as 0.595. Above 1300 rpm, vibration amplitudes and noise levels were found higher; which showed higher risk of cavitation. From the analysis, it was found 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.

Key words: blade rounding, cavitation, guide vanes, impeller trimming, pump as turbine, rotational speed, small hydropower.