CFD Modelling of a Pump as Turbine (PAT) with Rounded Leading Edge Impellers for Micro Hydro Systems

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Abstract. A Pump as Turbine (PAT) is one of micro hydro system components that is used to substitute a commercially available turbine due to its wide availability and low acquisition cost. However, PAT have high hydraulic losses due to differences in pump-turbine operation and hydraulic design. The fluid flowing inside the PAT is subjected to hydraulic losses due to the longer flow passage and unmatched fluid flow within the wall boundaries. This paper presents the effect of rounding the impeller leading edges of the pump on turbine performance. A CFD model of a PAT was designed to simulate virtual performance for the analysis. The aim of this study is to observe the internal hydraulic performance resulting from the changes in the performance characteristics. Highest efficiency was recorded at 17.0 l/s, an increase of 0.18%. The simulation results reveal that there is an improvement in hydraulic performance at overflow operation. The velocity vector visualization shows that there is a reduction in wake and consequently less flow separation along impeller flow passages. However, adjusting the sensitive impeller inlet geometry will also alter the velocity inlet vector and consequently change the velocity triangles for the turbo machinery system.

1 Introduction

Off-grid micro hydro power is one of most favourable types of renewable energy for generating electricity in rural areas in developing countries. Micro hydro plants with power ratings ranging from 1 to 15 kW are a normal range that can be found in most micro hydro sites. Not surprisingly, this range of power rating requires minimum technical skill to operate and maintain, eliminating professional technical expertise. Commercially available turbines such as Pelton, Crossflow, Francis and Kaplan turbines are used as the hydraulic driving mechanism. However, these types of turbines are difficult to manufacture with basic power tools and are normally imported from abroad, increasing the overall cost. The use of a pump in reverse flow, called a pump as turbine (PAT) can substitute traditional turbines, offering an affordable, feasible and practical solution for developing countries [1]. The main advantages of pumps as turbines are low capital investment and ready availability; consequently, the shorter payback period makes them suitable for self-funded micro hydro projects.

The hydraulic losses in PAT is because of long flow passage and unmatched fluid flow across the turbine as it is not designed to run in reverse flow [2]. Modifications to optimize the performance were proposed to enhance the hydraulic characteristics and consequently increase the efficiency. The modifications that were proposed include trimming the impeller blades, adjusting the blade number, adding splitter blades, installing guide vanes and rounding impeller leading edges [3-7]. Among all the modifications, rounding the impeller leading edges is the simplest method to increase PAT efficiency. This modification can be achieved by simple hand tools; grinding the impeller leading edges to a bullet shape. The purpose of rounding the impeller leading edges is to reduce the jet wake produced by sharp edges that caused flow separation.

Studies on rounding the impeller leading edges show enhanced hydraulic performance. There is an increase in efficiency between 1 and 3% [8]. A simulation model at constant speed and free vortex analysis showed a reduction in wakes at the impeller leading edges. The rounding of the impeller leading edges was found to be more beneficial for radial type flow with specific speeds less than 200 [9]. The fast flow of water along the blade passage suppresses the flow separation to a smaller region. However adjusting the sensitive inlet geometry of the impeller may change the velocity inlet vector and change the Euler momentum in the energy transfer equation [10].

The optimization process of PAT has reached the stage where internal hydraulic performance can be accomplished through a comprehensive understanding of the flow visualization. The visualization of interfaces between fluid flow, rotating impeller and pump casing can be achieved through simulation modeling. In addition, simulation modeling has the ability to investigate the fluid interaction under unsteady flow for fine adjustment, and pinpoint the root cause of the performance in the turbo machinery study. The aim of this paper is to study the effect of rounding the leading edges of impellers, on PAT performance through computation simulation modeling. This enables internal hydraulic analysis that can determine the hydraulic changes causing the variations in PAT performance.

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