An experimental investigation of design parameters for pico-hydro Turgo turbines using a response surface methodology

The Turgo turbine is a hydroelectric impulse turbine generally suited for medium to high head applications. This type of turbine has gained renewed attention in research due to its potential application to millions of off-grid pico-hydroelectric sites (5 kW-or-less), including water treatment plants in the United States and millions of off-grid homes around the world. At present, these sites are largely left undeveloped due to prohibitive installed costs ($/kW). The literature about Turgo turbines is scarce and indicates that theory and experiment do not adequately explain the significance of certain design parameters, such as the effect of nozzle diameter, d, jet inlet angle, α, number of blades, Z, and blade speed, φ, on the turbine's efficiency, η_{turgo}.

These four factors were used in a three-level (3^4) central composite response surface experiment. A low-cost Turgo turbine made from tablespoons and readily available materials was built and tested. A second order regression model was developed to predict the turbine's efficiency as a function of each parameter and their interactions:

$$\begin{aligned}\eta_{turgo} = {} & -42.077 + 0.243Z + 5.634d + 232.249\varphi - 75.786\sin^2\alpha - 0.0816Z^2 \\ & - 0.248d^2 - 494\varphi^2 + 2.916Z\sin\alpha + 0.729d\sin\alpha - 66.505\varphi\sin\alpha \\ & - 0.0262Zd + 5.9Z\varphi + 5.197d\varphi\end{aligned}$$

The turbine design can be optimized with respect to efficiency using this equation. Additionally, the effects of blade angle orientation and jet impact location on efficiency were investigated and found to be of relatively little significance. The turbine built for this study reached a maximum power of 1.5 kW and a 62% efficiency.

The outcome of this investigation is a set of standardized equations to optimize the most important design parameters of a Turgo turbine. Hence this work enables the custom design and local manufacture of low-cost efficient Turgo turbines. In addition, the results can be expressed in terms of dimensionless parameters, which allow for scaling to systems larger than 5 kW.