Effect of Blade Friction on Performance of Micro-Hydro Pelton Turbines: Mathematical Modeling and Experimental Verification

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ABSTRACT

Water turbines have been used in electricity generation for well over a century. Hydroelectricity now supplies 19% of world electricity and 44% (as at 2012) of Sri Lanka's electricity also comes from hydropower. Micro Hydro is a term used for hydroelectric power installations that typically produce up to 20 kW of power in Sri Lankan context. Many Micro-hydro power plants are operated with Pelton turbines. The main reasons for using Pelton turbines are that they are very simple and relatively cheap. As the stream flow varies, water flow to the turbine can be easily controlled by changing the number of nozzles or by using adjustable nozzles. Since most of the micro hydro Pelton turbines are now manufactured locally, it was revealed that much attention is not paid to the surface finish of the turbine buckets. On the other hand due to sand erosion of turbine parts bucket surface are getting rough day by day. Most of the research that had been done on turbines were focused on improving the performance with particular reference to turbine components such as shaft seals, speed increasers and bearings. There is not much information available on effects of blade/bucket friction on the performance of Pelton turbine. The main objective of this research is to analyze the performance of Micro hydro Pelton turbine particularly with respect to their blade friction.

The governing laws of fluid dynamics, relevant to the application were used to develop a theoretical model to estimate the effect of blade friction on Pelton turbine performance. Then the developed mathematical model was validated experimentally. All the experiments are carried out in a Pelton turbine standard test bench. The power developed by the turbine was measured by keeping all the relevant parameters that affect to the power development, constant other than the friction of the bucket. The friction of the buckets was varied by varying surface roughness of the buckets. Different roughnesses of the surface was obtained by pasting various grades of sands one at a time on the surface of the buckets.

It was concluded from the developed mathematical model and the experimental testing that power developed by a Pelton turbine increases when the surface roughness of the turbine bucket decreases. It was also proved from the research that splitter thickness of the buckets is also affect the power developed by the turbine. When the thickness of the splitter increases power developed by the turbine decreases. Therefore it is recommended from the study that Pelton turbine buckets must be smooth as much as possible and splitter of the buckets should be as sharp as much as possible to generate more power from a power plant.

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Key words: Pelton turbine, Bucket surface roughness, Splitter thickness

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NOTATION

c_f	Coefficient of friction
D	Diameter of the jet
D_h	Hydraulic diameter
F_{co}	Coriolis force
F_{ct}	Centrifugal force
h	Thickness of the flow sheet
H	Water head
l	Width of the flow sheet
L	Total distance of the flow path
l_1	Width of the flow sheet at the inlet
l_2	Width of the flow sheet at the outlet
P_b	Over pressure on the bucket
P_{co}	Power dissipated due to coriolis force
P_{ct}	Power dissipated due to Centrifugal force
P_f	Power dissipated due to direct friction
P_{in}	Power loss due to indirect effect of friction
P_p	Power dissipated due to pressure variation
P_1	Total power developed by the turbine
P_2	Power developed
r	Radius of the bucket
R	Mean radius of the runner
t	Thickness of the splitter
U	Velocity of the flow in the nozzle
U_1	Velocity of the Pelton runner
V	Relative velocity of water
v_1	Absolute velocity of water at the entrance to the bucket
V_1	Relative velocity of water at the entrance to the bucket
v_2	Absolute velocity of water at the exit from the bucket
V_2	Relative velocity of water at the exit from the bucket
$v_{f,o}$	velocity of flow at outlet

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$v_{\mathrm{w,o}}$	velocity of whirl at outlet
$v_{\mathrm{f,i}}$	velocity of flow at inlet
$v_{\mathrm{w,o}}$	velocity of whirl at inlet
x	Distance measured along the flow path
β	Blade angle
δ	Boundary layer theory
δ^*	Displacement thickness
θ	Momentum thickness
τ_0	Shear stress
$\dot{m}$	Mass flow rate
$\dot{m}_{sp}$	Mass flow rate hit the splitter

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