Analysis and Optimization of Guide Vane Jets to Decrease the Unsteady Load on Mixed Flow Hydroturbine Runner Blades

B. J. Lewis*, J. M. Cimbala* and A. M. Wouden*
Corresponding author: BJL5176@PSU.EDU

* The Pennsylvania State University, USA.

Abstract: As the runner blades of a mixed flow hydroturbine pass through the wakes created by the upstream guide vanes, they experience a significant change in absolute velocity, flow angle, and pressure. The addition of jets to the trailing edge of the guide vanes has been found to reduce the velocity variation seen by the runner blade. An optimization procedure will be conducted to determine the best jet design.

Keywords: Hydroturbines, Trailing Edge Blowing, Turbomachinery, CFD

1 Introduction

The flow through a hydroturbine during off-design operation is highly unsteady, resulting in load variation on the runner blades, flow separation, and vibration. One cause for load variations on hydroturbine runner blades is the presence of wake profiles created by the upstream distributor vanes. As the runner blades pass though these wakes, they experience a significant change in absolute velocity, flow angle, and pressure. Reducing the unsteady load on runner blades would allow for leaner designs, without sacrificing machine integrity or safety margins.

Significant research has been conducted on trailing edge blowing and momentumless wakes. For example, Leitch et al. [1] studied the complete flow through an axial turbofan, and found that the flow into the rotor was made more uniform by using trailing edge blowing to minimize the shed wakes, thus reducing the unsteady rotor-stator interaction. However, no research has been published on the use of trailing edge blowing in mixed flow devices, such as hydroturbines.

2 Preliminary Results and Future Work

The GAMM Francis Turbine [2] geometry was used to evaluate the feasibility of adding a single slot trailing edge jet to a mixed flow hydroturbine. As shown in Figure 1, one periodic guide vane passage was analyzed. For simplicity, the runner blade was not included, only the flow passage and distributor vanes. The effect of the jet on the runner was evaluated by measuring the velocity at the location where the leading edge of the runner passes through the guide vane wake. Two jet velocities were selected for evaluation–a weak jet, and a strong jet, with flow rates of 1% and 3% of the inlet flow rate, respectively. Velocity magnitude profiles for the jet cases are compared to those of the non-jet case in Figure 2. The results show a decrease in velocity variation for the weak jet case at locations near the band. However, the weak jet causes an increase in variation near the crown.

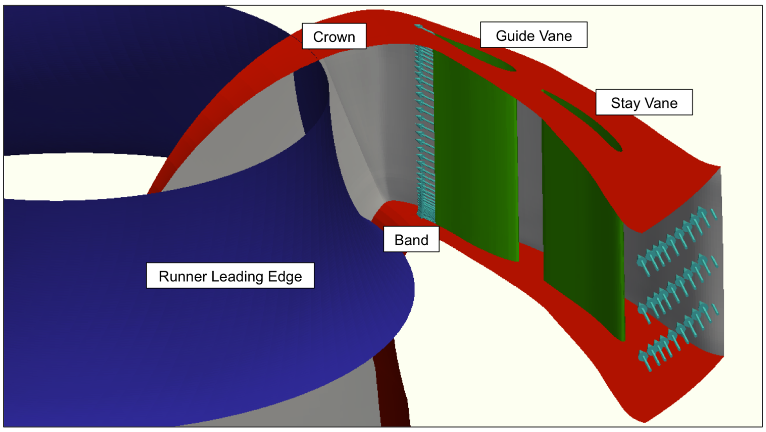

Figure 1: Isometric view of flow through GAMM Francis Turbine. One periodic guide vane passage is shown; also shown is the location of the leading edge of the runner blade.

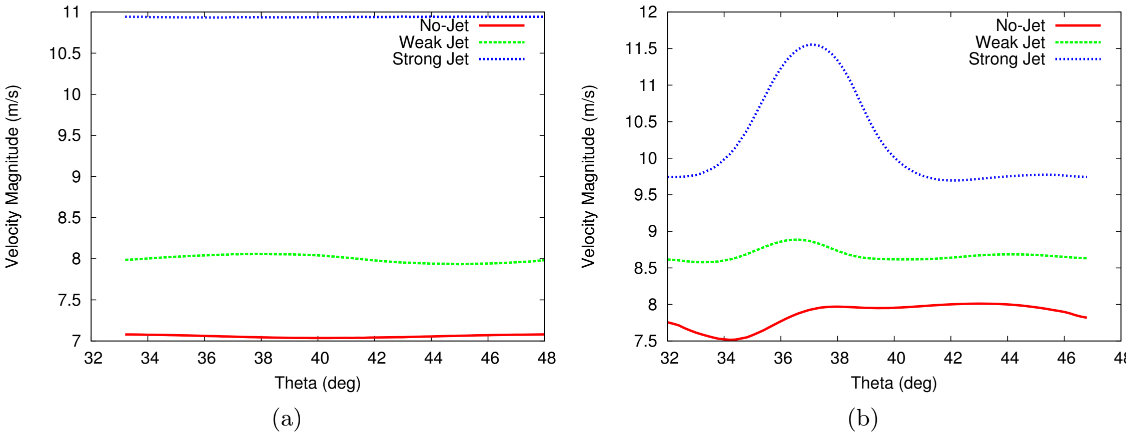

Figure 2: Velocity magnitude profiles at the location of the leading edge of the runner blade for a position a) near the crown and b) near the band.

Another observation is that the addition of the jet results in a circumferential shift of the wake location and greater swirl velocity, which could have a significant effect on the relative velocity impinging on the runner blade and alter the operating condition of the turbine. Lastly, for the normal case, the wake is effectively diffused at locations near the crown. Therefore, no jet is needed in the upper section of the guide vane. Removing the jet from this area would reduce the required mass addition to the flow, and the power to supply the jet.

In future work an optimization procedure on the following parameters will be conducted to determine the best jet configureation: jet width and configuration, jet flow rate, power required to supply the jet, jet/wake dissipation rate, and the effect of swirl on jet/wake dissipation.

References

[1] T.A. Leitch, C.A. Saunders, and W.F. Ng. Reduction of Unsteady Stator-Rotor Interaction Using Trailing Edge Blowing. *Journal of Sound and Vibration* (2000) vol. 235(2), pp. 235.

[2] E. Parkinson. Turbomachinery Workshop ERCOFTAC II, test case 8: Francis turbine. *IMHEF Report*, T-91-3,1995.