Hydrokinetic Turbine Testing in a Cavitation Tunnel: Investigating Cavitation Characteristics and Hydrodynamic Performance

Authors:
Mohammed Islam, National Research Council of Canada
Jinxing Huang, CanmetEnergy / NRCan
Olivier Lévesque, Université Laval
Yanran Xia, Université Laval
Guy Dumas, Université Laval
Julien Cousineau, CanmetEnergy / NRCan

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A comprehensive experimental investigation was conducted to evaluate the hydrodynamic performance and cavitation behaviour of a generic horizontal-axis hydrokinetic turbine. The turbine was tested in a controlled cavitation tunnel across a wide range of tip-speed ratios and cavitation numbers representative of real-world operating conditions, enabling the simultaneous assessment of cavitation phenomena and turbine performance matrix.

The test program produced detailed visualizations of cavitation phenomena, including tip vortex, sheet cavitation, and cloud cavitation, alongside high-resolution measurements of drag and power coefficients. Turbine efficiency, as measured by the power coefficient, was strongly influenced by the cavitation number, with an optimal range observed before the sharp performance declined due to flow separation and cavitation onset. Cavitation number was found to govern both the type and severity of cavitation, with low values triggering a progression from stable tip vortex cavitation to more disruptive sheet and cloud cavitation. These unsteady regimes were associated with power losses, increased drag, and altered flow structures. The findings underscore the importance of turbine design optimization to manage the local cavitation number and maintain turbine efficiency in hydrokinetic energy applications.

Force measurements demonstrated high repeatability, with uncertainty margins within ±2.75% for drag and ±4.0% for power coefficients under extreme cavitating conditions. Stroboscopic imaging provided detailed visual records of cavitation dynamics, supporting observed links between flow conditions and turbine performance. The resulting dataset offers a high-fidelity benchmark for validating numerical models and informs the optimization of turbine designs for improved efficiency and cavitation resilience in real-world hydrokinetic energy applications.

This paper presents the experimental investigation of hydrodynamic performance and cavitation behavior of a horizontal-axis hydrokinetic turbine. It highlights the key findings on how cavitation number influences the turbine performance along with visualizations of cavitation phenomena.