Flow measurements at the entrance of the Tr-Francis turbine runner in no-load operating conditions

Araz Rezavand Hesari, Anthony Munoz, Maxime Coulau, Yvan Maciel, Sébastien Houde
Heki, Department of Mechanical Engineering, Université Laval, Québec, Canada

ABSTRACT

With the popularity of new energy sources, more and more startups and longer off-design operating conditions are seen in the operation of hydraulic turbines. Particularly in the case of Francis turbines, fixed blades and constant synchronization speed limit the high-efficiency region to a narrow range of flow conditions. Off-design points are the main damaging conditions for hydraulic turbines. The Tr-Francis project studies the flow-induced excitations in speed-no-load and startup conditions to identify and characterize the phenomena that contribute to damages at these operating points. Measurements at the inlet of the runner and in the interblade channels are of special importance due to the existence of multiple interblade vortices, possible blockages and complicated flow structures that are likely to cause damaging excitations.

However, due to the technical difficulties involved in flow measurements at the inlet of turbines, especially Francis turbines with little available space, few and limited studies have been performed at this location. This work introduces a methodology to conduct these experiments and suggests solutions to the associated problems. Details of the required technological innovations are presented. Stereoscopic and high-speed particle image velocimetry is performed for the first time at the inlet of a Francis turbine (Tr-Francis) with the use of endoscopes for both the cameras and the laser light. Four radial-azimuthal planes at different spans are chosen for this study in no-load operating conditions. The planes cover the vaneless space and a considerable part of the interblade channel. This provides quantitative flow information in the channels and allows to compare the flow structures at different spans. Data acquisition is performed in time-resolved and phase-locked modes allowing to follow the flow phenomena and compare the average flow at different positions, respectively. Multiple interblade vortices are detected in speed-no-load at the vaneless space and in the interblade channels of the runner. To the knowledge of the authors, these vortices had never been measured before. Iso-contours of $\lambda_c$ in Figure 1 show the coexistence of two vortices at the vaneless space and in the vicinity of the blade leading edge. One is located on the suction side and the other one on the pressure side of the blade. They are considered to be related to the important reverse flow on the suction side of the blade.

Figure 1 In-plane velocity vectors in rotating reference frame superposed on the iso-contour of $\lambda_c$ showing two vortices in the vicinity of the leading edge of the blade. The blade shape is illustrated in grey and its shadow with the green dashed line. “s” represents the blade span at the leading edge.