

4. Hydrodynamics of a pump-turbine operating at off-design conditions in generating mode: experimental investigation

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Modern pump-turbines are subject to frequent switching between the pumping and generating modes with extended operation under off-design conditions. Depending on the specific speed of the pump-turbine, the discharge-speed as well as torque-speed characteristics at constant guide vanes opening can be “S-Shaped”. In this case, the machine operation may become strongly unstable at runaway speed and beyond, with a significant increase of structural vibrations and noise.

In the present work, hydrodynamics of a low specific speed radial pump-turbine scale model experiencing unstable operation at runaway condition in generating mode for 10° guide vanes opening angle (see Figure 1) is experimentally investigated. Measurements of wall pressure in the stator synchronized with high-speed flow visualizations in the vaneless gap between the impeller and the guide vanes using air bubbles injection are performed. Detailed analysis presented in Hasmatuchi¹ et al. (2011) is focused on the onset of the flow instabilities when the machine is brought from best efficiency point (BEP) to runaway and turbine brake mode. At these severe operating conditions, one stall cell covering about half of the vaneless gap circumference is found to rotate with the impeller at subsynchronous speed (about 70% of the impeller rotational frequency), being the effect of rotating flow separations developed in several consecutive impeller channels that lead to their blockage. High-speed movies reveal a quite uniform flow pattern in the guide vanes channels at BEP, whereas at runaway the flow is highly disturbed by the rotating stall passage; the situation is even more critical at low positive discharge, where backflow and vortices develop in the guide vanes channels during the stall passage (see Figure 1). Then, a specific image processing technique is detailed and applied to create a synthetic instantaneous view of the flow pattern on the whole guide vanes circumference, for a low positive discharge operating point, using the acquired high-speed visualizations.

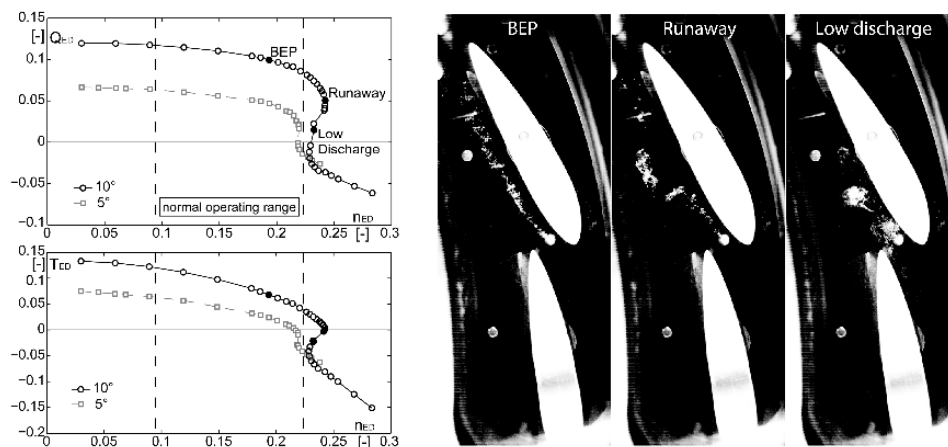


Figure 1 : “S-shaped” characteristics for discharge and torque factors in generating mode (left); instantaneous air bubbles flow visualizations in one guide vanes channel at BEP, runaway and low discharge operation (right)

¹ Hasmatuchi, V., Farhat, M., Roth, S., Botero, F., and Avellan, F., 2011, “Experimental Evidence of Rotating Stall in a Pump-Turbine at Off-Design Conditions in Generating Mode”, Journal of Fluids Engineering, Transactions of the ASME, 133