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Time-Resolved PIV Measurment at the Runner Exit During a Homologous Startup Sequence

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Because of the growing integration of intermittent energy sources into the power grid, hydraulic turbines undergo more frequent transient operations such as startup. Different field studies have highlighted that startups are some of the most damaging events for hydraulic turbines. They can induce high stress levels in the runner, potentially leading to structural damage. The complex transient fluid-structure interactions associated with start-ups make them one of the hydraulic turbines' most critical and challenging operating conditions. Key parameters such as rotational speed, guide vanes opening speed, inertia of rotating components, and startup duration influence stress levels in the runner. To investigate the startup behaviour of a 140 MW Francis turbine at the Jean-Lesage generating station (Manic-2), a homologous startup scenario was implemented on a reduced-scale model of a medium-head Francis turbine installed on the Heki test stand at Université Laval.

As a part of the Tr-Francis project, stereoscopic Time-Resolved Particle Image Velocimetry (TR-PIV) measurements at the runner outlet, along with strain measurements on the runner, were conducted to analyze fluid-structure interactions during startup. The runner was explicitly designed to achieve a scaled structural response homologous with the prototype turbine.

This presentation introduces the methodology for performing stereoscopic TR-PIV measurement at the runner outlet during homologous startup sequences. It presents the endoscopic camera configuration and the laser sheet location. The measurement plane extends from the trailing edge of the runner to a region crossing the rotation axis within the conical diffuser. Preliminary measurements reveal that flow dynamics exhibit considerable temporal and spatial variation. Consequently, four different “time between frames” for each image pair were empirically determined to ensure the reliability and accuracy of PIV velocity fields. Results of different velocity field analyses are presented, including the procedure developed to evaluate windowed average velocity fields using sixty repetitions of the homologous startup sequence.