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Stress predictions in a Francis turbine at no-load operating regime

J.F. Morissette, J. Chamberland-Lauzon, B. Nennemann, C. Monette, A.M. Giroux, A. Coutu and J. Nicolle

Abstract

In the operation of hydraulic turbines, no-load and very low load conditions are among the most damaging. Even though there is no power generation, there is still a significant amount of energy which has to be entirely dissipated, mainly in the runner, where the flow is quite complex, with large scale unsteady and chaotic vortices resulting from partial pumping. This paper presents different approaches to perform stress analyses at low load conditions on a Francis turbine, taking into account the pressure fluctuations on the runner blades due to the large stochastic flow structures inherent in no-load operating regimes. With appropriate mesh density and time step, unsteady computational fluid dynamics (CFD) simulations using the SAS-SST turbulence model can be used on a Francis runner to predict the pressure fluctuations with reasonable accuracy when compared to measurements. These calculated pressure loads can then be used to predict the dynamic stresses with finite-element analyses (FEA). Different approaches are discussed ranging from quasi-static single-blade models to full runner time-dependent one-way fluid-structure interaction (FSI). Pros and cons of the different modelling strategies will be discussed in a detailed analysis of the structural results with comparisons to experimental data. Once the time signal of the stochastic stress at no-load conditions is obtained, the runner fatigue damage related to this operating condition can be estimated using different tools such as time signal extrapolation and rainflow counting.