Estimation of runner side chamber behavior of Francis turbines for shaft line dynamics

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Abstract. The analysis of dynamic fluid behavior in runner side chambers of Francis turbines to estimate the effect on the shaft line behavior is presented. The shaft line analysis of hydropower units is carried out to ensure stable behavior of the shaft line as well as a smooth vibrational behavior. At first, mechanical stiffness and mass properties of rotating and non-rotating components of the power unit as well as oil-film properties are necessary parameters for the shaft line modelling. In hydropower, the fluid inside and around the turbine runner can also have a relevant influence on the shaft line behavior. Here, the added mass effect is well known in hydropower engineering. Sometimes, high shaft vibrations due to a self-excitation mechanism have been observed at hydropower units that were caused by the leakage flow of the fluid around a Francis runner. Therefore, the consideration of the effects of the surrounding fluid on the shaft line is a serios topic for a reliable dynamic shaft line assessment. In this contribution, the fluid flow in the runner chamber at the band of Francis runners is investigated. The fluid behavior is described by bulk-flow models, in which average velocities and pressures over the clearance are used. The non-linear flow behavior is solved in two steps. First, a non-linear analysis is performed to calculate the steady state flow field for centric position of the rotor. Second, a linear perturbation analysis for the moving rotor is carried out to derive parameters for the shaft line analysis. Results of this approach will be compared to ones obtained by CFD.

1. Introduction

The shape of Francis runner side chambers has a significant impact on the shaft line system of hydraulic turbo machines. Especially the arrangement of seal and side chamber is a decisive factor whether damping is added to the shaft line or a self-exciting mechanism acts. In case that a self-excitation mechanism is present, sufficient damping has to be provided by the bearings. Otherwise, high shaft and bearing vibrations are observed at natural frequency of the shaft line system [1, 2, 3]. In the recent years, a trend to operate Francis runners also at deep part load and speed no load is present. Under these operating conditions, vortices in the water passage cause a broad band excitation on the shaft line. Here, a well damped system is necessary for reasonable operating behavior.

Therefore, the effect of the runner side chamber on the shaft line behavior is of interest during design phase. The behavior of seals was investigated by Childs et al. [4, 5]. He used a perturbation expansion of the bulk-flow model for the leakage path between the runner and the housing to calculate representing parameters for the interaction between fluid and structure. This approach was later extended to compressible media by Gupta et al. [6]. In parallel, Dietzen et al. [7] developed a CFD approach based on finite difference method to determine parameters