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Simulation of flow-induced vibrations of a radial gate with underflow

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In hydraulic engineering, different sources of flow-induced vibrations exist. Vibrations of a hydraulic structure can be caused by turbulences in the approach flow, by instabilities arising at the structure itself or by the coupling of the surrounding flow with the movement of the structure. While the exciting force in the flow exists even if the structure does not vibrate in the first two cases, the third one is more complicated: the forces in the flow arise due to the movement of the structure and the vibration of the structure is driven by the forces in the flow. Such loop of mutual control is referred as self-excitation or in the field of hydraulic engineering sometimes called movement-induced excitation. (Naudascher and Rockwell 1994)

The presented project deals with self-excited vibrations on a radial gate with underflow. The gate is known to vibrate under certain conditions with small gap width and low tailwater levels. For the numerical modelling of the gate, the interDyMFoam solver was used. This solver is part of the widely used open-source CFD software OpenFOAM and provides an efficient tool for coupling solid body motion with free-surface flow. Since the vibration of the modelled gate was a rotational vibration around the trunnion points, the model could be reduced to two dimensions. A fixed water level was used as boundary condition on the inflow and outflow boundary. Even though the full coupling is inevitable for self-excited vibrations, the coupled simulation is restricted in some points due to the complex nature of the prerequisite conditions. The small openings that are typically prone to self-excited vibrations require locally a very fine mesh. Additionally, high pressure gradients occur both in time and space due to the structural movement. These factors both have a negative effect on the stability of the simulation. Therefore, the free vibration of the gate is restricted to a prescribed vibration with a fixed frequency and amplitude. This improves the stability of the simulation but additional data about the predominant vibration is needed. The application of a 2D model brings another restriction to the simulation; the use of a LES-type turbulence model is not feasible therefore a k-ω-model is applied. The highly turbulent flow regime beneath the gate is thereby simplified and small scale vortices that occur in nature cannot be represented in the simulation.

Data from an extensive measuring campaign was used to calibrate the numerical model. Despite the restrictions in the model, the results look reasonable related to the pressure fluctuation beneath the gate. The described method serves as a useful engineering tool to check gate design for self-excited vibrations. Furthermore, the results enable an interesting view on the underlying process of interaction between vibrating gate and flow.

Literature