5th International Workshop on
Cavitation and Dynamic Problems in Hydraulic Machinery,
September 8-11, 2013, Lausanne, Switzerland

Experimental Study of Fluid Structure Interaction in a Kaplan Turbine Runner Blade

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Investigation of the unsteady pressure distribution on the runner of reaction turbines is essential to have better understanding of the flow condition in such complex machines. The results can be used to evaluate the runner performance and investigate the flow condition in blade channel. They are also useful for evaluation of the water supply systems performance; guide vanes, stay vanes and spiral casing. The last one plays an important role in evaluating the lifespan and overhaul schedule of the rotating parts including runner and bearings. In low head turbines, Kaplan and propeller, there are low number of blades without any support at the shroud. The blades and other rotating parts of the turbine may experience significant deflection and vibration according to the periodic forces.

The performance of the U9 Kaplan turbine model which was the subject of the study in [1-2] was investigated at three operating points. Piezo-resistive sensors were placed on suction side of one of the runner blades and pressure side of the adjacent blade to investigate flow situation in the blade channel. The power spectrum of the results showed a distinct peak at runner frequency as well as guide vane passing frequency showing the poor performance of the water supply system. The phase averaged results, illustrated in Fig 1, showed separation on the guide vanes close to the lip-entrance region of the spiral casing. This reparation results in flow asymmetry at the spiral casing outlet which results in pressure oscillation on the blades. The maximum amplitude in phase averaged results is close to 16% of the head; however, instantaneously it can reach up to 60% which is way higher than the value considered for bearing design (10%). This shows that the current trend in numerical simulations that consider symmetrical distribution at the inlet of the guide vane row is not valid. The results also proved the wobbling of the main shaft according to the asymmetry. This proved to be in agreement with the strain gauge measurements performed on the main shaft and displacement measurements on the bearings of the prototype.

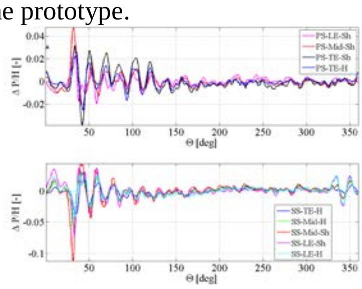

Fig. 1 – Phase averaged pressure fluctuation on the blades

During the Part load, the power spectrum of the sensors proved the existence of the rotating vortex rope (RVR) in the draft tube. The RVR frequency in rotating domain ($1-f_{RVR}$) showed to be the most significant frequency in all sensors which is an asynchronous phenomenon. The next highest peak in the power spectrum was proved to be f_{RVR}. This frequency was synchronous for all the pressure sensors located on different blades. This proves that the RVR results in axial oscillation of flow in whole turbine conduit. The frequency was captured everywhere in the test rig from penstock to the outlet of the draft tube.

Keywords: Kaplan turbine, blade pressure measurements, blade fluctuation

References

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