Simulations of Characteristics for a Reversible Pump-Turbine

- Impact of Small Geometry Changes

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Abstract

Reversible pump-turbines (RPT), are widely used today because of their ability to balance the power production and consumption at a reasonable cost. Intermittent new renewable power sources such as wind power and solar energy is increasingly coming into the market and they have less ability to control when the energy is to produced and in what amount. To store the energy one pumps water up to a reservoir. This requires pumping ability and a single stage reversible pump turbine can be more cost effective than a pump together with a turbine. The main elements of a singe stage reversible pump turbine is the spiral casing, stay vanes, guide vanes, turbine runner (impeller) and draft tube. In turbine mode the guide vanes are used to control the flow through the turbine. For a fixed guide vane opening, one can express the combination of flow (Q), speed (N) and pressure (head – H) as a curve. These curves is commonly denoted characteristics and is typically expressed as functions of the non-dimensional flow and speed

Qed=Q/(D^2 sqrt(g*H)) and Ned=(n*D)/sqrt(g*H)

For a low specific pump turbine the characteristics are often very steep at part load operation in turbine mode. Problems with stability and high pressure and flow variations are reported from different pump power stations. Examples of this are reported in [1] and [2]. The shape of the characteristics may also be S-like, as reported in [3]. Compared to Francis turbine characteristics the RPT-characteristics are steeper – a direct consequence of the compromise involved in designing a machine that shall operate both as a pump and a turbine. In pump mode the friction in the water conduits is added to the static head, increasing the actual net head of the unit, while in turbine mode friction losses reduce the net head. Thus the pump needs a larger inlet diameter compared to a conventional Francis turbine. Moreover, the pump characteristics, expresses as the pump head H as function of Q at constant rotation speed is directly related to the pump outlet blade angle (turbine blade inlet angle). A small blade angle gives a steep pump characteristics, something which is desirable to obtain a large operating range without excessive problems with pump cavitation. In the traditional method of designing pump turbine runners most of the computational effort is focused on operation around the best efficiency point in turbine mode and pump mode. The actual shape of the turbine and pump characteristics is only discovered in the model test rig, where there is limited scope for modifications. The goal of this work is to develop and validate computational tools for predicting the turbine- and pump characteristics. Furthermore, it is expected that through this work a better understanding of the relation between various geometry parameters (inlet diameter, inlet blade angle, curvature of profile at inlet) and the shape of the turbine characteristics can be obtained, leading to impeller designs with better dynamic performance.

In this work the characteristics for an RPT are simulated using both a steady state solver, MRFSimpleFoam, and the transient solver TurbDyMFoam. The transient results are then averaged in order to get the steady state operation points. For the steady state simulations only one channel of the runner is simulated. Cyclic boundary conditions are then used at the borders. The transient simulation includes the whole 360 degree runner. For both simulations the guide vanes and a radial outlet zone are included. The simulations are two-dimensional.

Key words: Reversible Pump Turbine, Characteristics, OpenFOAM

References

[1] P.K. Dörfler, A.J.E., R.N.Pendse, P.Huvet, M.V.Brahme. Stable operation acvhieved on a single -stage reversible pump-turbine showing instability at no-load. In Proceeding of the 19th Symposium on Hydraulic Machinery and Systems. 1998. Singapore.

[2] Klemm, D., Stabilisierung der Kennlinien einer Pumpenturbine im Bereich zwischen Turbinen-Teillast und Rückwärtspumpenbetrieb. Voith Forschung und Konstruktion, 1982. Heft 28, Aufsatz 2.

[3] Martin, C.S. Instability of pump-turbines with s-shaped characteristics. in In Proceedings of the 20th IAHR Symposium on Hydraulic Machinery and Systems. 2000. Charlotte, USA.