Characteristics of Abnormal Flow in a Model Pump Turbine during Off-design Conditions

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Long Abstract

Introduction

Abnormal flow (e.g. backflow and vortex) is an important characteristics of inner flow passing through rotating machinery during off-design conditions. For reversible pump turbine, such kind of abnormal flow usually happens during the off-design conditions in generating mode and could induce significant pressure fluctuation, vibrations and blockage of channels, leading to the instability problems of pump turbine [1-4]. Hence a thorough understanding of the characteristics of the abnormal flow is desirable for further performance improvement of pump turbine. Specifically, backflow inside pump turbines plays an important role on the turbine performance in turbine brake and runaway modes. However, the features of backflow inside pump turbine have not been fully investigated in the literature. In the present paper, a quantitative analysis of the backflow phenomenon during different operating conditions will be performed together with its features in the whole pump turbine.

1. Details of simulations

In the present paper, a model Francis pump turbine will be numerically simulated using SST k-ω turbulence model. The details of the simulated model pump turbine are: nominal diameter 1.92 m; rated speed 500 rpm; number of stay vanes 20; number of guide vanes 20; number of blades 9. In the simulations, typical working conditions with different guide vane openings are selected to investigate the abnormal flow.

2. Results and discussions

Firstly, an experimental verification of our numerical investigation is performed. Figure 1 shows the comparison of the characteristic curve (Q_{11}-n_{11} curve with Q_{11} being the discharge factor and n_{11} being the rotational speed factor) obtained by the model test and predicted by our simulations. There are total nine data points in each curve with the maximum error 4.31%, which is quite acceptable for a valid numerical simulations.

Data analysis was focused on the quantitative analysis of backflows (in terms of the amplitude and total discharge) and regions dominated by the backflow inside the whole passage of the pump turbine (from spiral case to the guide vanes, vaneless space, runner and draft tube). During off-design conditions, backflows is prominent inside the runner and also distribute quite non-uniformly in different blade channels. Along S-shaped characteristics curve, the feature of backflows also varies strongly.

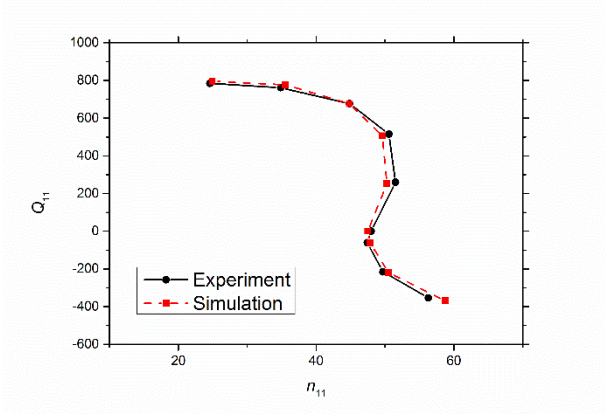

Figure 1. Comparison of the characteristic curve obtained by the experiment and predicted by our simulations. Q_{11} is the discharge factor and n_{11} is the rotational speed factor.

References

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