Structural characteristic analysis of the guide vanes of a pump turbine which working at the slight opening region

Qingfeng JI, Institute of Water Resources and Hydro-electric Engineering, Xi'an University of Technology, Xi'an, China
Weili LIAO, Institute of Water Resources and Hydro-electric Engineering, Xi'an University of Technology, Xi'an, China
Honggang FAN*, State Key Laboratory of Hydroscience and Engineering
Department of Thermal Engineering, Tsinghua University, Beijing, China
Haixia YANG, State Key Laboratory of Hydroscience and Engineering Department of Thermal Engineering, Tsinghua University, Beijing, China

Long Abstract

Introduction

Reversible pump turbine (RPT) is designed for pumping water from a lower reservoir to a higher reservoir by using the surplus energy in the power grids. Furthermore, this water have to go down to generate electrical energy by RPT at peak hours or in case of emergency. RPT have to change the working condition between pump mode and turbine mode [1]. In order to meet the requirement of power grid, RPT usually works at low load off-design working condition. Due to RPT's special way of operating, it's hard to guarantee the stability of the units. Few years ago, both in TianHuangping pump storage power station [2] and YiXing pump storage power station [3], the abnormal sound and vibration occurs at the distributor of the RPT which in the pump mode when the guide vane opening is very small. In order to resolve this problem, B Nennemann [4] has conducted a detailed research about the abnormal phenomena which happened in YiXing pump storage power station by using 2-D periodical CFD simulation. Eventually, the author acclaimed that the unexpected bi-stable flow conditions and a self-excited torsion mode flutter vibration of the guide vane caused this problem, moreover, the vibration problem can be eliminated by modifying the shape of the guide vane successfully. Addressing the issue of TianHuangping, H G Fan [5] studied the HT of the guide vane of the RPT during the startup process and shutdown process in turbine mode by 2-D periodical CFD simulation. His work indicated that repeating reversal of fluid occurs when the guide vane at slight opening during the shutdown process in turbine mode. This phenomena finally results in the dramatically increasing of the HT which makes the vibration happens.

Our previous work [6] has performed the 3-D CFD simulation of the startup process of the pump turbine of Tian Huangping pump storage power station which in the pump mode by implementing the dynamic meshing technique. The results indicates that the main flow between the guide vanes has experienced a deflection when the guide vane opening is very small, and this deflection leads to the sharply changing of the hydraulic torque on the guide vanes, if the transmission of the distributer cannot adapt this changing immediately, the vibration and abnormal sound will occur in the unit.

Based on the previous flow field analysis [6] of the dynamic process. This paper presents a structural characteristic analysis of the guide vanes when the pump turbine works in pump mode at slight opening region. The one-way FSI method was carried out to calculate the structural characteristic of guide vanes during the main flow deflection process. And the vibration characteristic of the guide vanes were analyzed. The result shows that the position of the guide vane has a significant influence on the stress and strain of guide vanes.

1. Methods

In this paper, the simulation was performed by using the commercial CFD solver-ANSYS workbench.

As same as our previous work [6], the geometry of prototype pump turbine of Tian Huangping pump-storage power station was implemented. The geometry model is shown in Figure.1 and the characteristics of the parameters are listed in table 1.

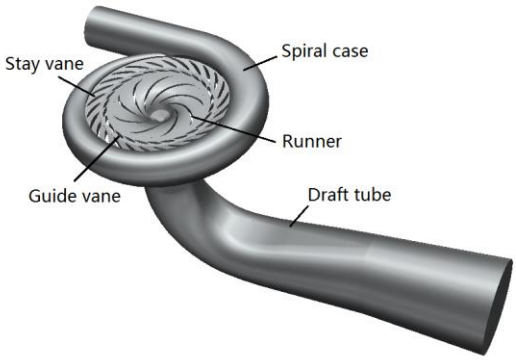
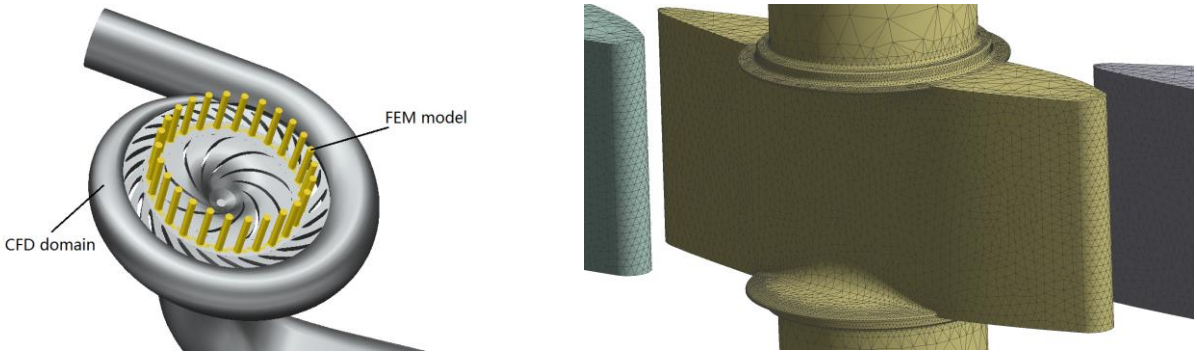


Figure 1. CFD computational domain of the pump turbine

Table 1 Parameters of the pump-turbine

Parameters	Value
D_2 (mm)	2045
b_0 (mm)	262
Runner blade number	9
Guide vane number	26
Stay vane number	26
Rated speed (rpm)	500
Head (m)	610



(a) geometry of the guide vanes (b) mesh of single guide vane

Figure 2. FEM model of guide vanes

Table 2 Material parameters of the guide vanes

Parameters	Value
b_0 (mm)	262
Guide vane number	26
Material density ρ (kg/m3)	7850
Young's modulus E (GPa)	206
Poisson's Ratio γ	0.28

In addition, tetrahedral mesh was used for the FEM model of the guide vanes, it has 5276840 elements and 8175137 nodes totally. Figure 2 and Table 2 shows the FEM model and material parameters of the guide vanes.

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