Dynamic Behavior in Prototype Impeller of Francis Turbine Analysis

MAO Zhongyu, Department of thermal engineering, Tsinghua University, Beijing, China
WANG Zhengwei*, Department of thermal engineering, Tsinghua University, Beijing, China

Long Abstract

Introduction

The hydraulic stability of Francis turbines is very important for safe operation of the station. Pressure fluctuation can produce high vibrations in the impeller of Francis turbines [1]. Then, the dynamic stress due to the vibration of runner might be detrimental, possibly to cause fatigue failure, if the runner were designed without proper consideration on its dynamic behavior[2]. Therefore, an accurate understanding of the dynamic behavior of impeller such as natural modal and dynamic stress, especially when it is submerged in water, is of most importance.

As the impeller is submerged in water in actual operation, the fluid added mass would influence the natural frequencies. Both experimental test and numerical analysis has discovered that the natural frequencies in water are different from that in air the added mass effect of surrounding water and the result of numerical agree well with experiment [3,4].

Due to consideration that vibration displacement is very small, the analysis of dynamic stress in runner has been handled as one-way fluid-structural interaction problem. Namely the excitation force is calculated by whole passage flow analysis that is ignored the structural deformation and considers the rotor-stator interaction effect. Many researchers have engaged in calculated dynamic stress in Francis runner by the transient response analysis taken account into the added mass effect of surrounding water using an acoustic fluid formulation[5,6].

Both modal and dynamic stress analysis in Francis runner doesn't take account into the added mass effect of water in clearance, which is between crown and runner chamber or between band and chamber. However, the added mass in clearance would obviously effect the modal and dynamic stress in runner.

This paper thoroughly researches the dynamic behavior of prototype impeller of Francis turbine. The natural frequencies and modal in air, passage flow and passage flow with clearance was analyzed in detail. Then the one-way FSI method was used to calculate the dynamic stresses in the Francis turbine impeller in different conditions. And the influence on pressure fluctuation and dynamic stress of passage flow and the clearance was analyzed and compared.

1. Methods

The model was based on a Francis turbine impeller. The following table shows the defining parameters for the impeller:

Table 1. Defining impeller parameters

Runner diameter [mm]	Number of blades [-]	Number of guide blades [-]	Rated head [m]	Rated speed [r/min]	Material density ρ [kg/m3]	Young's modulus E [GPa]	Poisson's ratio γ [-]
2665	17	20	250	375	7.75	207	0.3

In this research, the whole model of passage flow was established, including the clearance in crown,

band and seal (Figure 1). The excitation force in unsteady conditions is calculated by whole passage flow analysis while the modal and dynamic stress are calculated by only the impeller domain including the structure and passage flow (Figure 2).

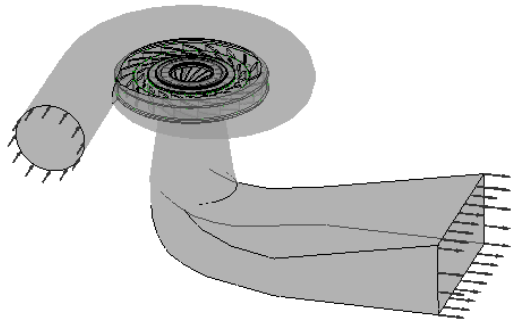
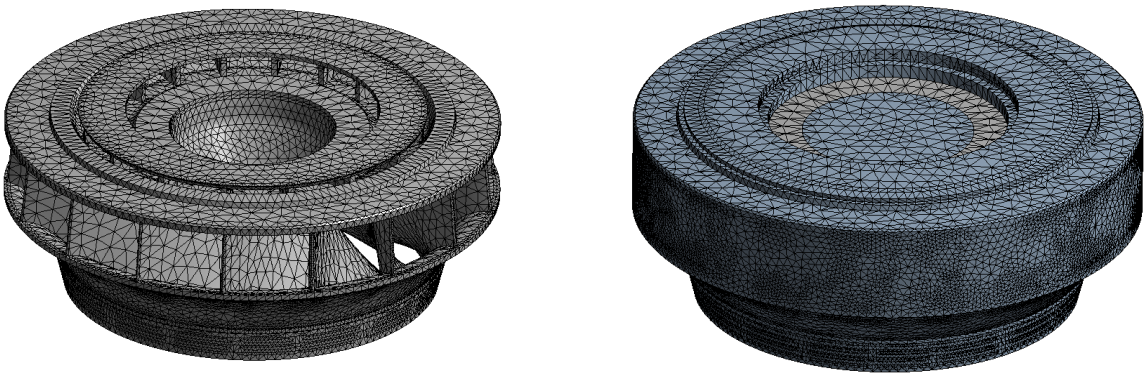


Figure 1.The whole model of passage flow(include clearance)



(a) in air *(b) in water(include clearance)*

Figure 2.FEM model of dynamic behavior analysis

To find the influence of passage flow and the clearance in different condition, this paper analyzed the dynamic behavior in 4 conditions, which is shown in the table below.

Table 2. The typical operation

Rated head Rated output	Rated head High output	High head Small load	High head Big load
H250A20	H250A23	H293A8	H293A18

References

[1] Liang Quan-Wei. Dynamic characteristic analysis of Francis turbine with considering FSI[D]. Master Thesis, Beijing: Tsinghua University, 2003. (In Chinese)

[2] Xiao R, Wang Z, Luo Y. Dynamic stresses in a Francis turbine runner based on fluid-structure interaction analysis [J]. Tsinghua Science & Technology, 2008, 13(5): 587-592.

[3] Egusquiza E, Valero C, Liang Q, et al. Fluid added mass effect in the modal response of a pump-turbine impeller[C]//ASME 2009 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. American Society of Mechanical Engineers, 2009: 715-724.

[4] Lixia Z, Wei Z, Zhaohong Y. Modal analysis of Francis turbine blade based on fluid-structure interaction theorem[J]. International Journal of Modelling, Identification and Control, 2010, 10(1): 101-105.

[5] Seidel U, Hübner B, Löfflad J and Faigle P 2012 Evaluation of RSI-induced stresses in Francis runners. 26th IAHR Symp. on Hydraulic Machinery and Systems. Beijing, China

[6] Guillaume R, Deniau J-L, Scolaro D, Colombet C 2012 Influence of the rotor-stator interaction on the dynamic stresses of Francis runners. 26th IAHR Symp. on Hydraulic Machinery and Systems. Beijing, China