

The numerical simulation based on CFD of hydraulic turbine pump

X H Duan¹, F Y Kong¹, Y Y Liu¹, R J Zhao¹, Q L Hu¹

¹ National Research Center of Pumps, Jiangsu University, Zhenjiang, Jiangsu 212013, China

E-mail: 694140559@qq.com

Abstract. As the functions of hydraulic turbine pump including self-adjusting and compensation with each other, it is far-reaching to analyze its internal flow by the numerical simulation based on CFD, mainly including the pressure field and the velocity field in hydraulic turbine and pump. The three-dimensional models of hydraulic turbine pump are made by Pro/Engineer software; the internal flow fields in hydraulic turbine and pump are simulated numerically by CFX ANSYS software. According to the results of the numerical simulation in design condition, the pressure field and the velocity field in hydraulic turbine and pump are analyzed respectively. The findings show that the static pressure decreases systematically and the pressure gradient is obvious in flow area of hydraulic turbine; the static pressure increases gradually in pump. The flow trace is regular in suction chamber and flume without spiral trace. However, there are irregular traces in the turbine runner channels which contrary to that in flow area of impeller. Most of traces in the flow area of draft tube are spiral.

1. Introduction

Computational fluid dynamics (CFD), which is theoretical and practical, describes the numerical solution of the flow field quantitatively on the time and space by computer numerical calculations and a method of image displayed[1]. The relationship of performance parameters between pumps and PAT was predicted by theoretical analysis and the empirical formulas based on the experimental data[2]. However, turbine Pump has some advantages, such as low cost and the ability of simulating complicated or desirable fluid motion. As the functions of hydraulic turbine pump including self-adjusting and compensation with each other, it is far-reaching to analyze its internal flow.

2. Computation of parameters and conditions

Table 1. The main parameters of the pump and the turbine

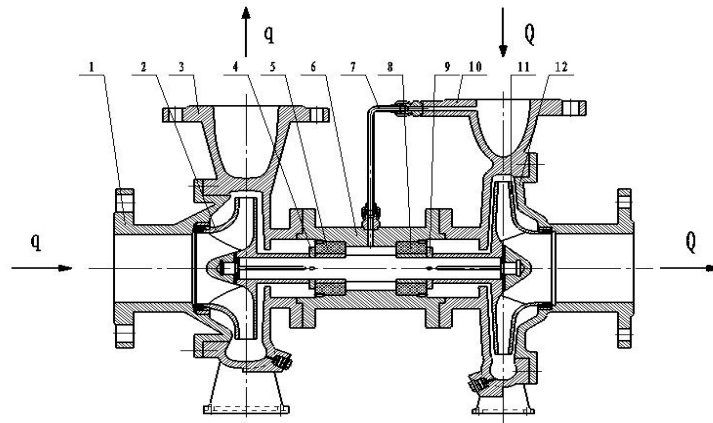
Pump flow /m ³ h ⁻¹	Pump head /m	N /r min ⁻¹	T /°C	Turbine flow /m ³ h ⁻¹	Turbine head /m	P /KW	ρ /kg m ⁻³
60	11	1475	20	90	41.5	1.8	998.2

National Science Foundation(2013BAK06B02), Project supported by Postgraduate Innovation Foundation of Jiangsu Province(CXZZ13_0678)

Author: Xiaohui Duan,(1990-),Male, Jiangsu Province, master degree



Content from this work may be used under the terms of the [Creative Commons Attribution 3.0 licence](https://creativecommons.org/licenses/by/3.0/). Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.



1.pump lid 2.impeller 3.Pump body 4.Balance disc 5.Sliding bearing 6.Connector 7.Rushing pipette 8.Sliding bearing 9.Balance disc 10.Turbine body 11.Runner 12.Turbine lid

Figure 1. Structure diagram of hydraulic turbine

3. The geometric model and numerical simulation

3.1. Solid model of fluid region

Using Pro/Engineer software, the three-dimensional solid models are made. The models are presented in figure2 to figure3[3].

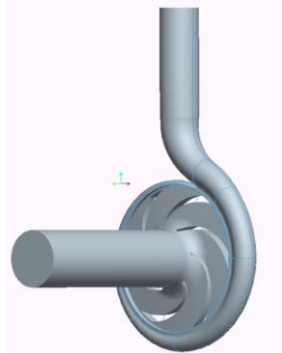


Figure 2. Hydraulic Turbine

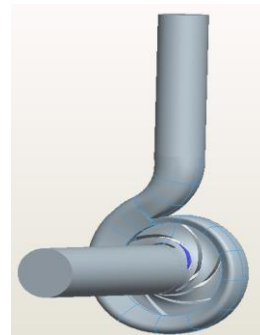


Figure 3. Pump

3.2. Mesh generation of fluid region

The number of grid of hydraulic turbine is 1158877 and pump is 1458943. The grids are presented in figure4 to figure5[4].

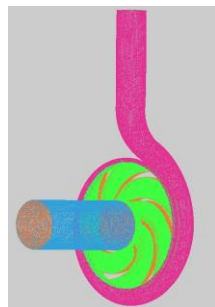


Figure 4. Meshes in Hydraulic Turbine

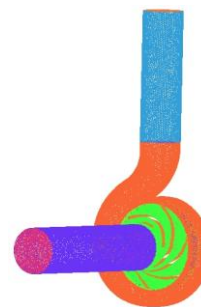


Figure 5. Meshes in Pump

3.3. Turbulence Model

At present, the standard $k-\varepsilon$ model is the most basic one of the double equations model being the most widely used the eddy viscosity model. The equations[5] are as follows:

$$\frac{\partial}{\partial t}(\rho k) + \frac{\partial}{\partial x_i}(\rho k u_i) = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_k} \right) \frac{\partial k}{\partial x_j} \right] + G_k - \rho \varepsilon - S_k \quad (1)$$

$$\frac{\partial}{\partial t}(\rho \varepsilon) + \frac{\partial}{\partial x_i}(\rho \varepsilon u_i) = \frac{\partial}{\partial x_j} \left[\left(\mu + \frac{\mu_t}{\sigma_\varepsilon} \right) \frac{\partial \varepsilon}{\partial x_j} \right] + C_{1\varepsilon} \frac{\varepsilon}{k} G_k - C_{2\varepsilon} \rho \frac{\varepsilon^2}{k} + S_\varepsilon \quad (2)$$

Where: μ_t — turbulent viscosity, $\mu_t = \rho C_\mu \frac{k^2}{\varepsilon}$; G_k — turbulent kinetic energy, $G_k = \mu_t \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) \frac{\partial u_i}{\partial x_j}$; $\sigma_k, \sigma_\varepsilon$ — turbulence Prandtl constant of $k-\varepsilon$ equation; S_k — viscous stress $S_k = 1.0$; S_ε — turbulence stress $S_\varepsilon = 1.3$; $C_\mu = 0.09$; $C_1 = 1.44$; $C_2 = 1.92$

3.4. The simulation and analysis of internal flow field in pump and hydraulic turbine

The inner flow field in pump and hydraulic turbine are simulated by ANSYS CFX, and then the velocity profile and pressure profile are analyzed to get some conclusions through the pictures from the simulation.

3.5. The analysis of pressure profile in hydraulic turbine

The pressure value compared to 101325 Pa is a relative value in this model[6].

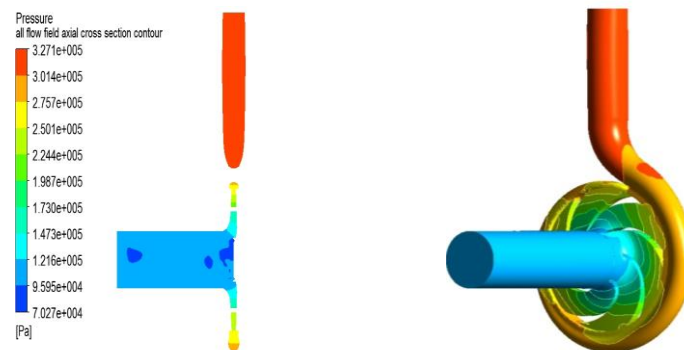


Figure 6. Static pressure distribution diagram of hydraulic turbine

From Figure 6, the static pressure is lower and lower as the order of intake pipe, turbine flume, impeller and draft tube. The dividing line is obvious among the different pressure fluid, and the static pressure value is rather low in the draft tube.

The static pressure contours of the whole flow passage of hydraulic turbine are shown in Figure 6. As can be seen from the picture, the static pressure of the water diversion chamber, the runner and the draft tube is decreasing in order. The indoor static pressure of the water diversion chamber begins to decrease from the IX section, which is decreasing as the diversion chamber flow section area reducing. Some regions appear high-pressure. The static pressure of the runner is decreasing from the inlet to the outlet and the pressure gradient is significant. The static pressure of draft tube is basically constant.

3.5.1. The analysis of pressure field of the internal flow region of the pump. The pressure values in the picture are relative to the reference value of the 101325 Pa of the model. And the values in the following static pressure contours are relative.

The static pressure contours of the axial section of the whole passage of pump is shown in Figure 7. As can be seen from the picture, the static pressure of the water inlet pipe, the water diversion

chamber, the impeller, the water pressing chamber and the water outlet pipe is gradually decreasing in order. And the pressure gradient is significant.

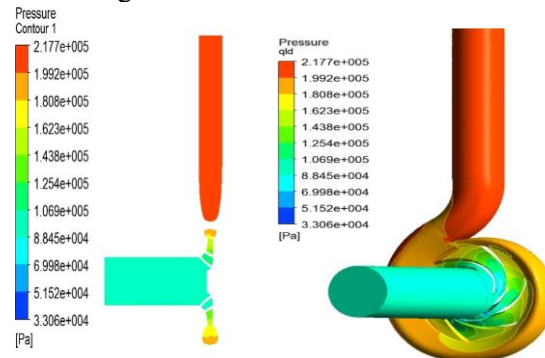


Figure 7. Static pressure contours of the whole passage of pump

The static pressure contours of the whole passage of pump is shown in Figure7. As can be seen from the picture, the pressure of the suction chamber, the impeller, the pump chamber and the outlet pipe is gradually increasing. The static pressure gradient of liquid impeller is significant, which is increasing gradually.

The indoor static pressure of the pumping chamber is decreasing from I section to XIV section. Some regions appeared high-pressure. The static pressure of impeller passage increased gradually from the inlet to the outlet direction, the adverse pressure gradient. And the pressure gradient is significant. The static pressure of outlet pipe is basically constant.

3.5.2. The analysis of velocity field of the internal flow region of the hydraulic turbine. The velocity vector distribution of the whole flow passage of pump is shown in Figure8. The velocity vector distribution of the axial section of the whole flow passage is shown in Figure8. As can be seen from the picture, the velocity of the inlet pipe, the suction chamber, the impeller and the pumping chamber increase first, then decrease. The liquid velocity value reached the maximum in the impeller. And it reached the minimum in the draft tube. The velocity field of inlet liquid in the tube is regular, which is spiral in the tail pipe and the outlet pipe.

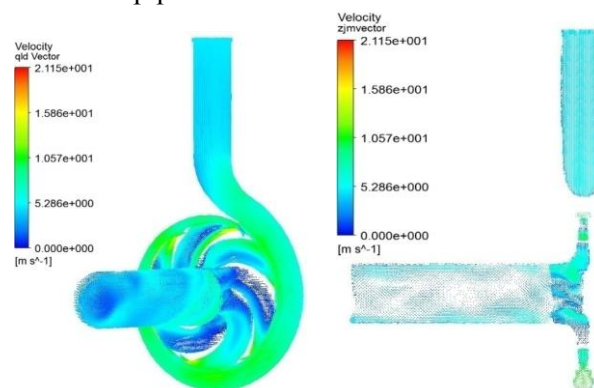


Figure 8. Velocity vectors contours of hydraulic turbine

The trace diagram of the whole flow passage of pump is shown in Figure9. As can be seen from the picture, the trace in the inlet pipe and the water diversion chamber is regular. There is no spiral trace appearing. There is irregular trace appearing in the flow passage of impeller. Most of trace in the tail pipe is spiral.

3.5.3. The analysis of velocity field of the internal flow region of pump. The velocity vector distribution of the whole flow passage of pump is shown in Figure10. As can be seen from the picture, the trace in the suction chamber and the impeller is regular. And the trace of the outlet pipe is bending up.

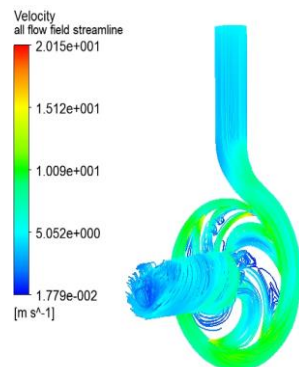


Figure 9. Trace diagram of the whole passages in hydraulic turbine

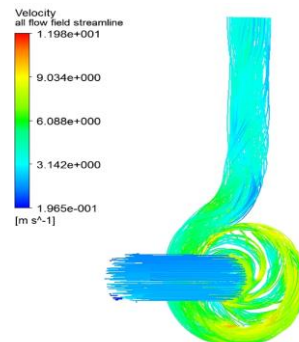


Figure 10. Trace diagram of the whole passage in pump

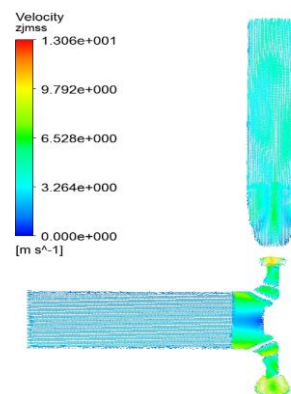
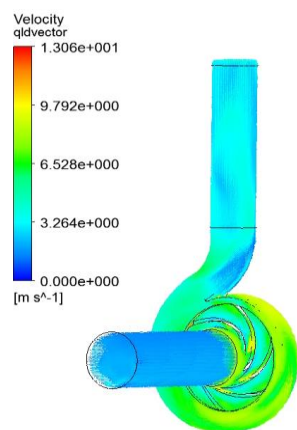


Figure 11. Velocity vectors contours of pump

The velocity vector distribution of pump is shown in Figure 11. As can be seen from the picture, the relative velocity of the suction chamber, the impeller, the volute and the outlet pipe increases first, then decreases.

The liquid relative velocity value reached the maximum in the flow passage of the impeller. And it reached the minimum in the center of back cover plate. The velocity field in the suction chamber and the impeller is regular. And there is vortex of the velocity field in the volute. The velocity field in the outlet pipe is regular.

4. Conclusion

In the hydraulic turbine, the static pressure of the suction chamber, the impeller, the tail pipe is lower and lower, the pressure gradient is significant. In the pump, the pressure of the suction chamber, the impeller, the pumping chamber and the outlet pipe is gradually increasing.

The trace in the inlet pipe and the diversion chamber is regular, There is no spiral trace appearing. There is irregular trace appearing in the flow passage of the turbine impeller which contrary to in the follow passage of pump impeller. Most of trace in the tail pipe is spiral.

5. References

- [1] Wang F J 2004 *The Analysis of Computer Fluid Dynamics* (Beijing: Tsinghua University Press)
- [2] Wang T, Kong F Y, He Y Y, Yang S S 2013 The current research status of centrifugal pump for turbine *Journal of Drainage and Irrigation Machinery Engineering*, **08**:674-680

- [3] Yang S S, Kong F Y, Su X H , etc 2012 Numerical simulation and external characteristic of pumps and pump as turbine *Academic Journal of Xi'an Jiaotong University* , **3(46)**: 36-41.f
- [4] Yang S S, Kong F Y, Shao F, et al. 2010 Numerical simulation and comparison of pump and pump as turbine *ASME Fluids Engineering Summer meeting*(Montreal:Canada) 1-10
- [5] Xie L H, Zhao Xinyu 2013 *ANSYS CFX analysis and simulation of fluid* (Beijing: Electronic Industry Press)
- [6] Yang S S, Shahram Derakhshan, Kong F Y 2012 Theoretical numerical and experimental prediction of pump as turbine performance *Renewable Energy*, 507-513