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Performance analysis of single-channel pump with different wrap angles

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Abstract. When a single-channel pump is used to transport living things, the rotating action of the impeller will cause damages to the living things. To improve the survival rate of the single-channel pump for transporting living things and improve the performance, the effect of the impeller wrap angle on the performance of the single-channel pump was studied by numerical simulation. The external characteristic curve is analyzed and the change of the pressure field of the flow field in the flow channel with the wrap angle is grasped. The pressure pulsation at the monitoring points is analyzed, and the influence law of the wrap angle on the performance of the single-channel pump is obtained. This law lays the foundation for subsequent single-channel pump design

1. Introduction

The single-channel pump is a centrifugal pump with a special impeller structure, suitable for conveying liquids containing large particles or fibers and other debris. It has the highest non-clogging and anti-winding performance among non-clogging pumps. The efficiency of this pump is relatively high, the power curve is stable, and it has the characteristics of non-destructive and good abrasion resistance for conveying materials. Sweden FLYGT Company [1] has been producing submersible sewage pumps since 1956. Single-channel impellers have been widely used in its submersible sewage pumps. A. Kratez [2] firstly comprehensively summarized the design and selection of non-blocking pumps in 1979 and compared the hydraulic performance of various pump impellers. He analyzed the non-destructive performance of various pumps on conveyed materials through experimental results and found that single-channel impellers perform best in non-destructive conveying of solids.

In 1993, Guan et al. [3-4] summarized the design methods of single-channel pumps based on a large number of experimental studies and design practices. He analyzed the structure of the single-channel impeller and the reason for its excellent non-clogging performance and established an empirical formula for determining the geometric parameters of the impeller by statistical analysis. Liu [5] proposed a new method to improve the hydraulic design of a single-channel impeller in 2001. Tan [6] et al. discussed the single-channel pump in 2017 and analyzed the influence of the blade exit angle on the performance.



Blade wrap angle is an important geometric parameter that affects the performance of a single-channel pump. In this study, the CFD numerical simulation method is used to analyze the pressure distribution of the flow field. The influence of the change of the wrap angle on the performance of the single-channel pump combining with the change of the external characteristics. The mechanism of the wrap angle affecting the single flow channel pump is obtained by changing vortex and pressure pulsation in the flow channel. This study provides a theoretical basis for subsequent single-channel pump design.

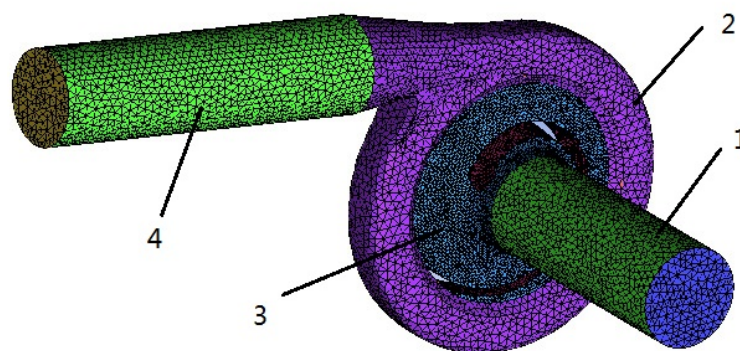
2. Model and numerical analysis method

2.1. Model

The design parameters of the model are: flow $Q_d = 300\text{m}^3/\text{h}$, revolution $n = 300\text{rpm}$, head $H = 10\text{m}$, specific speed $n_s = 112$ and volute outlet diameter $D_d = 217\text{mm}$. Impeller wrap angles are taken at 310° , 320° , and 330° for analysis. According to the design parameters, the impeller is three-dimensionally designed, and the blade is drawn by interpolation. To avoid the influence of the inlet and outlet on the flow field in the flow channel, an inlet section and an outlet section with a diameter of 4 times have been added. Full flow field calculation is applied, including impeller, volute, inlet and outlet sections. The calculation model is shown in Figure 1.

2.2. Numerical model and meshing

The pump inlet and outlet positions are appropriately extended to reduce the influence of boundary conditions [7]. The calculation domain is the entire flow area from the extension of the entrance to the extension of the exit. The grid is unstructured, and the grid on the impeller is encrypted. The grid correlation verification is performed with the change in the predicted value of head less than 1%. The total number of grids is 500,000, 700,000 and 900,000. The grid quality is all above 0.3, which meets the grid quality requirements for calculation.



1-Extension of inlet; 2-Volute; 3-Impeller; 4-Extension of outlet

Figure 1 Calculation domain and meshing of single-channel pump

2.3. Boundary conditions

This study uses fluent to perform the calculation of a single-channel pump. The flow field is divided into four parts, which are impeller, volute, inlet extension, and outlet extension. Interfaces between different parts are set to interface for convenient calculation. The inlet condition is set as velocity-inlet, and the outlet is set as outflow. The wall of each section is set as a non-slip solid wall [8]. The calculation settings are shown in Table 1.

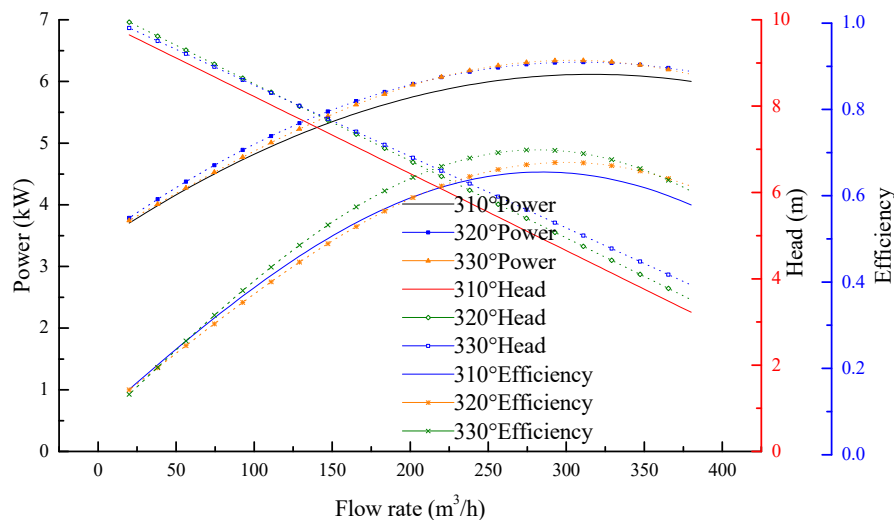
Table 1 Numerical model and working conditions

Numerical method	Calculation model
Solving mode	Unsteady
Turbulence model	SST $K-\omega$
Pressure discrete form	Standard
Coupling method	SIMPLEC
Difference mode	One order upwind scheme
Water density	998.2kg/m^3
Dynamic viscosity coefficient	$0.001003\text{kg(m}\cdot\text{s)}$
Inlet speed	$0.5\text{m/s}\sim 4.11\text{m/s}$
Revolution	300rpm

3. Results and discussion

3.1. External characteristics

The numerical simulation is applied to obtain the external characteristic curves of single-channel pumps with different angled impellers. The figure shows that as the wrap angle increases, the pump efficiency and the head increases. Under the design conditions, increasing the impeller wrap angle within a certain range is conducive to improving the head and efficiency of the pump, but it also increases the power of the pump.

**Figure 2** External characteristics of the single-channel pump with different wrap angles

3.2. Flow field analysis

The flow field information in the single-channel pump is obtained by CFD numerical calculation. The section at the centerline of the flow channel is taken and its pressure cloud diagram is analyzed, as shown in the figure. With the increase of the wrap angle, the low-pressure area at the blade inlet position shows some changes, and the pressure in the flow channel decreases. The pressure at the tongue position is significantly reduced, which is conducive to the transportation of living things.

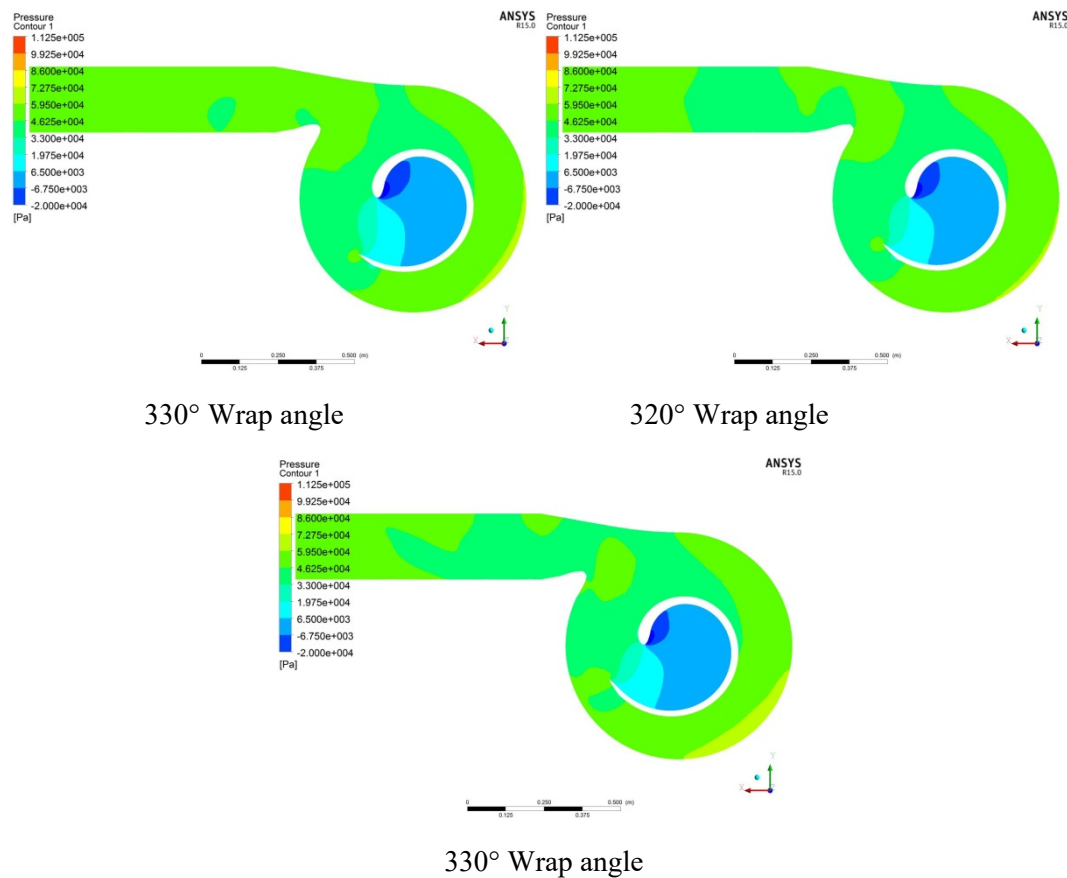


Figure 3 Pressure cloud picture of sections with different wrap angles

3.3. Pressure pulsation analysis

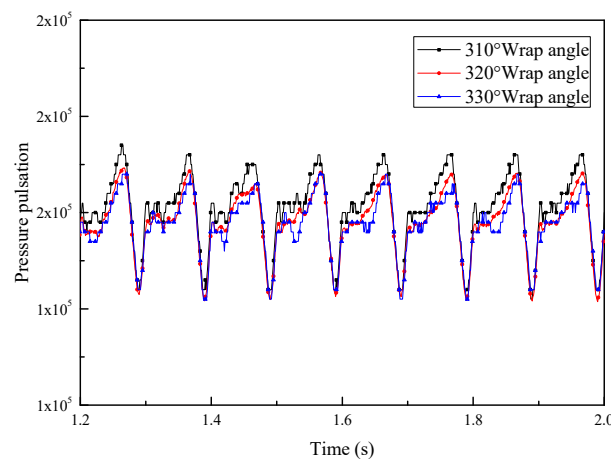


Figure 4 Pressure pulsation

Monitoring points are set in the impeller rotation range to obtain pressure pulsations in the flow field during the impeller rotation, as shown in Figure 4. When the wrap angle is low, the amplitude of the pressure pulsation is large, corresponding to the cloud picture. The increase of the wrap angle makes the amplitude of the pressure pulsation at the corresponding point in the flow field decrease, thereby

reducing the damage to moving objects in the flow field, which is beneficial to living things transportation.

4. Conclusion

By calculating the performance of the single-channel pump with different wrap angles, the changes of external characteristics are analyzed.

1. The wrap angle of the single-channel pump impeller has a significant influence on the performance.
2. The increase of the impeller wrap angle is conducive to increasing the head and efficiency of the single-channel pump, while also increasing the power.
3. increasing the wrap angle helps reduce pressure pulsations in the flow channel. For a single-channel pump to transport living things, it effectively reduces the influence of pressure pulsations on the living things in the flow field, which is beneficial to increasing the survival rate.

Acknowledgments

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