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Analysis of effects of impeller inlet width on the performance of centrifugal pump

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ABSTRACT

In order to study the influence of different impeller inlet width on the performance parameter of centrifugal pump, we utilize the method of CFD simulation, getting the pressure distribution in different condition of impeller inlet width. And then through theoretical calculation, we gain the lift and efficiency under various situations of impeller inlet width and do the analysis and research on them. The results show that when the inlet width of centrifugal pump impeller is 66mm, the comprehensive performance is better. This provides a reference for the design and production of centrifugal pump.

Keywords: Centrifugal pump; Impeller inlet width; Computational fluid mechanics; Comprehensive performance

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INTRODUCTION

Centrifugal pump is a generic machinery, which is commonly used in PCB (Printed Circuit Board) chemical etching, the production and processing of agricultural products, minerals separation, metallurgy, electric power, and shipbuilding, construction of national defense and the city drainage industry and many other industries [1]. However, the inlet width of impeller has a great impact on the comprehensive performance of centrifugal pump. Aiming at the improvement of the performance of the centrifugal pump, researchers made a lot of related study. For instance, Chen Songsong et al [2] optimized and analyzed the efficiency of semi-open impeller centrifugal pump, Guo Pengcheng et al [3] adopted the method of three-dimensional steady flow numerical simulation to well design the centrifugal pump impeller. But researches on effects of different impeller inlet width on the performance of centrifugal pump is relatively less. This passage used the way of theoretical calculation and CFD simulation to study a certain type of centrifugal pump, obtaining the lift, speed, efficiency and stress distribution in different width of impeller. Through the comprehensive analysis of the performance parameters, it showed that when the inlet width of centrifugal pump impeller is 66mm, the comprehensive performance is better, which offered a reference for the design and production of this kind of centrifugal pump.

2. The hydraulic design of centrifugal pump

The centrifugal pump which we research and design in this passage requires the pump to provide a rate of $24m^3/h$ flow in the working conditions whose lift is 25m .In addition, the necessary cavitation allowance of the pump NPSHr is 4m and the service fluid is required to be water, whose temperature is less than 80℃and density is $1000kg/m^3$. Utilizing the traditional speed coefficient method to design the hydraulic model of pump, three dimensional model of impeller is shown in Fig. 1.Among them, the inlet diameter of the pump(D0) is 64mm, the inlet diameter of the impeller(Dj) is 66mm, the outlet diameter of the impeller(D2) is 144mm,the number of vanes(z) is 6, the width of vanes(b) is 12mm,the thickness of vanes(ə) is 4mm and the outlet angle of vanes(ß2) is 22.5°.

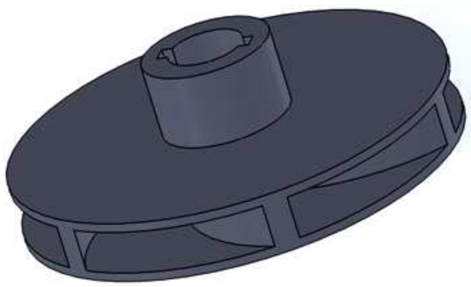

Fig.1 Three dimensional model of impeller

3. CFD simulation

3.1 The setup of inlet width of impeller

In this simulation, we study its effects on the total performance of centrifugal pump by changing the inlet width of impeller. Based on the 66mm-impeller inlet width that determined by the hydraulic design of centrifugal pump, we set five values to do the analysis and simulation research, two of which is less than referenced inlet width, two of which is more than referenced inlet width. These five values is respectively 60mm, 63mm, 66mm, 69mm and 72mm.

3.2 Simulation process

The model of internal flow channel of the pump is assembled by the model of impeller internal channel and the pump shell channel, except these, channel model of centrifugal pump inlet is also included. The simulation process in this paper is mainly composed of grid division, boundary conditions and solving process [4].

(1) Grid division. Firstly, use the SolidWorks to establish the three-dimensional model of centrifugal pump, save it as *.XT file and import it into Gambit. Then merge the interface between impeller internal channel model and the pump shell channel model. Next, make use of unstructured tetrahedron mesh to do the grid division. At last,adjust the surface and body which is respectively in the Zones of GAMBIT , set the non-contact boundary of impeller inlet flow channel as velocity inlet and set the outlet boundary of the pump shell channel as effluent boundary. In order to achieve the most ideal results of simulation, the impeller flow channel is arranged as a rotating body, meanwhile, the non-rotating pump shell channel and inlet channel are respectively arranged as static body.

(2) Boundary conditions. Entrance boundary is velocity inlet, in which the speed is 2.16m/s.Set the exit boundary conditions as pressure outlet, the outlet pressure will be 0.5MPa, the remaining settings leave in default.

(3) Solving process. Initialize numerical values of model after setting up the boundary conditions,and then set a monitor to solve. We can gain the stress distribution of centrifugal pump internal channel under the condition that impeller inlet width is respectively 60mm, 63mm, 66mm, 69mm and 72mm.Concrete situations are shown in Fig.2.

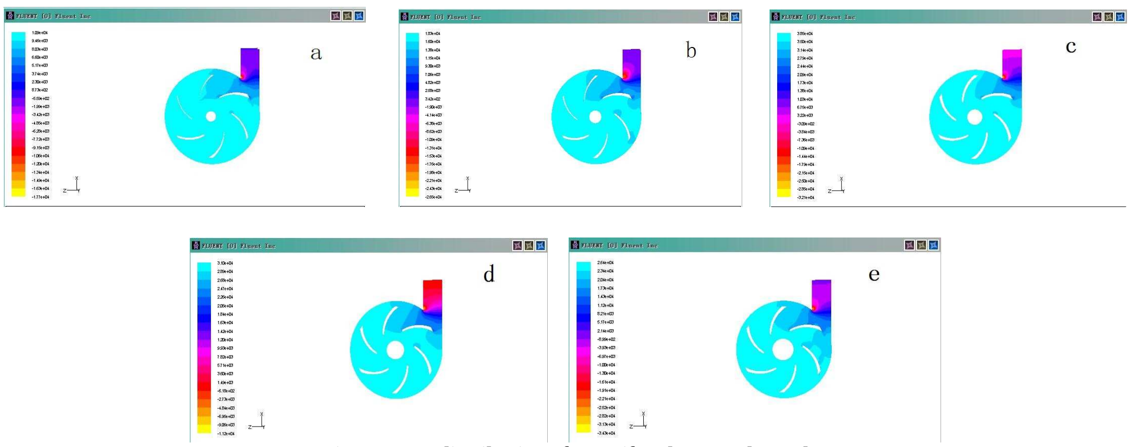

Fig.2 Stress distribution of centrifugal pump channel

4. Theoretical calculation and analysis

4.1 Theoretical calculation[5]

The approximate computational formula of centrifugal pump lift is

$$H = \frac{P_{out} - P_{in}}{\rho g} \quad (1)$$

In the formula (1), P_{out} is average pressure value of inlet cross-section; P_{in} is average pressure value of outlet cross-section; ρ is fluid density,g-gravity acceleration.

And computational formula of shaft power is

$$P = M\omega \quad (2)$$

In the formula (2), M is the sum of moment vectors; ω is angular velocity.

The computational formula of the efficiency of the centrifugal pump is

$$\eta = \frac{\rho g Q H}{M\omega} \quad (3)$$

In the formula (3), ρ is fluid density; g is gravity acceleration; Q is traffic; H is lift.

Based on the figure 'stress distribution of centrifugal pump channel ' and the formula(1-3), we can calculate the lift and efficiency of centrifugal pump under the different impeller inlet width. Performance parameters of centrifugal pump is concretely shown in table 1.

Table 1. performance parameters of centrifugal pump with different impeller inlet width

Port width (mm)	*Lift* (m)	*Traffic* (m^3/s)	*Efficiency* (%)
60	27.18	240	64.25
63	31.78	240	58.87
66	29.15	240	65.73
69	30.56	240	64.92
72	31.24	240	63.48

4.2 Results analysis

Combining Fig.2 with table 1,we can know: when inlet width increases from 60mm to 63mm,lift increases from 27.18m to 31.78m,whose growth is relatively large, but efficiency decreases from 64.25% to 58.87%,which is also very large; when inlet width increases from 63mm to 66mm,lift decreases from 31.78m to 29.15m, however, efficiency rises from 58.87% to 65.73%,this increase in efficiency is substantial and when the lift meets the requirement of design, this group of data is better; when inlet width increases from 66mm to 69mm,lift increases from 29.15m to 30.5m ,but efficiency falls down from 65.73% to 64.92%,though the decreasing amplitude is not big, we can see from Fig. 27 that inlet pressure of channel has a bigger decrease, in this case, anti-cavitation ability of the pump will be greatly reduced; when inlet width increases from 69mm to 70mm,lift increases from 30.56m to 31.24m,the growth is not obvious, but efficiency reduces from64.92% to 63.48%,decrease is also not big, inlet pressure becomes lower, in this way, anti-cavitation ability of the pump will fall further. Therefore, conclusion can be drawn: different inlet width values can earn different degrees of changes of centrifugal pump's lift and efficient of impeller. Through the above analysis of statistics ,we can conclude that when the inlet width of centrifugal pump impeller in this paper is 66mm,the comprehensive performance is better.

CONCLUSION

This paper is mainly through the design of hydraulic model of centrifugal pump and used CFD to simulate the stress distribution of the pump under different conditions of impeller inlet width. Then by the method of theoretical arithmetic, we get the lift and efficiency under various situations of impeller inlet width and finally do the analysis and research on the comprehensive performance parameters. The results show that when the inlet width of centrifugal pump impeller is 66mm,the comprehensive performance is better. This provides a reference for the design and production of centrifugal pump.

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