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EMPERICAL STUDY OF CAVITATION PERFORMANCE IN MULTI-STAGE CENTRIFUGAL PUMP ANALYZING CAVITATION MODEL

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ABSTRACT

One of the sources of instability in a very pump is cavitation inside the pump. Cavitation of a pump is that the results of poor internet positive suction head (NPSH) and might occur inside the whole vary of in operation conditions. Cavitation might cause 3 totally different and undesirable effects:

(1) A drop by headcapacity and potency curves,

(2) Injury to the blade by indentation and erosion, and

(3) Structure vibration

And ensuing noise. Therefore, the cavitation method should be prevented by all means that. to forestall the onset of cavitation we've got to notice the start of the cavitation method within the pump. To notice the start of the cavitation method, the emitted noise are often used, among different prospects. Specifically, a noise spectra structure are often wont to notice the start of cavitation and its development. Experiments have shown that there's a separate frequency tone, at 147 Hz, that is powerfully obsessed with the cavitation method and its development. Therefore, noise spectra can even be wont to confirm the NPSH needed or the important price, representing the higher limit of the permissible pump operation while not cavitation.

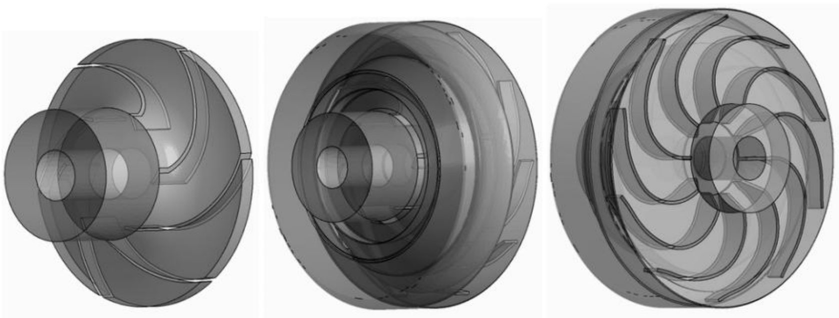
I. INTRODUCTION

During the operation of pump, once the native pressure at pump vane water is less than the force per unit area at native temperature, the liquid flow possible creates cavitation and affects the performance of pump. Cavitation not solely generates noise and vibration that cause unacceptable levels of stress and cut back element life attributable to fatigue[1], however conjointly introduce unfavorable characteristics of pump performance even at or close to the planning purpose. In recent years, several investigations have contributed to the understanding of the complicated three-dimensional flows, performance prediction and therefore the technique of pump optimisation style, by suggests that of each experimental and numerical approaches. above all, attributable to the joint evolution of pc power and therefore the accuracy of numerical strategies, it's currently possible to use CFD codes for the prediction of the complicated three-dimensional cavitation flow within the entire pump and impeller-volute (or diffuser) interaction[2-4]. as a result of the complexness of cavitaion development, however, the data for the cavitation origin and development in pump specially in multi-stage pump is proscribed and much from satisfactory. during this paper, thus, a cavitation analysis model for pump was used supported the Rayleigh-Plesset bubble equation. The 3D flow field and vapor-liquid part distribution in a very multi-stage pump were computed by finding the bubble equation let alone two-phase turbulent governing equations. the method of bubble vaporization, growing and condensation were simulated and visualised. Then the curve of web positive suction head needed (NPSHr) for the pump was foreseen and verified by experimental knowledge. Cavitation calculation model of pump To simulate the cavitation,we used continuity equation,momentum equation and Rayleigh-Plesset equation [5] .Where the whole interphase mass transfer rate per unit volume is:

$$\dot{m}_{fg} = F\frac{3\alpha_g\rho_g}{R_B}\sqrt{\frac{2}{3}\frac{|p_v - p|}{\rho_f}}\operatorname{sgn}(p_v - p) \qquad (1)$$

where F is an empirical factor to which may differ for condensation and vaporization, designed to account for the fact that they may occur at different rates (condensation is usually much slower than vaporization). During computation, the following the initial parameters in cavitation model was applied by referring to Ref. [5]. Mean vapor bubble diameter RB =2 μm , initial volume fraction α g =0.0005, empirical factors for vaporization and condensation F_{xap} =50 and Fcond =0.01, respectively.

Numerical method Physical model and mesh generation. The impeller blades are back curve and the number of blades is 6. The diffuser is radial structure and the number of diffuser blades is 10. The threedimensional calculation domain is generated by Pro-E software as shown in Fig. 1. Furthermore, the tetrahedron mesh of the domain is generated by ANSYS ICEM software. The mesh numbers of entrance duct, impeller and diffuser are 46313, 300234 and 400581, respectively.



a) b) c)

Fig.1 Three dimensional calculation domain

a) Entrance duct and impeller
b) Front view of pump
c) Back view of pump

Solver and discrete scheme for governing equation. With standard k-ε turbulence model, coupling of pressure and velocity is calculated by SIMPLEC method. Discretion of pressure equation is standard scheme. Discretions of momentum, turbulence kinetic energy and dissipation rate are first-order upwind scheme. Multiple frame of reference and boundary conditions. Boundary condition at pump stage inlet is set with mass flow rate. Turbulent flow condition at pump entrance is given with intensity and hydraulic diameter. Outlet boundary condition is set with pressure outlet. Standard wall functions, based on the logarithmic law, are applied for near-wall treatment. To increase the stability of cavitation calculation, we first set the initial value of the gas vapor volume fraction of 0 to calculate single-phase flow field, then calculated cavitation flow.

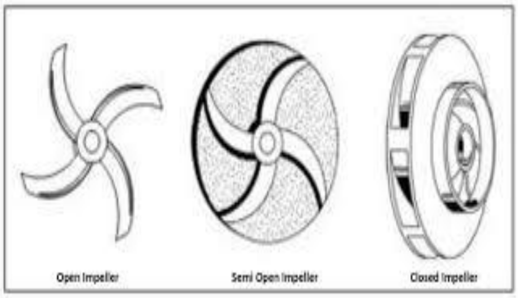


Fig.2 Design of impeller

Numerical results and analysis The calculation of NPSHr. The equation of net positive suction head (NPSH) is written as follows: g P p NPSH in v ρ − = (2) At any flow, by changing total pressure of pump inlet, we can get NPSH-H curve (Fig. 4) from Eq.2.In Fig. 4, when the NPSH closes to 2, head H decreases significantly. It shows that impeller cavitation incepts. When NPSH becomes smaller, the head curve becomes abruptly decreasing. According to regulation in pump industry, the point at which head decrease 3% is regarded as the net positive suction head required (NPSHr). Advanced Materials Research Vols. 317-319 415 To examine the effectiveness of the cavitation model and calculation method, calculated NPSHr values at different flows and tested result were compared. As shown in Fig. 5, the simulation results are close to measured results at designed condition and lower flow rates. But it has some deviation at higher flow rates, so it indicates that the cavitation model is satisfactory at designed condition and lower flow rates but not proper at higher flow rates. It may need some correction in vaporization coefficient of the cavitation model. Fig.4 Curve of NPSH-H（Q=16 m3 /h） Fig.5 Comparison of measured and calculated value of NPSHr Analysis of cavitation flow in impeller. While the total pressure at impeller inlet decreases to some degree, the liquid starts to form vapor bubble on the back sides of the impeller vanes. With continue decreasing in pressure, bubbles incept and develop constantly, resulting in change the distribution of pressure and velocity field in the impeller channels. Fig.6 is the variation of vapor phase distribution in the front view of the impeller in different NPSH. As the NPSH decreases, the bubble volume rate increases. In some case (NPSH=1.32m), the bubble volume rate is so high that the whole impeller channel is full of bubble and the impeller channel is blocked seriously, affecting liquid flow and leading to obvious decrease of the pump head. Fig.7 is the variation of vapor phase distribution at the back of blade in different NPSH.We can't see cavitation occurred in the front of impeller when NPSH=4.91,but we can see cavitation has been developed at the back of blade. The highest bubble volume fraction reached 60 percent.Through comparing the figure 6 and fig.7, we can know that the position of cavitation born is at the back of blade and after the impeller entrance. a) NPSH=4.91 b) NPSH=1.82 c) NPSH=1.41 d) NPSH=1.32 Fig.6 Vapor phase distribution in the front view of impeller in different NPSH To examine the effectiveness of the cavitation model and calculation method, calculated NPSHr values at different flows and tested result were compared. As shown in Fig. 5, the simulation results are close to measured results at designed condition and lower flow rates. But it has some deviation at higher flow rates, so it indicates that the cavitation model is satisfactory at designed condition and lower flow rates but not proper at higher flow rates. It may need some correction in vaporization coefficient of the cavitation model.

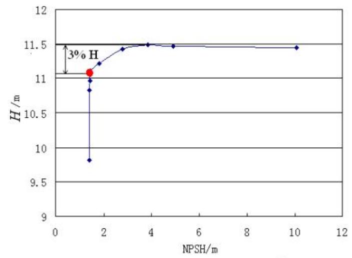


Fig.4 Curve of NPSH-H（Q=16 m^3/h）

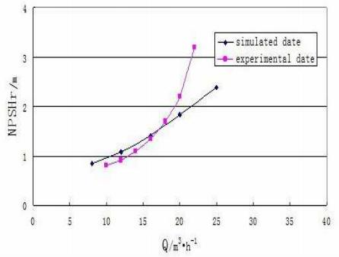
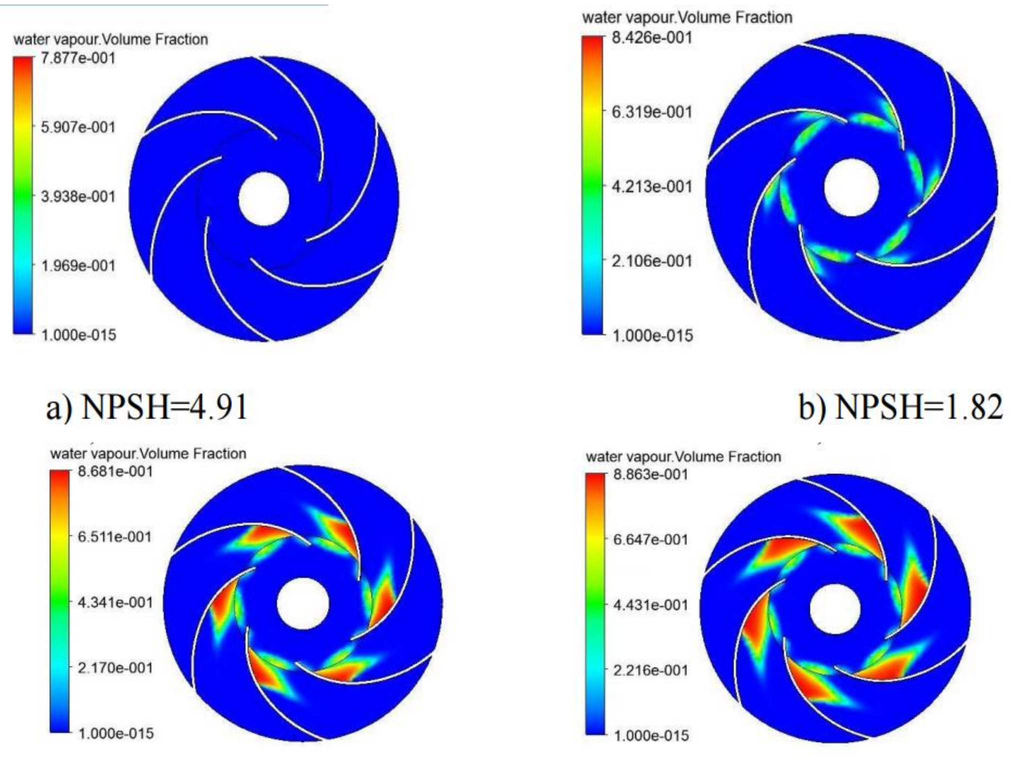


Fig.5 Comparison of measured and calculated value of NPSHr

Analysis of cavitation flow in impeller. While the total pressure at impeller inlet decreases to some degree, the liquid starts to form vapor bubble on the back sides of the impeller vanes. With continue decreasing in pressure, bubbles incept and develop constantly, resulting in change the distribution of pressure and velocity field in the impeller channels. Fig.6 is the variation of vapor phase distribution in the front view of the impeller in different NPSH. As the NPSH decreases, the bubble volume rate increases. In some case (NPSH=1.32m), the bubble volume rate is so high that the whole impeller channel is full of bubble and the impeller channel is blocked seriously, affecting liquid flow and leading to obvious decrease of the pump head. Fig.7 is the variation of vapor phase distribution at the back of blade in different NPSH.We can't see cavitation occurred in the front of impeller when NPSH=4.91,but we can see cavitation has been developed at the back of blade. The highest bubble volume fraction reached 60 percent.Through comparing the figure 6 and fig.7,we can know that the position of cavitation born is at the back of blade and after the impeller entrance.



a) NPSH=4.91 b) NPSH=1.82

c) NPSH=1.41 d) NPSH=1.32

Fig.6 Vapor phase distribution in the front view of impeller in different NPSH

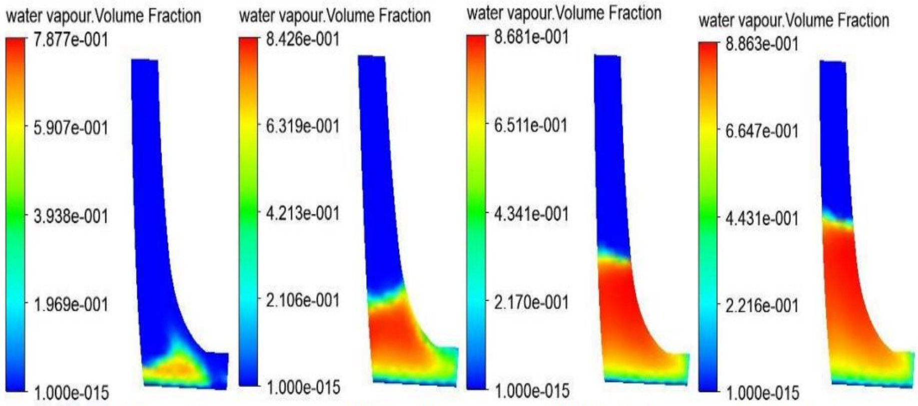


Fig.7 Vapor phase distribution at the back of blade in different NPSH

II. CONCLUSION

Cavitation model based on Rayleigh-Plesset equation was applied in this study to simulate 3-D turbulent flow field and to predict cavitation performance of multistage centrifugal pump. 1) We know that the bubble distribution with changes of pressure and flow. 2) The comparison of calculated value and measured result of NPSHr shows that the cavitation model is more reasonable at designed condition and low flow rate condition. 3) The numerical simulation in this paper could instruct to pump optimization design.

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