Investigation of Suction Vortices Behavior in Centrifugal Pump

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A numerical simulation on suction vortices behavior in centrifugal pump is carried out to investigate its influence on the internal flow through impellers including formation of cavitation by using a preconditioned governing equation with a homogeneous cavitation model. Natural and continuous suction vortices are supplied by a vortex generator. Total head, power and overall efficiency were calculated to obtain performance characteristics of two pump systems with and without suction vortices. Complicated internal flow phenomena through impellers such as flow separation, pressure loss, flow unsteadiness and performance due to the suction vortices are investigated and discussed.

1. INTRODUCTION

Centrifugal pump is commonly used in the industry because it has simple structure and covers a wide range of discharge flow rates and heads. So, to know the flow information on fluid engineering and to investigate the flow field is very important in the pump design. In the centrifugal pump, flow separation, pressure loss and noise are occurred by abnormal vortex flow and unsteadiness at low or high flow rates. Especially, air-entrained and submerged vortices often observed in sump pumps seriously damages to pump system. Therefore in the construction of pump station these vortices are not permitted and their disappearance must be verified by sump pump model test.

In this paper, a numerical simulation on suction vortices behavior in centrifugal pump due to the undesirable vortices is performed and their influence on the internal flow through impellers including formation of cavitation is investigated.

2. NUMERICAL METHOD

Gas-liquid two-phase flow of cavitating flow is possible to model into a pseudo single-phase flow by using concept of the homogeneous model. Under this model concept, the pressure for gas-liquid two-phase media is determined by using a combination of two equations of state for gas phase and liquid phase, that is written as follows[(1)]:

$$\rho = \frac{p(p+p_c)}{K(1\text{-}Y)p(T+T_c)+RY(p+p_c)T}$$

where, ρ, p, Y *and* T are the mixture density, pressure, quality of vapor and the temperature, respectively. R is the gas constant and K, p_c and T_c represent the liquid constant, pressure constant and the temperature constant for water, respectively.

Based on the cavitation model concept the 3-D governing equations for the mixture mass, momentum, energy and the gas-phase mass conservation can be written in the curvilinear coordinates as follows:

$$\frac{\partial \mathbf{Q}}{\partial t}+\frac{\partial \mathbf{E}}{\partial \xi}+\frac{\partial \mathbf{F}}{\partial \eta}+\frac{\partial \mathbf{G}}{\partial \varsigma}=\frac{\partial \mathbf{E}_v}{\partial \xi}+\frac{\partial \mathbf{F}_v}{\partial \eta}+\frac{\partial \mathbf{G}_v}{\partial \varsigma}+\mathbf{S}$$

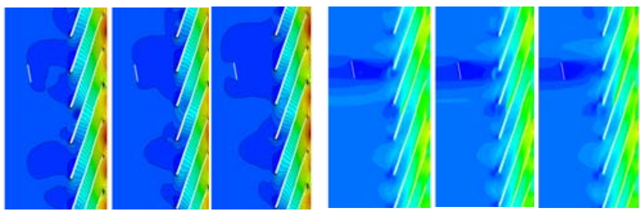
where $\boldsymbol{Q}$ $(=[\rho, \rho u, \rho v, \rho w, e, \rho Y]^T)$ is an unknown variable vector, $\boldsymbol{E}$, $\boldsymbol{F}$, $\boldsymbol{G}$ are flux vectors and $\boldsymbol{E}_v$, $\boldsymbol{F}_v$ and $\boldsymbol{G}_v$ are viscous terms. $\boldsymbol{S}$ is the source term. In order to treat hydraulic transients and hydroacoustics such as cavitating flow with compressible flow characteristic at low Mach number this equation is preconditioned and solved by using appropriate numerical methods[(2)].

3. NUMERICAL RESULTS

With the preconditioned governing equation a numerical simulation of internal flow in centrifugal pump with suction vortices was performed. Single-section centrifugal pump consisted of six blades impeller and shroud ring. Rotating speed of closed type impeller is 3000 rpm. In this study suction vortices are generated by vortex generator installed upstream from the inlet of impeller as shown in Fig.1. Due to the undesirable suction vortices unbalanced cavitation is formed on front surface of the impeller and growing and shedding with time. Consequently it causes the noise, vibration and damages to pump systems. Detailed flow phenomena due to the suction vortices are investigated and discussed at the presentation.

(a) $t=t_0$ (b) $t=t_0+0.012$ (c) $t=t_0+0.02$

Time evolution of void fraction contours (cross sectional plane)



(a) (b) (c) (a) (b) (c)

Pressure contours and velocity contours (blade to blade plane)

Fig. 1 Void fraction, pressure and velocity contours

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