Unsteady Numerical and Experimental Study of Cavitation in Axial Pump

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ABSTRACT

This paper presents an experimental and three-dimensional numerical study of unsteady, turbulent, void growth and cavitation simulation inside the passage of the axial flow pump. In this study a 3D Navier-Stokes code was used (CFDRC, 2008) to model the two-phase flow field around a four blades axial pump. The governing equations are discretized on a structured grid using an upwind difference scheme. The numerical simulation used the standard K-ε turbulence model to account for the turbulence effect. The numerical simulation of void growth and cavitation in an axial pump was studied under unsteady calculating. Pressure distribution and vapor volume fraction were completed versus time at different condition. The computational code has been validated by comparing the predicted numerical results with the experiment. The predicted of cavitation growth and distribution on the impeller blade also agreed with that visualized of high speed camera.

Keywords: Axial Pump, Cavitation, Computational Fluid Dynamics (CFD), Simulation, Unsteady, Void Growth

INTRODUCTION

As A general rule, axial flow pumps are usually selected for pumping large volumes of water against relatively low heads. The rotating element of an axial flow pump has the shape of a propeller. It is often mounted in a pipe or duct, and the fluid passes in an axial direction through the pump. It is not deflected away from the axis as with centrifugal pumps.

According to Bernoulli’s theorem, an increase in velocity in a fluid is accompanied by a decrease in pressure. For any liquid there is a lower limit beyond which the absolute pressure cannot decrease. This value is called the vapor pressure and depends on the nature of the liquid and local temperature. If at any point liquid flows into a region where the pressure is reduced to vapor pressure, the liquid boils locally and vapor pockets are formed. The vapor bubbles

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are carried along with the liquid, and when they reach regions of higher pressure, they suddenly collapse. This process is called cavitation. The collapsing action produces high-pressure pulses, often of the order of gigapascals. When such collapse takes place adjacent to solid walls continually and at high frequency, the material in that zone gets damaged. This is called pitting of solid surfaces. Cavitation is also accompanied by noise, vibration, and drop in efficiency.

**PREVIOUS WORKS**

A limited number of studies tried to simulate the cavitation in axial pumps. An energy model was used to predict the cavitation erosion in centrifugal pumps, but it predicts the hydrodynamic aspect of cavitation (Mostafa, et al., 1990).

Fukaya, et al. (2003) predicted the cavitation performance of an axial pump, but the model used does not include a turbulence model.

Okita et al. (2003) simulated the unsteady cavitating flow in a pump inducer. They used a numerical method for incompressible fluid flow, but it has been employed the compressibility through the low Mach number as an assumption.

Mostafa and Boraey, (2006) made an Experimental and numerical study of the two-phase flow field around a four blades axial pump based on steady conditions as an assumption.

Sedlář et al. (2008) made Analysis of Cavitation Phenomena in Water and its Application to Prediction of Cavitation Erosion in Hydraulic Machinery. This article also shortly described the experimental research of the cavitating flow aimed at the validation of the erosion potential model, development of the nuclei-content measurement and the validation of the bubble nucleation model.

Yang et al. (2009) made a numerical simulation of air-water Bubbly flow in axial flow pump Impeller. The numerical results demonstrate that air bubbles accumulate at the blade back near the impeller inlet because the lowest pressure on blade back happens.

De-sheng et al. (2010) investigated numerically and experimentally the unsteady flow of axial pump. This study focused on the comparison between the steady and unsteady results and not concerned with the cavitation phenomenon.

Tabar and Poursharifi, (2011) made pure experimental work to study the tip vortex cavitation inception in an axial flow pump. The pump characteristic curves were obtained. The cavitation phenomenon was observed with a camera and a stroboscope.

Mostafa and Adel, (2012) presented unsteady numerical simulation and void growth inside the passage of axial turbine. The results was compared with the previous studies and showed good agreement.

The main objective of this study is to simulate the unsteady 3-D Navier-Stokes equations, behavior of a cavitating axial pump with special interest in the cavity geometry, the pressure and void fraction fields. Also, it includes the effects of turbulence and fluid viscosity. The cavity shape will be determined over the blades and the 3-D flow field around the cavitating propeller. Also the performance curve of the pump will be obtained experimentally.

**EXPERIMENTAL SETUP**

In order to test the axial flow pump’s performance under cavitation, a closed loop system including an axial flow pump/Turbine was used. A schematic figure of the hydraulic equipments is illustrated in Figure 1.

The impeller has 4 vanes, which are adjustable and can be set at several different angles from 60 to 80°. The impeller diameter is 101 mm. The pump tested is driven by a D.C. electro motor, whose rated power is 2.2 kW. And its nominal speed is 3000 rpm. Pump’s casing which is made of plexi-glass material makes it possible to observe the pattern of fluid flow inside the pump. The photos were taken using a high speed camera 1000 fps. The photos showed the developed cavity along the blade leading edge in order to compare it with the numerical results.
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