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A study on multistage centrifugal pump performance characteristics for variable speed drive system

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Abstract

Nowadays centrifugal pumps are being widely used in the commercial, industrial and power plant applications and most of pumps operated by constant speed drive system. Therefore, pump consumes a huge energy of each nation's total energy. But it could be operated in variable speed drive system which would be provided energy saving. The purpose of this study is to investigate the pump performance characteristics of the multistage centrifugal pump with the variable drive system. For this study an experimental set up of the system was constructed to achieve the centrifugal pump performances such as H-Q, η-Q, P-Q curves and operating points which interact between performance and system curves. In the variable speed drive system, a vector controlled inverter driving (variable voltage variable frequency) was installed in the experimental system. A numerical investigation also applied for getting the pump performances for the validation and reliability of the pump design development and also the pressure and velocity effects in internal flows of the pump are analyzed. For the numerical analysis, the Navier-Stokes equations were discretized by the finite volume method and two equations transport turbulence (SST) model accounts for three dimensional steady flows. In the experiment system, we also carried out system head performance of the three pumps in parallel to compare with one pump system head for its validation. In order to get the energy saving rate using the inverter control variable speed drive system instead of the constant speed drive system, it is necessary to identify the specific duty cycle of the pump operation cycle and operating system curve of the pump. Hopefully, this paper will be useful as a guide for identifying a method of implementing a variable speed drive system with inverter control in the variable flow and pressure system.

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Keywords: Multistage centrifugal pump; Variable speed drive system; Inverter; Performance analysis; System curve; SST turbulence model;

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1. Introduction

A centrifugal pump is a type of fluid machine which is driven by a prime mover (e.g., an electric motor) used to impart energy to fluids, and continuously feed the required amount of such fluid to an intended height or distance [1]. The combination of rotating impeller and diffuser is called the stage. A multistage centrifugal pump might consist of several stages within a single housing, depending on the amount of pressure rise required of the pump [2].

According to statistics, pumps consume around 20% of the world total energy [3]. The energy efficiency of a system depends not only on the design of the pump but also, and more so, on its working conditions and system design [4,5]. The point of interaction is the only condition where the pump and system flow rates are equal and the pump and system heads are equal simultaneously. For the same type of pump operation, for one pump when the valve is fully open and flow rate compared with two or three pumps in parallel operation resulting to obtain the system curve. There are two driving systems. One is constant speed drive system which is installed with the pump and motor for transferring fluid. The other is variable speed drive system which is installed with pump, motor and inverter for changing speed. Inverter is a revolution control device which is used in the variable speed drive system [6, 7] and this control method is effectively used for pumps where operation time is long and output is high. Also energy savings are likely due to surface elevation and usually lower pumping rates and lower pipe friction losses can be obtained using variable speed drive system [5]. Assessment of the technical and economic advantages gained by using VSDs on centrifugal pumps have been a limited publicized in recent years. But with the performance and system curve we can't estimate satisfactory efficiency improvement using activated pump system. So, we have to find alternative method to evaluate the performance characteristics driving system.

Computational fluid dynamics (CFD) is being applied in the design of multistage centrifugal pump which can be used for numerical simulation to get the performance of the flow field inside the pump. CFD has proven to be a very useful tool in the analysis of the flow inside pumps, both in design and performance prediction. Much research has been carried out in the last years. Croba et al. [8] give an updated list of general selected papers while Denuset al. [9] give a more extended and specific bibliography. However, due to the difficulties of the task, most of these studies have been carried out with strong simplifications of the problem either in the geometry or in the flow characteristics. Research is slowly tending toward more complete simulations and approach developed follows the trend [10]. Numerical simulation makes it possible to visualize the flow condition inside a centrifugal pump, and provides the valuable hydraulic design information of the centrifugal pumps. For the numerical simulation in the pump, the main difficulty is to better reproduce the complex geometry configuration of the flow domain [11]. For these difficulties many of geometry are often considered for simplifications. In the literature, many hydrodynamics models are reported in 2D and 3D by using the CFD code and studied impeller diffuser interaction on the pump performance showed that a strong pressure fluctuation is due to the unsteadiness of the flow shedding from impeller [12, 13]. Both experimental and numerical approaches have been reported and have contributed to the understanding of the highly complex flow interactions that occur in a centrifugal pump [14].

In this paper, the study is focused on the pump performance characteristics of the multistage centrifugal pump with variable speed drive system. Therefore an experimental set up is constructed for both the one pump and three pumps in parallel. The pump performances were calculated by the electronic flow meter for the variable speed condition controlled by inverter. The system head curve calculated from both of one pump and three pumps in parallel. Also, we investigated the numerical simulation which predicts to get the pump performances and effect on pressure and velocity inside the pump. Thus these results compare with the experimental data for its effectiveness and reliability of the pump model DR 20-60.

2. Experimental Method

Fig. 1 shows the experiment layout of model pump and Fig. 2 represents the experiment layout of three pumps. The test layout is of the variable flow and pressure system. A fully computerized pump test facility is designed and built to obtain more accurate pump performance test data. Two electronic flow meters are used in the experiment system for better accuracy.

The working temperature and humidity were 28.5^0C and 81%. For each test, the rotational speed was set by the frequency inverter and the speed was measured by a torque meter showing in the pump operation panel. Pump head