Influence of Back Shroud Shape on Performance and Internal Flow of Fluid Food Pump

Toru Shigemitsu, Institute of Technology and Science, Tokushima University, Tokushima, Japan,
Takumi Matsubara, Graduate School of Advanced Technology and Science, Tokushima University, Tokushima, Japan,
Masahiro Sakaguchi, Graduate School of Advanced Technology and Science, Tokushima University, Tokushima, Japan,
Junichiro Fukutomi, Institute of Technology and Science, Tokushima University, Tokushima, Japan

Long Abstract

Introduction

It is said that world population will increase to 10 billion in several decades, so large quantities and stable supply of food are needed. Furthermore, a concern of food safety is also increasing nowadays. Fluid machines for fluid food have been used in wide variety of fields i.e. transportation, filling, and improvement of quality of fluid food. Flow conditions of those fluid machines are very complex and unclear because subject fluid of these fluid machines is fluid different from air and water. Ota et al. clarified an influence of a tip clearance, a blade outlet angle and a blade number on the performance of a centrifugal pump using oil [1],[2]. On the other hand, internal flow condition of the pump using fluid food is not known, however, there are a few report related to the flow condition in a pipe, where fluid food flows. Therefore, the design based on internal flow conditions is not conducted at present.

In this research, a centrifugal pump having small number of blade was used to decrease shear loss and keep a wide flow passage. Moreover, a semi-open impeller and two types of open impellers were adopted for this centrifugal pump in consideration of the manufacturing accuracy and simplification of the maintenance of the pump. It is important to investigate the influence of the back shroud shape on the performance and internal flow condition because the disk frictional loss was assumed to be large in this pump. In this paper, the performance and flow condition of semi-open impeller or two types of open impellers were shown and the relation between the performance and flow conditions was investigated by the numerical analysis results.

1. Experimental Procedure and Numerical Analysis Conditions

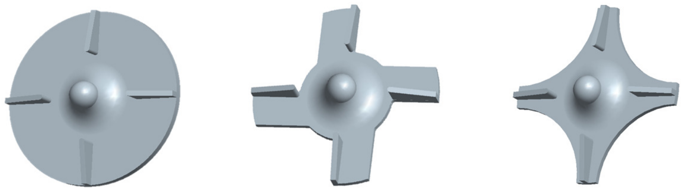
A radial blade(β_2=90°) was adopted for the base model to pump fluid, of which viscosity was higher than that of water. Furthermore, the blade inlet angle was set as β_1=90° to facilitate the maintenance and cleaning in the pump. Moreover, small number of blade was set as z=4 in this centrifugal pump. Semi-open impeller and two types of open impellers as shown in Fig.1 were used in order to suppress an increase of a disc frictional loss. The design flow rate, head and rotational speed were Q_d=65.3 l/min, H_d=2.5 m, and N_d=1650 min^{-1}. A two dimensional blade was used for the test rotor to facilitate the cleaning of the impeller and a tip clearance was c=0.5 mm.

Figure 2 shows the schematic diagram of the experimental apparatus. For the pressure performance evaluation, the static head differences on the wall between 2D_{in} upstream and 2D_{out} downstream of the rotor were measured by pressure transducers. The flow rate Q was obtained by an electromagnetic flow meter installed far downstream of the pump and torque was measured by a torque meter. Glycerol solution(40% volume density) was used in the experiment. The glycerol solution used in this research corresponded to a comparatively low viscous fluid food such as beer, sake, saccharose solutions, and soy sauce on the point of view of the viscosity range.

A numerical flow analysis was conducted to investigate the internal flow condition in detail. In the numerical analysis, the commercial software ANSYS-CFX was used and the numerical analysis was conducted with a numerical model which was the same with the test section of the experiment under the three dimensional unsteady condition.

2. Performanc and Internal Flow

Figure 3 shows the pump performances of each impeller using the 40vol% glycerol solution obtained by the experiment. The experiments were conducted in wide flow rate range from the shut-off to large flow rates. The head of open impellers were higher than that of the semi-open impeller by approx. 7% and the shaft power of the open impeller were higher than that of the semi-open impeller by approx.30%. As a result, the efficiency of the open impellers was lower than that of the semi-open impeller. The shear rate distributions near the hub side of each impeller were investigated by the numerical analysis and its results were shown in Fig.4. The shear rate distribution of the semi-open impeller was relatively larger than that of the open impellers and the shear rate was large near the edge of the back shroud in the case of the open impeller. Therefore, it is important to improve the edge shape to decrease the shear loss around it. The performance and internal flow were discussed based on the flow condition around rotor in this paper.



(a) Semi-open (b) Type A (c) Type B

Figure 1. Geometry of Rotors

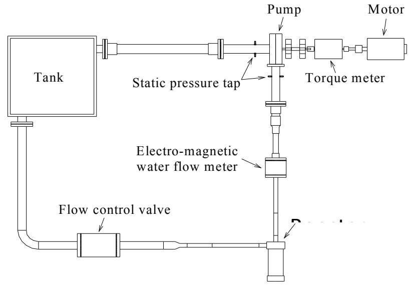
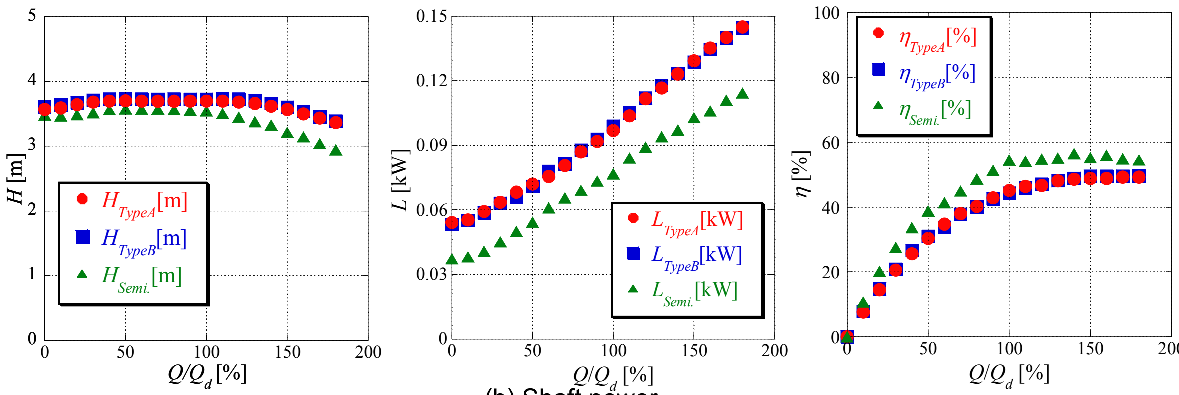
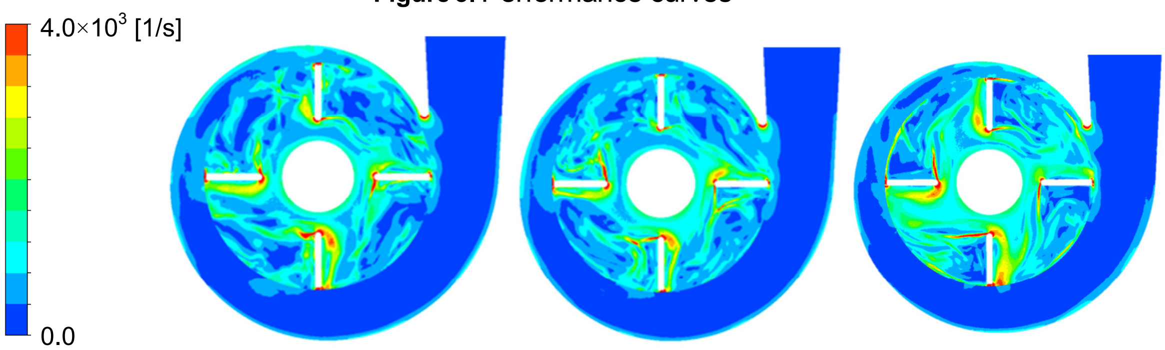


Figure 2. Schematic diagram of experimental apparatus



(a) Head (b) Shaft power (c) Efficiency

Figure 3. Performance curves



(a) Type A (b) Type B (c) Semi-open

Figure 4. Share rate distributions in clearance of back shroud

References

[1] Ohta, H., Aoki, K. and Nakayama, Y., 1985, “Study on the Centrifugal Pump for High Viscosity Liquids (Effects of Clearance Ratio),” Trans. JSME (in Japanese), Vol.51, No.472, pp.4295-4300.

[2] Aoki, K., Yamamoto, T., Ohta, H. and Nakayama, Y., 1985, “Study on Centrifugal Pump for High Viscosity Liquids (Effect of Impeller Output Angle on the Pump Performance),” Trans. JSME (in Japanese), Vol.51, No.468, pp.2753-2758.