K6-21

A Study of Eccentric Excursion Blood-Pump for Ventricle Assist Devise
An Estimating of Fluid Force Acting on Impeller

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Abstract: A magnetic or fluid suspension prevents the rotating impeller of the pump from contacting the internal surfaces of the housing and help reduce mechanical wear and thrombus formation. The noncontact suspension is, however, maintained usually with low power, and therefore the impeller/rotor usually makes an eccentric excursion around the central axis and sometimes spins off the orbit contacting the pump housing. Knowing the fluid forces acting on the rotor, thus, should help design an efficient suspension mechanism. In this study, the fluid force acting on the impeller of an eccentric excursion blood-pump was studied in an experimental system where the eccentric impeller position was varied by shifting the impeller/rotor axis from the axis of rotation by 0.0 to 0.4 mm with an increment of 0.1 mm. The estimation of fluid force acting on the impeller revealed that the larger the eccentricity of the impeller, the larger the force on the impeller. When the eccentricity of the impeller increased to 0.4 mm, the head pressure developed by the pump increased by approximately 22 %. This study shows enable to reduce rotational speed with keeping performance.

１． Introduction

Mechanical circulatory support has been effective for treatment of end-stage heart failure in adult patients. The devices used to support adults are too large to cause dangers of thrombosis and hemolysis in children [1-3]. The development of miniature ventricular assist devices suitable for children is thus in urgent need.

In turbo-machines rotating at high speeds, should the machines run at the speeds higher than a critical speed, the eccentric excursion occurs around the main axis of rotation. In addition, if the forces acting on the impeller are extremely high, the impeller may spin off from its excursion orbit to contact the pump casing. This effect could lead to destruction of blood cell elements known as hemolysis. This study examines experimentally the forces acting on the impeller of a mixed flow pump model with the impeller making an eccentric excursion around the main axis of rotation.

２． Materials and Methods

2.1 Implementation of eccentric excursion movement

In the experimental setup, referring to Figure 1, a sleeve mechanism was designed to produce an eccentric excursion motion around the central axis. A belt wrapped around the sleeve was rotated to create an eccentric excursion of the impeller around the central axis (Figure 2). Fluid force acting on the impeller was estimated as the eccentricity was varied from 0.0 to 0.4 mm with the increment of 0.1 mm. The test rig consisted of an inlet and outlet reservoir, a test pump with eccentric excursion mechanism driven by two sets of servo-motors. All data were acquired using a LabVIEW data acquisition system. Regular tap water was used as a working fluid.

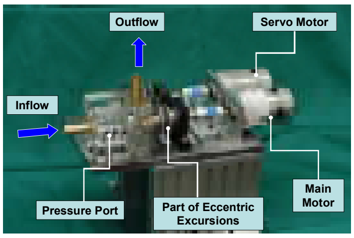

Fig. 1 Experimental set-up

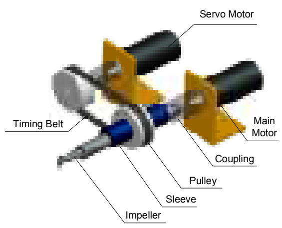

Fig. 2 Sleeve mechanism

2.2 Pump concept

The impeller comprises two blades with its thickness being 1 mm (Figure 3). The external diameter of the impeller body including blades is 10 mm and the length of the impeller body is 20 mm twice its diameter (Figure 4). The pump is designed to operate at 10,000 rpm providing 2.0 L/min flow against the head pressure of 80 mmHg.

2.3 Radial force acting on the impeller

To estimate the force acting on the impeller, four pressure measurements, two in the axial direction and two in the radial direction with 10 mm spacing, were simultaneously performed. Figure 5 illustrates the locations of the pressure taps and the coordinate system used for the radial fluid force analysis. The pressure surrounding the impeller was measured using a pressure sensor through pressure ports incorporated in the pump casing wall.

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For static pressure measurement, extreme care was provided for Helmholtz resonance during design of pressure ports. A difference of average pressure (= $P_1 - P_2$) was then calculated for each tap location per the shifted impeller center. To then derive a radial force component in the y directions at each tap, the pressure differential at each tap was multiplied by a projected two-dimensional surface (=surface area; impeller diameter $\phi D \times \Delta h$) of the impeller’s cross-sectional area (=Δh).

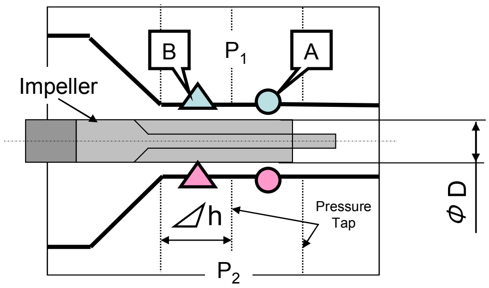

Fig. 5 the locations of the pressure taps

3．Results

The head pressure vs. pump flow known as *H-Q* curves for three different eccentric values (impeller speed N = 10,00 rpm) were shown in Figure 6. The graph shows that the vertical axis is pressure, and the horizontal axis is flow rate. The head pressure H increased as the eccentricity increased for the same flow level. To estimate fluid force was shown in Figure 5.

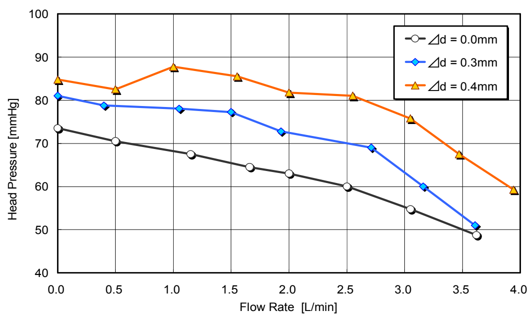

Fig. 6 Hydraulic Characteristics

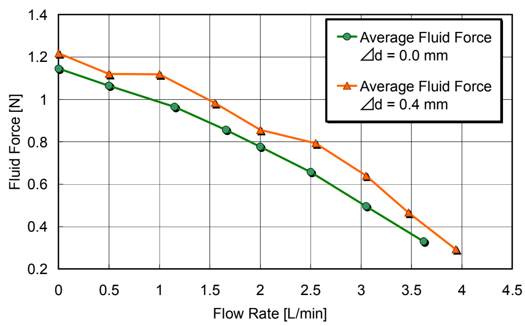

Fig. 7 Fluid force acting on the impeller

4．Disscution

In this study, a system in which eccentric excursion motion of the impeller can be varied from 0.0 to 0.4 mm from the central axis has been designed to evaluate the effect of eccentricity of the impeller motion on the pump performance.

As for the hydraulic characteristics due to eccentric excursion motion of the impeller, the head pressure increased as the eccentricity increased. Although the impeller speed was kept constant, as the eccentricity increased, the hydraulic characteristics improved for the fluid was compressed against the casing wall by the eccentric motion of the impeller. The maximum rise in the hydraulic characteristics of 22 % was observed with the eccentricity of 0.4 mm. By shifting the impeller, the power was probably passed to the fluid that leaked around the impeller and hence improved the hydraulic characteristics. The variation in the gap between the impeller blade and the pump casing contributed mainly to improvement in the hydraulic characteristics of the pump.

As for estimating fluid force. Under Δd = 0 mm, range of Fluid Force is from 0.33 to 1.15 N. And Under Δd = 0.4mm, it is from 0.29 to 1.22 N. As curves illustrates, under near flow rate, Fluid Force on Δd = 0.4 mm is larger than one on Δd = 0 mm. Although we have quantified the fluid force acting on the impeller by making an eccentric excursion motion of the impeller around the central axis, in the actual setting the native heart motion also affects the eccentricity and the frequency of excursion.

5．Conclusions

・Hydraulic Characteristics are affected offset values of impeller.

・Fluid Forces on Large offset (Δd = 0.4 mm) are larger than one on Non - offset (Δd = 0.0 mm).

6．Reference

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