DYNAMIC SUSPENSION CHARACTERISTICS OF A COMPACT DOUBLE STATOR AXIAL GAP MOTOR WITH FULL MAGNETIC LEVITATION DURING ROTARY BLOOD PUMP OPERATION

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Abstract. Compact magnetically suspended motors have been demanded to achieve miniature pediatric VAD which has long life expectancy and better hemocompatibility. An ultra-compact 5-degrees of freedom controlled self-bearing motor has been developed in this study. The motor consists of two identical motor stators and a levitated impeller sandwiched by both stators, and is driven as 6-slot and 4-pole synchronous permanent magnet motor. This paper investigated impeller suspension characteristics during centrifugal pump operation with closed circulation loop. The developed maglev pediatric VAD can produce enough flow rate to provide circulatory support for pediatric heart disease patients. The motor can completely levitate the impeller and sufficiently suppress the impeller vibration, that is indicating well suspension performance.

1. Introduction

Impeller suspension is one of the most significant components to achieve long life expectancy and better blood compatibility in rotary ventricular assist devices (VADs) development. There has been increasing research interest in magnetic suspension technology for next generation VADs, and magnetically levitated motors are being employed in several clinically available VADs for adult heart failure patients [1]. Currently, pediatric VADs which have durability and blood compatibility are strongly demanded [2]. However compact magnetically levitated VAD for use in pediatric patients are still not available due to difficulty of device miniaturization maintaining sufficient suspension performance and higher torque production. In this research, an ultra-compact 5-degrees of freedom (5-DOF) controlled axial gap self-bearing motor which has diameter of 22 mm and total height of 33 mm has been developed for pediatric VADs [3]. Magnetic circuit design and static suspension performance evaluation of the developed motor has been previously presented [4]. This paper investigated dynamic suspension characteristics during centrifugal blood pump operation.

2. Materials and Methods

The developed 5-DOF controlled self-bearing motor has two identical motor stators to suspend a levitated centrifugal impeller axially (Fig. 1). The motor is driven as synchronous permanent magnet motor. The double stator mechanism makes rotating torque double and can achieve 5-DOF control of levitated impeller postures. The levitated impeller has axially magnetized 4-pole neodymium permanent magnets on both surfaces. Thickness of the permanent magnet is 0.8 mm. The stator core made of soft magnetic iron (SUY-1) has 6-slot structure and concentrated windings for magnetic suspension and rotation are integrated and wound on each stator tooth. Turn numbers of control windings are 105. Magnetic gap between rotor and stator surfaces is 1.3 mm.

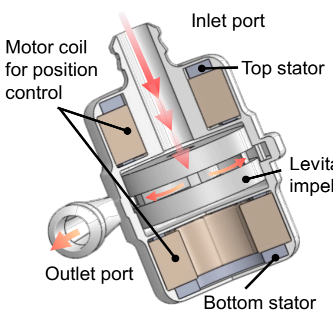


Fig.1. Schematic of the 5-DOF controlled self-bearing motor for pediatric VAD

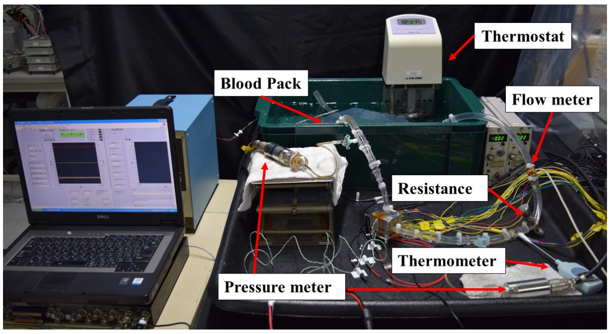
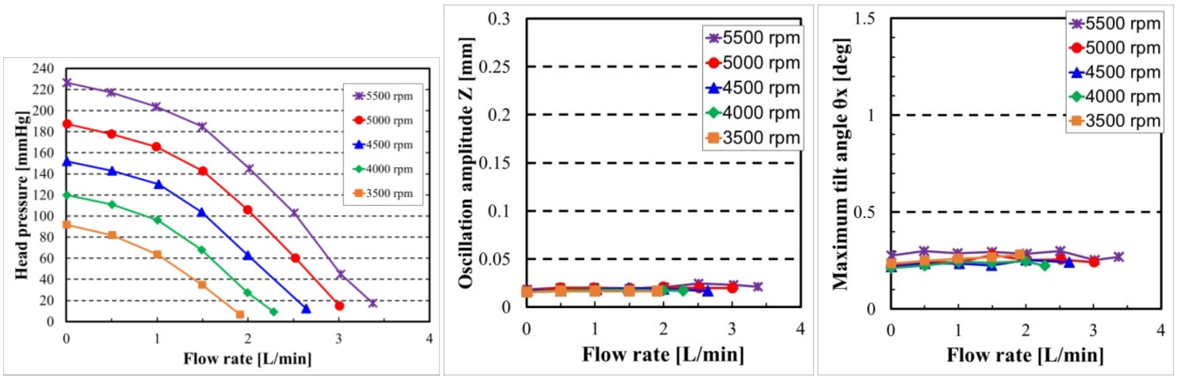


Fig.2. Closed circulation loop system for pump characteristics and suspension performance evaluation.

The developed motor was combined with centrifugal blood pump to evaluate dynamic impeller suspension characteristics during pump operation by using closed circulation loop as shown in Fig.2. 40wt % glycerol water solution at temperature of 37℃ was used as working fluid to mimic viscosity of blood. The centrifugal impeller was levitated with 3-DOF control (z, θ_x and θ_y) as a first step. HQ curve over a rotating speed range from 3500 rpm to 5500 rpm was evaluated. Axial oscillation amplitude and inclination angle around x and y axes were then evaluated. The axial oscillation amplitude was calculated as half of peak to peak value of impeller displacement.

3. Experimental Results

Pump performance and magnetic suspension performance are shown in Fig. 3. The developed maglev centrifugal pump can regulate the flow rate from 0.5-2.5 L/min with a head pressure of 100 mmHg at rotating speeds of 3500-5500 rpm as shown in Fig.3 (a). The achieved HQ curves indicate that the developed pump can applicable to 1-6 years old patients growing up. The levitated impeller was fully suspended with 3-DOF control over every rotating speed. The axial oscillation amplitude and the inclination angle were less than 0.03 m and 0.3 degrees, as shown in Fig 3 (b) and (c). The vibration of the levitated impeller was sufficiently suppressed with magnetic suspension force. As a next step the levitated impeller will be suspended with 5-DOF control and radial suspension performance will be evaluated. In addition to above, the frequency response evaluation of magnetic suspension system will also be carried out.



(a) (b) (c)

Fig. 3 HQ characteristics of centrifugal blood pump and dynamic impeller suspension performance of double stator maglev motor: (a) HQ curves with different rotating speeds, (b) maximum axial oscillation amplitude and (c) maximum inclination angle around x axis.

Conclusions

The miniaturized 5-DOF controlled self-bearing motor has been developed for pediatric VAD which has higher durability and better blood compatibility. The pump performance and dynamic impeller suspension characteristics during pump operation were evaluated with closed loop circulation circuit. The levitated impeller was completely levitated up to the rotating speed of 5500 rpm. The developed pediatric VAD achieved flow demand (0.5-2.5 L/min) for pediatric circulatory support, and indicated sufficient potential of stable magnetic suspension in VAD operation.

References

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