DYNAMIC ANALYSIS OF THE HYDRODYNAMIC BEARING OF A TWO-STAGE PEDIATRIC LEFT VENTRICULAR ASSIST DEVICE

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Introduction

Ensuring the dynamic stability of hydrodynamically levitated impellers in novel left ventricular assist devices (LVADs) is essential during their design process. The objective of this study was to assess the non-linear behavior of the hydrodynamic journal bearing of a two-stage pediatric LVAD considering the motor characteristics.

Methods

To assess the dynamic properties of the hydrodynamic bearing in combination with the motor characteristics, analytic and in-silico methods were combined. An electric motor was designed to meet the requirements of the two-stage LVAD. The magnetic attraction forces introduced by the motor influence the axial and radial stiffness of the impeller. Such reluctance forces were determined using electromagnetic finite element methods simulations. The hydraulic force acting on the impeller surface was obtained using computational fluid dynamics. This force, together with the radial magnetic attraction force of the motor, was used in the equations of motion which were coupled with the Reynolds equations. The non-linear system, initialized with a position near center, was solved for the impeller position within the bearing clearance [1]. Furthermore, a convective heat transfer simulation was performed to determine the temperature increase of the fluid due to the motor losses in the bearing gap.

Results

The motor is a permanent magnet synchronous machine with a nine-slot, four-pole design (Figure 1).

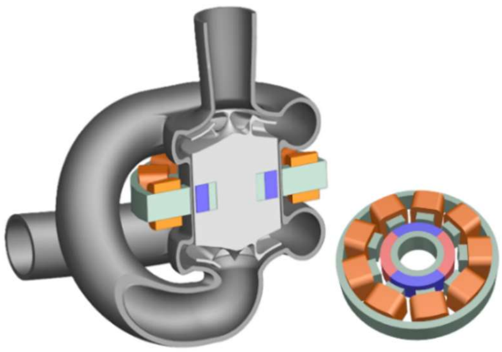

Figure 1: Two-stage LVAD with the motor (left), nine-slot, four-pole motor design (right).

The axial reluctance force centers the impeller in the axial direction with a stiffness of -1.74 N/mm, preventing an axial touchdown during operation. The radial attraction force acts in the direction of the smallest distance between the stator and the impeller with a stiffness of +9.30 N/mm. The maximum hydraulic force acting radially on the impeller surface is 0.03 N. The results of the non-linear analysis indicate that the dynamic forces, the bearing reaction forces and the external forces applied to the impeller are imbalanced, leading to an unstable behavior, pulling the impeller outwards to the housing wall and eventually causing a touchdown. However, introducing an additional external force of 0.65 N at a fixed angle results in an equilibrium position at an eccentricity ratio of 0.47 for the main operating condition of 6400 rpm (Figure 2).

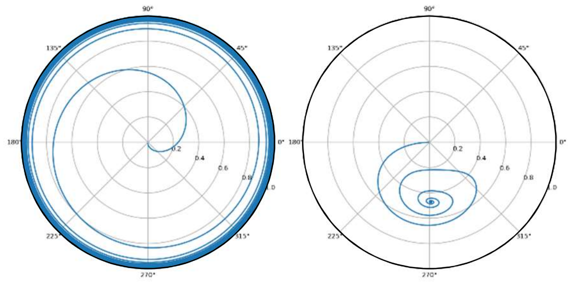

Figure 2: Unstable trajectory of the impeller for the main operating condition (left), equilibrium position with additional external force (right).

The maximum local temperature increase of the fluid due to the motor losses is 37.2 °C and therefore within the tolerable 2 °C increase.

Discussion

The non-linear analysis of the dynamic behavior of the radial hydrodynamic journal bearing of a two-stage LVAD combined with the motor characteristics indicates that the introduction of an additional external force leads to a stable bearing operation. It has to be considered that the required force and the resulting equilibrium position depend on the rotational speed of the impeller. Future work will explore using the motor to provide this additional force.

References

1. Khonsari et al., ASME J. Vib. Acoust, 115(3):303-307, 1993.

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