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순환 채널과 공동 현상을 고려한 하드디스크 스핀들 시스템의 동특성 해석

Dynamics of a HDD Spindle System with the FDBs and Recirculation Channels Considering Cavitation

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1. Introduction

Fluid dynamic bearings (FDBs) have been applied in computer hard disk drive (HDD), because they not only prohibit the solid contact between the rotating and stationary parts, but also provide the damping effect in addition to the stiffness. However, one of the problems of FDBs is the occurrence of cavitation, which may affect the performances of FDBs. Recirculation channels are introduced to prevent cavitation and their location affects cavitation occurrence. So both cavitation and the effect of recirculation channels must be considered in order to analyze the performances of FDBs. Many researchers have studied the static and dynamic characteristics of FDBs and the dynamic behavior with the equations of motion of a rotating part [1-3]. However, they didn't consider cavitation as well as the effect of recirculation channels in their analysis.

This paper investigates the relationship between the variation of axial load and cavitation area of FDBs considering the effect of recirculation channels in a HDD spindle system by the transient analysis. The cavitation area is calculated by solving the Reynolds equations using the finite element method (FEM). The six nonlinear equations of motion of a spindle are solved by using forth-order Runge-Kutta method.

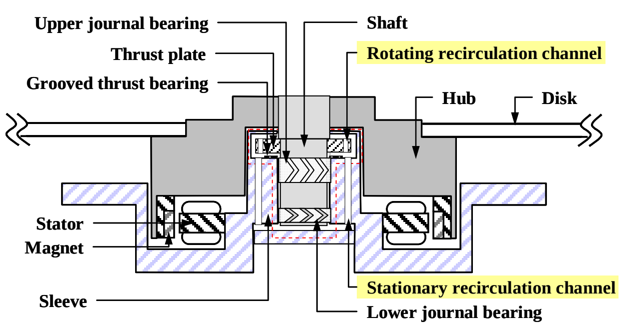

Fig.1 Structure of a HDD spindle system with recirculation channels

2. Method of Analysis

Figure 1 shows the structure of spindle motor with three rotating recirculation channels (RRCs) in rotating thrust and three stationary recirculation channels (SRCs) in stationary sleeve.

Figure 2 shows the coordinate of the coupled journal and thrust bearings, and the Reynolds equations for journal and thrust bearing can be written as follows by using the cylindrical coordinates:

$$\frac{\partial}{R\partial\theta}\left(\frac{h^3}{12\mu}\frac{\partial p}{R\partial\theta}\right)+\frac{\partial}{\partial z}\left(\frac{h^3}{12\mu}\frac{\partial p}{\partial z}\right)=\frac{\dot{\theta}_z}{2}\frac{\partial h}{\partial\theta}+\frac{\partial h}{\partial t} \quad (1)$$

$$\frac{\partial}{r\partial\theta}\left(r\frac{h^3}{12\mu}\frac{\partial p}{\partial r}\right)+\frac{\partial}{r\partial\theta}\left(\frac{h^3}{12\mu}\frac{\partial p}{r\partial\theta}\right)=\frac{\dot{\theta}_z}{2}\frac{\partial h}{r\partial\theta}+\frac{\partial h}{\partial t} \quad (2)$$

where p , h , $\dot{\theta}_z$ and μ are the pressure, thickness of fluid film, rotating speed and viscosity. FEM is used to solve the Reynolds equation with the recirculation channels to calculate the pressure distribution.

Assuming a rigid rotor, the motion of the spindle system is described in terms of six degrees of freedom, i.e., three translational motions in r , ϕ and z directions and three angular motions in θ_r , θ_ϕ and θ_z directions. Six nonlinear

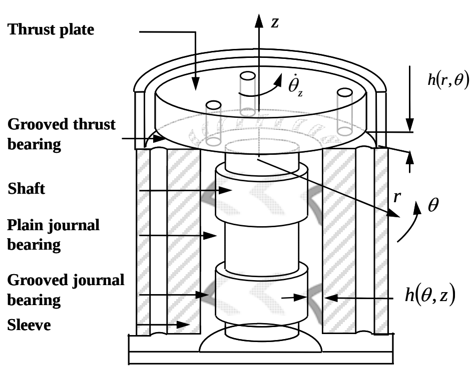

Fig.2 Cylindrical coordinate of the coupled journal and thrust bearing in a HDD system

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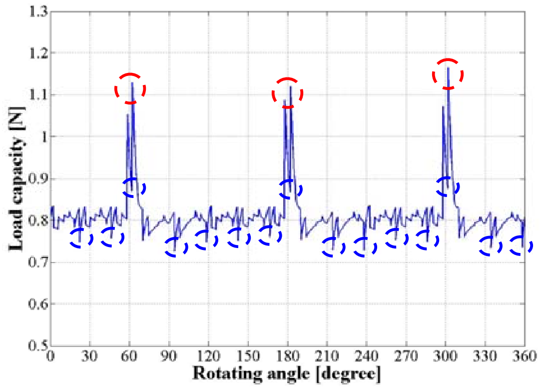

Fig.3 Variation of total axial load capacity

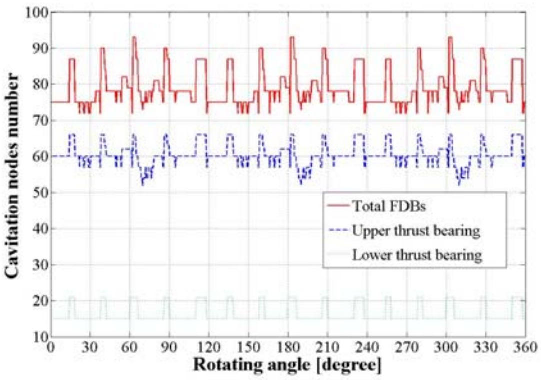

Fig.4 Number of the cavitation node

differential equations are derived by considering weight of a rotor, bearing force, centrifugal force of mass unbalance and axial magnetic force.

Cavitation characteristics of the fluid film are approximated by Reynolds boundary conditions and cavitated nodes in FDBs are examined at each time step during the transient analysis.

3. Results and discussion

Figure 3 shows the axial load capacity during one rotation of rotor. The 3 circles at the load capacity around 1.1 N mean that the load capacity is suddenly changed due to the overlapping effect between RRCs and SRCs. If RRCs overlap SRCs, the upper thrust bearing, the lower thrust bearing and lower part of lower journal bearing are connected with the area of oil-air interface through the recirculation channels. Then, the internal boundary condition of the lower thrust bearing and lower part of lower journal bearing is suddenly changed so that the total axial load capacity is affected.

Figure 3 also shows that the total axial load capacity changes 15 times during one rotation just as the 15 circles indicate at the load capacity around 0.6 N. It results from the overlapping effect between RRCs and thrust grooves. If RRCs overlap thrust grooves, cavitation occurs in the diverging section of upper thrust bearing. Thus cavitated nodes also occur in the lower thrust bearing through rotating

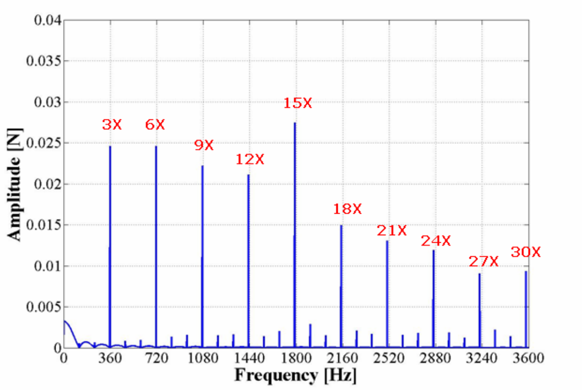

Fig.5 Frequency spectrum of the excitation force of z direction

recirculation channels.

Figure 4 shows the cavitated nodes number in FDB parts. The cavitated nodes occur in the upper thrust bearing and the lower thrust bearing and fluctuate 15 times. This result proves that the overlapping effect between RRCs and thrust groove generate cavitated nodes and change the total axial load capacity.

Figure 5 shows the excitation frequencies of axial direction from FDBs. The excitation force of 3X comes from the overlapping effect between RRCs and SRCs and 15X comes from the overlapping effect between RRCs and thrust grooves. Other frequencies are the harmonic frequencies. The amplitude of 15X is the highest among all the excitation forces. It indicates that the overlapping effect between RRCs and thrust grooves plays the important role on the axial load capacity.

4. Conclusion

This paper investigates the axial load and cavitation area of FDBs considering the effect of recirculation channels. Depending on the location of RRCs, they affect the cavitation area in FDBs and the axial load changes due to the overlapping effect between RRCs and SRCs, as well as between RRCs and thrust grooves. They also generate the excitation force and the consequent vibration of a spindle motor with specified frequencies.

References

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