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A Study on Ferro Fluid Dynamic Bearing Spindel Characteristics by High Frequency Vibration Ssystem

M.Miwa[1], H.Harita[1], T.Nishigami[1], R. Kaneko[1], and H.Unozawa[2]

[1]*Department of Opto-Mechatronics, Faculty of System Engineering, Wakayama University, 930 Sakaedani, Wakayama, 640-8510, Japan*
[2]*Ferrotec Corporation, 1-4, Midoridaira, Yokaichiba, Chiba 289-2131, Japan*

Ball bearings (BB) are generally used in spindles of disk drives at present, but they have been known that BB generate high frequency vibration. Fluid dynamic bearings (FDB) having high-rotational accuracy and small vibration characteristics have been developed as next generation spindles. Especially, a ferro fluid bearing (FFB) spindle has the advantage to prevent leakage and dispersion of lubricating oil using a ferro seal. In this study, we measured damping characteristics and frequency characteristics of these bearing spindles using a high-frequency vibration base. High frequency excitation was added to these bearing spindles mounted on the vibration base, and we proved that FFB and FDB spindles have effective damping..

Keywords : damping effect, ferro fluid bearing, high frequency excitation

1. INTRODUCTION

At present, memory capacity increase and high speed read/write performance are required for next generation hard disk drives. To increase memory capacities of file memory devices, improvement of recording density is necessary. Both reduction of recording track width and higher head positioning accuracy are important to improve recording density.

Ball bearings (BB) are generally used in spindles of disk drives at present, but they have been known that BB generate high frequency vibration. Therefore, improvement of head positioning accuracy in high frequency region is difficult when BB are used. Several improvements of BB have been done[1], but they have limits to supress BB vibrations.

Then, another type of spindles using fluid dynamic bearings (FDB) having high-rotational accuracy and small vibration characteristics have been developed as next generation spindles. Especially, a ferro fluid bearing (FFB) spindle has the advantage to prevent leakage and dispersion of lubricating oil using a ferro seal. However, FDB(includes FFB) mechanism is different from BB. So we think that not only rotational accuracy but also shaft stiffness and spindle's damping effect are important to evaluate for spindle estimate.

In this study, we measured damping characteristics and frequency characteristics of these bearing spindles using a high-frequency vibration base driven by a piezo actuator. Using the high-frequency vibration base, high frequency excitation was added to these bearing spindles mounted on the vibration base, and we proved that FFB and FDB spindles have effective damping. Also we have measured spindle runout of these spindles using a lock-in amplifier to increase S/N ratio and succeeded in measurements of nano meter order displacements.

2. EXPERIMENTAL SETUP

Fig.1 shows the experimental setup. A spindle has been mounted on a newly developed vibration base. High frequency excitation has been enabled using a piezo actuator (Tokin NLA-10x10x18). Acceleration sensors (Fuji ceramics B21S-N704) have been installed to the vibration base for measurements in frequency domain. Also displacement sensors (MTI ASP-1-ILA) have been attached to a spindle for measurement of spindle runout. Outputs of sensors have been measured by an oscilloscope and an FFT analyzer.

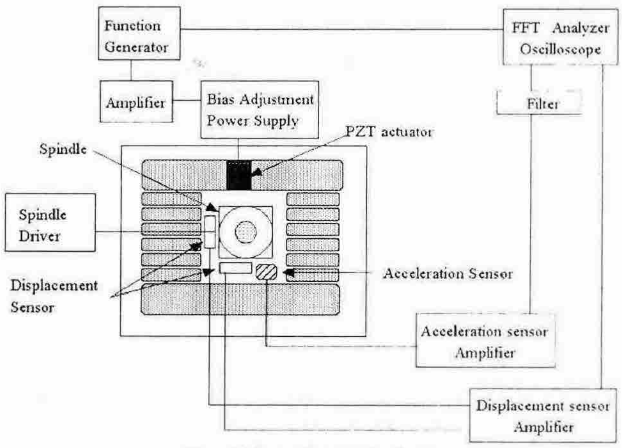

Fig. 1 Experimental Setup

3. RESULTS

We have applied step waveform signals to the piezo ac tuator to vibrate the vibration base, and have measured s tep response of the vibration base by an FTT analyzer u sing acceleration sensors under following conditions.

1.Vibration base + dummy mass which is equal to a s pindle
2.Vibration base + a ferro fluid bearing spindle
3.Vibration base + a ball bearing spindle

Fig.2 shows the results. In comparison with case 1.2 a nd 3, the peak value near resonance points of vibration base in case 2 is lower than that in case 1 and 3. It sho ws that the ferro fluid in the spindle works as a damper in this case. And from the results FFB spindle case, th e peak value of the FFB spindle rotates at 10krpm is sm aller than that of the spindle dose not rotate, additionally the peak value of 20krpm case is smaller than that of 1 0krpm case. It proves that damping effect becomes larger with spindle rotation. From these results, we did simula tion of this experimental setup as two-degree-of-freedom vibration system(Fig.3), and estimated unknown value of FFB spindle's damping effect.

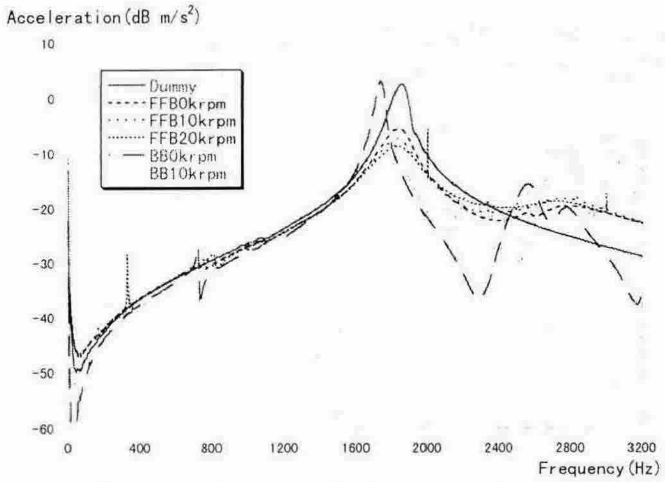

Fig. 2 Step Response of vibrated spindles

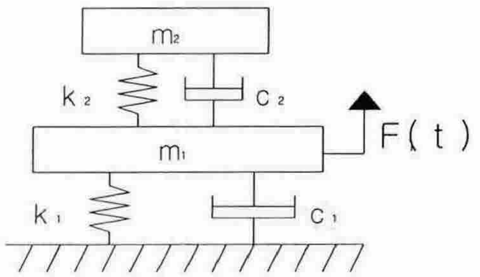

Fig. 3 Simulation model

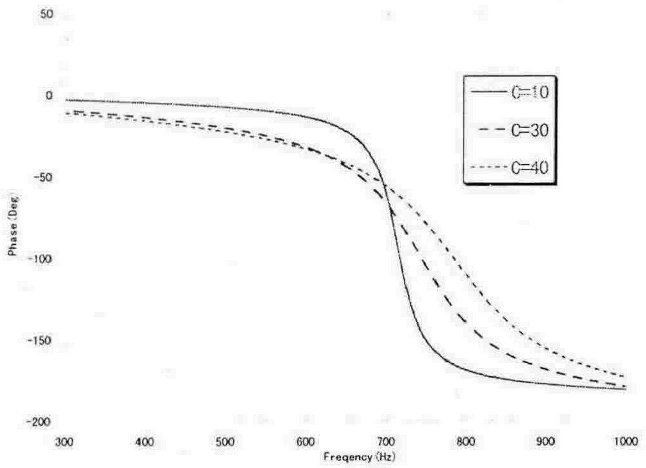

Fig.4 Phase Difference (Simulation)

By this simulation, the resonance point peak value of a hub (spindle's rotating part) at near 730Hz in Fig.2 will disappear or decrease with spindle rotation. But experim ental data dose not show it. So we did next experiments.

We measured the displacement of hub part (spindle runout) using vibration base : input signal for vibration was sine wave(300～1kHz by 5Hz step). Fig.4 shows the simulation results, and Fig.5 shows the experiments, as phase difference. Simulation and experiments were totally different. In Fig.5, if spindle does not rotate, phase deference curve is similar to simulation curve. But if spindle rotates, the shape becomes different. The phase inverses before resonance point (near 730Hz), then it returns after resonance point, and it inverses again. This phenomenon also appears in Fig.6. In Fig.6, the resonance point peak appears at about 730Hz with no rotation. But when spindle rotates, this peak splits into two peaks at near 630Hz and near 760Hz. And one peak at near 630Hz moves to lower, and the other peak near 760Hz moves to higher region with spindle rotation. We think that this phenomenon is caused by gyroscopic action of spindle's rotating part[2]. We are going to develop a new simulation model and procedure to evaluate damping and stiffness of spindles.

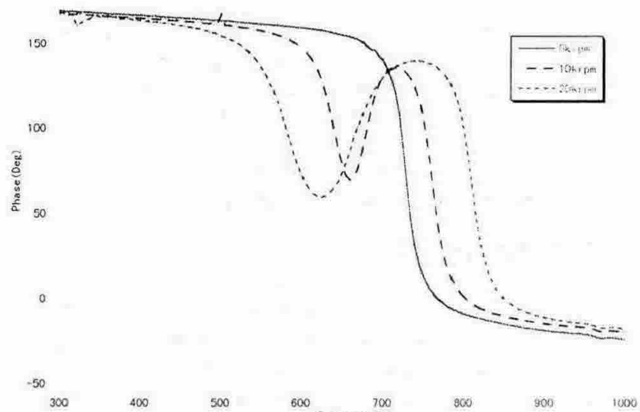

Fig.5 Phase Difference (Experimental)

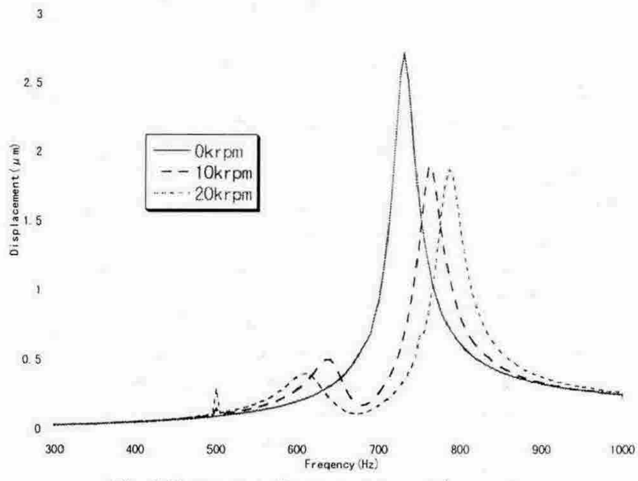

Fig.6 Frequency Response (experiments)

7. REFERENCES

[1]S.Noguchi, K.Tanaka and K.Ono, "Theoretical Analysis of a Ball Bearing used in HDD Spindle Mortors for Reduction of NRRO", IEEE Trans. Mag., vol.35, no.2, pp845-849, 1999.
[2] Ku,C.-P.R., "Dynamic Charateristics of Hard Disk Drive Spindle Motors Comparison Between Ball Bearings and Hydrodynamic Bearings",Transactions of ASME Journal of Tribology, Vol.118, pp.402-406,1996.