ASIATRIB 2002International Conference
JEJU ISLAND, KOREA

A Study on Hydrodynamic Stiffness Characteristics of Air Bearing for High Speed Spindle

J. Y. Lee [1] D. W. Lee S. H. Seong[2] Y. C. Lee

[1] *Department of Mechanical and Precision Engineering, Graduate School, Pusan National University*
San 30, Jangjeon-Dong, Kumjung-Ku, Pusan609-735, KOREA
[2] *Department of Mechanical and Precision Engineering, Pusan National University*
San 30, Jangjeon-Dong, Kumjung-Ku, Pusan609-735, KOREA
[3] *Department of Precision Mechanics, Yonam College of Engineering*
780, Kanoa-Dong, Jinju-City, Gyungnam, KOREA

This study was carried out as one of efforts to overcome difficulties in air bearing design due to low stiffness and low damping. Hydrodynamic effects on hydrodynamic stiffness of a fluid film in a high speed air bearing with two-row air sources are investigated. The hydrodynamic effects by the high speed over DN 1,000,000 and eccentricity of a journal which are not considered in conventional design of an air bearing need to be reconsidered. The hydrodynamic effects, which dominantly influence on the load capacity of air bearing, are caused mainly by journal speed, eccentricity, and the source positions. The two-row source arrangement in the air bearing produces quite unique hydrodynamic effects with respect to pressure distribution of the air film. Optimal arrangement of the two-row sources improves performance of an air bearing in film reaction force and loading capacity of high speed spindles.

This study compares the pressure distributions by numerical simulations as a function of eccentricity of journal and the source positions. The air source position 1/7L from one end of an air bearing was found to be superior to source position of 1/4L. The dynamic stiffness were obtained using a two-dimensional cutting method which can directly measure the cutting reaction forces and the displacements of the spindle in two directions using a tool dynamometer and transducer sensors.

Heat generation in the air film can not be negligible over the speed of DN 2,000,000.

In order to analysis effects of heat generation on the characteristics of air bearing, high cooling bearing spindle and low cooling bearing spindle were tested and compared. Characteristics of the frequency response of shaft and motion of run out errors were different for the spindle. The test results show that, in the case of low cooling bearing spindle, the stiffness became smaller due to heat generation.

The results, which were obtained for high speed region, may be used as a design information for spindle which can be applied to precision devices such as ultra precision grinding and ultra high speed milling.

Keywords : Font, Heading System, Illustrations, References, Submission

1. INTRODUCTION

Externally pressurized air journal bearing is in wide use in high speed rotating machinery and high precision spindle system because of its advantages such as low friction, low heat generating character and averaging effects of the pressure deviation in the air film in bearing.

The necessary to catch the performance of air bearing is being increased for developments of highly efficient high speed machinery. Therefore, the stiffness and damping values of air bearing is characteristics value to express air bearing's performance. The measuring of air bearing's stiffness coefficient have to be carried out efficiently because it is the greatest important design factor and the load capacity of air bearing is less than any other fluid film bearing because of low viscosity.

An air film in air bearing has a disadvantage that we can not expect the boundary lubrication in a state of emergency. In order to deal with this kind of problem, a number of engineer have investigated for the improvement of the loading capacity and high dynamic coefficients [2-7].

But these studies have been analyzed theoretically in the static states or in the air film for single row air source. Up to now, in the case of two row air sources of air bearing, the source position which is the existing design factor have choose 1/4L of bearing total length from the end of air bearing. A number of theoretical and experimental analysis have been carried out at this position. An international company, Westwind Turbines Ltd., the investigation contents of Poole and J.W.Powell express well Fig.1.

However, the air bearing clearance have been designed on the tight condition of 10-20μm and we have to always consider hydrodynamic effects into the air film in high speed region.

The design factors of air bearing have to reconsider in the side of load capacity and choose again the source position including the hydrodynamic effects in high speed region. Therefore, a final goal of this paper is to find the new boundary condition of the source position through the theoretical analysis according to the source position and experiments loading to the journal

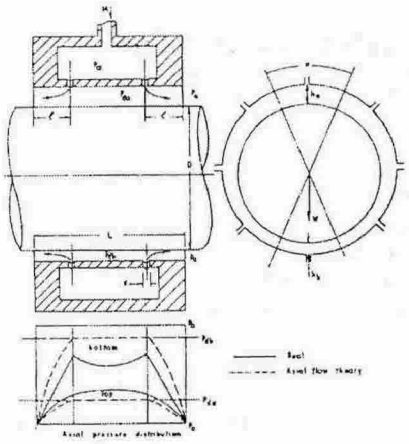

Fig. 1 Design parameters for the air bearing

2. NUMERICAL ANALYSIS

The air-film pressure distribution in bearing to have two row sources is determined from following reynold equation. In order to solve the loading capacity, air supply source is assumed as a line source and the following assumptions are adopted.

(1) It's possible to disregard the other velocity gradient except the velocity gradient of the film thickness directions.
(2) The surface of the bearing and journal is completely flat.
(3) The air flow in the air film is isothermal, viscous and laminar.
(4) The non-slip condition at the film boundaries applies at the plane surface only.

Therefore, the reynold equation for the air film under the air bearing and journal is expressed in the following form.

$$\frac{\partial}{\partial x}\left(Ph^3 \cdot \frac{\partial P}{\partial x} \right) + \frac{\partial}{\partial y}\left(Ph^3 \cdot \frac{\partial P}{\partial y} \right) = 6\eta \cdot U_1 \cdot \frac{\partial (Ph)}{\partial x}$$

3. EXPERIMENTS

At this research, there are taken the cutting force in the dire ction of primary stiffness through carrying out two dimension cutting with using the tool dynamometer and the load capacity by both signals for the cutting resistance and the displacement simultaneously with using the capacitive precision displaceme nt sensor which has an ability of the decomposition , 5nm. In v iew of the results so far achieved that method, the practical an d reliable dynamic coefficients of bearing may be given. The c onfigurations of this experiment have good merits two as follo ws.

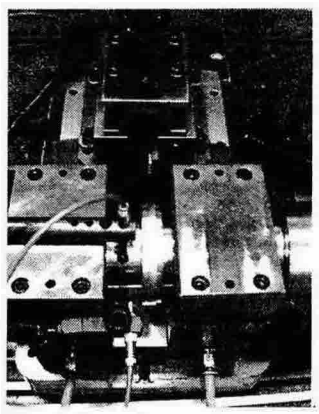

Fig. 2 Experimental set-up

4. DISCUSSION

The characteristics of air-lubricated film and the loading capacity according to the source position have been investigated through the theoretical analysis and the experiments. The theoretical analysis represents that the hydrodynamic effect occurred and source positions cause the hydrodynamic effect of the different shape. At the result, the different pressure-distributions according to the source positions have an influence to the dynamic coefficients and bearing stiffness. The experimental results too have proved these facts showing that the stiffness of 1/7L is superior to the stiffness of 1/4L.

5. REFERENCES

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