ASIATRIB2002InternationalConference
JU ISLAND, KOREA

An Application of Coordinate Transformation Method on Lubricating Characteristics of Negative Pressure Slider

Pyung Hwang [1], Sang-Shin Park [2], Eun-Hyo Kim [3]

[1] *School of Mechanical Engineering, Yeungnam University*
214-1 Dae-Dong 712-749 Gyongsan, Kyongbuk, KOREA
[2] *School of Mechanical Engineering, Yeungnam University*
214-1 Dae-Dong 712-749 Gyongsan, Kyongbuk, KOREA
[3] *Graduate student, Department of Mechanical Engineering, Yeungnam University(Now, Mirae Co.)*
214-1 Dae-Dong 712-749 Gyongsan, Kyongbuk, KOREA

The lubricating characteristics of negative pressure slider were performed by using divergence formulation method with the coordinate transformation method. This method makes it possible to deal with an arbitrary configuration of a lubricated surface. The pressure profile of the slider is calculated. These results are compared to that from direct numerical method. The steady-state, including minimum film thickness, pitching and rolling angle are calculated by multi-dimensional Newton-Rapson method. The stiffness and damping characteristics are also calculated.

Keywords : Negative Pressure Slider, Generalized Coordinate System, Divergence Formulation

1. INTRODUCTION

The computer hard disk drive has head and disk. The head is used to read and write record on the disk. It is flying above the disk by pressure of the air film. This air film thickness needs to be reduced in order to increase the magnetic recording capacity.

A Negative Pressure Sliders (NPS) were developed for this purpose. These sliders have parts on which the subambient pressure is generated. This pressure pulls the head near to the disk. These sliders also offer less flying height sensitivity to disk velocity, higher stiffness of the air bearing and faster take off [1] than the conventional two rail sliders. White [2] presented a design of a Transverse and Negative Pressure Contour (TPC) slider and showed the above advantages. Bogy [3] performed FDM analysis about static and dynamic characteristic of negative pressure slider, Kawabata [4] suggested divergence formulation (DF) method to the lubricated journal bearings.

In this work, we applied the coordinate transformation method to the negative pressure sliders of complicate geometry. The static pressure is calculated and the steady states are found from moment equilibrium conditions. Then the stiffness and damping characteristics are calculated using the small perturbation method.

2. THEORETICAL BACKGROUND

2.1 Steady state position

Steady-state means that supporting force by air pressure equals to the external load and moments of pitching and rolling angle about pivot point becomes zero. To obtain pitching, rolling angle and minimum film thickness at steady-state, multi-dimensional Newton Raphson method is applied.

$$
\begin{aligned}
f_1(h_{min.}\alpha,\beta) &= (F - F_O) \\
f_2(h_{min.}\alpha,\beta) &= M_y \\
f_3(h_{min.}\alpha,\beta) &= M_x
\end{aligned}
\qquad (1)
$$

2.2 Stiffness and damping

When the film thickness is changed slightly, the pressure distribution is changed. The integration of pressure variation (ΔP) results in the variation of load carrying capacity (ΔF). The stiffness is the ratio of variation of load (ΔF) to the amount of change in the film thickness (Δh).

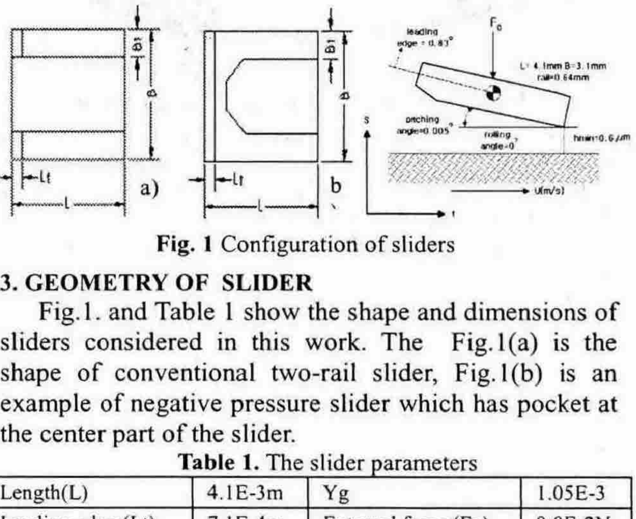


Fig. 1 Configuration of sliders

3. GEOMETRY OF SLIDER

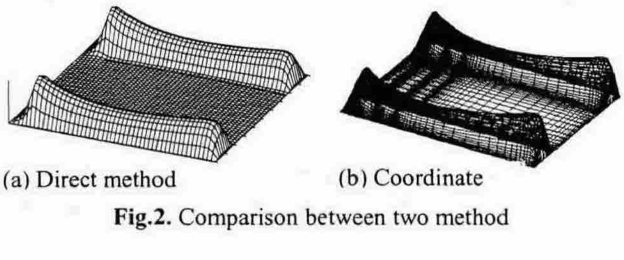
Fig.1. and Table 1 show the shape and dimensions of sliders considered in this work. The Fig.1(a) is the shape of conventional two-rail slider, Fig.1(b) is an example of negative pressure slider which has pocket at the center part of the slider.

Table 1. The slider parameters

Length(L)	4.1E-3m	Yg	1.05E-3
Leading edge (Lt)	7.1E-4m	External force (Fo)	9.0E-2N
Width (B)	3.8E-3m	External x moment	-1E-7
Rail width (Bt)	6.4E-4m	External y moment	-1.5E-5
Xg	2.1E-3m	Leading edge angle	0.83

4. COMPUTATIONAL RESULTS

3.1 Two rail slider



(a) Direct method (b) Coordinate

Fig.2. Comparison between two method

Fig.2 shows that the pressure profiles from the direct method and the coordinate transformation method are similar.

The load carrying capacity versus velocity is calculated for the conventional two-rail slider. The results are compared to that from direct method [4] and semi-implicit method [2] as shown in Fig.3. The load carrying capacities from all three methods are coincident for the whole range of velocity within 5% errors.

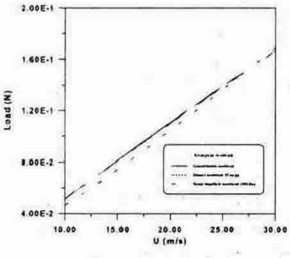


Fig.3 Load versus velocity

3.2 Negative pressure slider

Fig.4 (a) shows the height function of the slider and Fig.4 (b) shows the corresponding pressure profile. The part, where height is suddenly increased, is called the step boundary region. The positive pressure is generated from leading edge

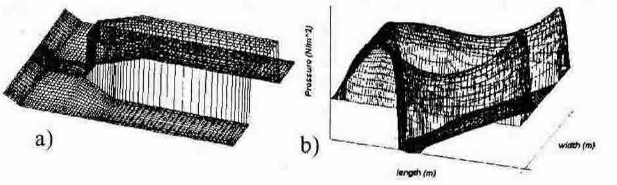
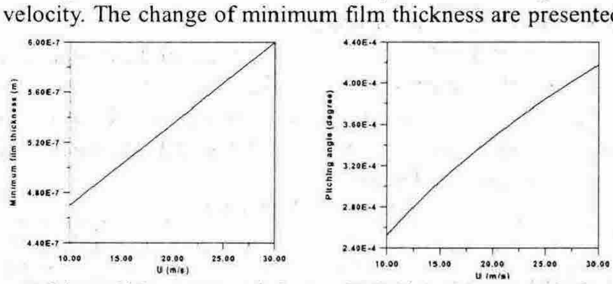


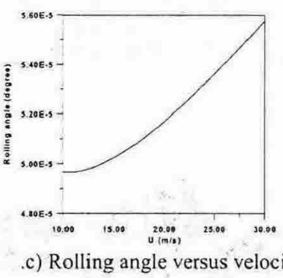
Fig.4. An Example of pressure profile for NPS

and the saddle shaped positive pressure is generated along the two-side rail. The negative pressure is made at the step boundary region because compressed air is expanded when they met abruptly increased height.

Fig.5 shows the variation of steady-state according to disk velocity. The change of minimum film thickness are presented



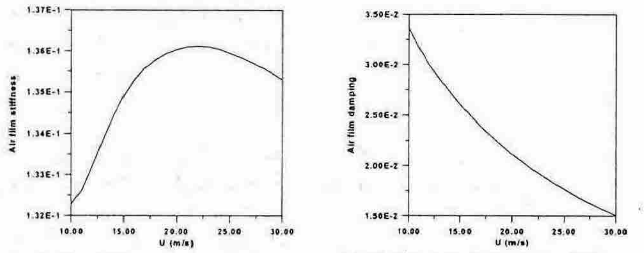
a) Minimum thickness versus velocity b) Pitching angle versus velocity



.c) Rolling angle versus velocity

Fig.5. Static characteristics of NPS

in Fig.5(a). The load carrying capacity is increased according to the disk velocity. This phenomenon means that the increasing rate of positive pressure at the side rail is greater than that of negative pressure. The increased load carrying capacity push the head away from the disk. As the result, the minimum film thickness is increased. Fig.5(b),(c) show the variation of pitching and rolling angle versus velocity. As velocity increase, rolling and pitching angle grow linearly. This indicates that the increasing rate pressure at the leading edge is greater than any other part. The increased leading edge pressure makes the slider to be rolled slightly.



a) Air film stiffness versus velocity (b) Air film damping versus velocity

Fig.6. Dynamic characteristics of NPS

Fig.6(a) is the graph about the influence of velocity on air bearing stiffness. There is a specific tendency that the graph increases up to 20m/s due to positive effect and it decreases over 20m/s due to negative effect.

4. CONCLUSIONS

In this paper, a useful program is developed, which can handle the complicated geometry and compressible fluid lubrication. In this program we adapted the coordinate transformation method to the negative pressure slider with ultra low film thickness. We have calculated the pressure distribution for the conventional two-rail slider and compare the load carrying capacity to those from direct method and semi-implicit method. The results are well coincident with in 5% error. We also calculated the pressure profile of the negative pressure slider effectively by this method.

5. NOMENCLATURE

p - pressure, R*p is density
h, h_{min} - film thickness and minimum film thickness
Q - mass flux
α,β - pitching and rolling angles
F, F_0 - total load and external load
M_x, M_y - force momentum in pitch and roll directions
X_g,Y_g - coordinates of external force application

6. REFERENCE

[1] Peng,J.-P., and Hardie,C.E., "Characteristics of Air Bearing Suction Force in Magnetic Recording Disks", ASME J. of Tribology, Vol. 118,pp.549-554 ,1996.

[2] White,"Flying Characteristics of the Transverse and Negative Pressure Contour ("TNP") Slider Air Bearing", J. of Tribology Vol. 119 April ,pp. 241-248, 1997.

[3] Miu, D.K. and Bogy D.B., "Dynamics of Gas-Lubricated Slider Bearings in Magnetic Recording Disk Files- Part I :Experimental Observation", J. of Trib., Trans. ASME, Series F, Vol. 108, pp. 584-588, 1986.

[4] Nobuyoshi Kawabata," A Study on the Numerical Analysis of fluid film Lubrication by the Boundary Fitted Coordinate System [Fundamental Equation of DF method]",JSME Int. J.,Vol.31,No.1,pp107-113, 1988.