พฤติกรรมการลอยตัวของหัวอ่านในฮาร์ดดิสก์เมื่อมีอุณหภูมิอากาศโดยรอบเปลี่ยนแปลงไป

Flying Characteristics of the Air Slider Bearings in HDD Under Ambient Temperature Change

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บทคัดย่อ

บทความฉบับนี้อธิบายพฤติกรรมการลอยตัวของหัวอ่านในฮาร์ดดิสก์เมื่ออุณหภูมิอากาศโดยรอบเปลี่ยนแปลงไป โดยนำสมการโมดิฟายด์เรย์โนลด์ร่วมกับสมการโบวซ์แมนน์มาประยุกต์กับระเบียบวิธีเชิงตัวเลข ซึ่งได้นำวิธีนิวตัน–ราฟสันร่วมกับวิธีผลต่างสืบเนื่องและวิธีมัลติกริดเพื่อหาการกระจายความดันและระยะการลอยตัวของชุดหัวอ่านที่สภาวะคงที่ เมื่ออุณภูมิของอากาศโดยรอบเปลี่ยนแปลงไปมีความสำคัญต่อการเปลี่ยนแปลงระยะการลอยตัวต่ำสุดของหัวอ่านชนิดความดันต่ำกว่าบรรยากาศในฮาร์ดดิสก์

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Abstract

This paper describes the flying characteristics of the sliders in HDD under ambient temperature change. The slider bearing is a self acting with straight rails for the magnetic storage in hard disk drives. The modified Reynolds equations based on a linearized version of the Bolzmann equation were formulated. Numerical scheme based on the finite difference method and multi-grid multilevel technique with Newton's method were implemented to obtain the flying characteristics of ultra-thin head sliders in steady state. Under ambient temperature change, the pressure profile and flying height were calculated with varying rail length, rail width, and load and disk velocity. The ambient temperature changes are significantly affecting the performance characteristics of the sub-ambient pressure sliders air bearing in hard disk drives.

Keywords*:* Flying Characteristics, Air Slider Bearings, Finite difference technique, Multi-grid-multi-level Techniques.

1. Introduction

In order to increase the recording density and interface performance of magnetic hard disk drives (HDD), it is essentially to minimize spacing between the slider and disk surface at the trailing edge. Presently, the flying height for commercially available disk drives with a recording density of 100 Gb/in^2 is on the order of 10 nm [1].

The air bearing slider utilizes the combination of a thin lubricating air film theory using the finite difference method [2] and adaptive multi-grid method [3] to provide a pressure distribution and flying height. The objective of these studies is to analyze the phenomenon of each parameter on minimum flying height by simulation.

2. Theoretical analysis

Analyzing lubrication theory, Reynolds equation has been utilized to calculate pressure distribution and flying height. In this study, Reynolds equation is established by combination between Navier-Stokes equation and Continuity equation by the hypothesis that the surface of air bearing and disk are smooth. Lubrication fluid is Newtonian, laminar flow, constant viscosity, ideal gas and isothermal condition. Inertia force and body force of fluid have been neglected because film thickness is very small and the slip condition has been considered.

The slip models currently used to predict pressures in head-disk interface in HDD are the first-order slip model [4], second-order slip model [5], 1.5-order slip model [6] and Boltzmann-Reynolds model [7][8]. The governing equation for each of these models and the no-slip model can be written in the dimensionless form as equation (1) [9].

$$\frac{\partial}{\partial X}\left(Q\frac{\partial P}{\partial X}\right)+\lambda^2\frac{\partial}{\partial Y}\left(Q\frac{\partial P}{\partial Y}\right)=\Lambda\frac{\partial}{\partial X}(PH) \qquad (1)$$

While $Q=\phi(P,H)PH^3$ and $\phi(P,H)$ is Poiseuille flow factor which takes the Boltzmann-Reynolds model as shown in equation (2) and A_0, A_1, A_2 and A_3 are the constants that depend on Kn/PH.

$$\phi(P,H)=A_0+A_1\left(\frac{Kn}{PH}\right)+A_2\left(\frac{Kn}{PH}\right)^2+A_3\left(\frac{Kn}{PH}\right)^3 \qquad (2)$$

Film thickness equation

The equation of flying height is analyzed from the surface of air bearing of head slider that can be written in dimensionless form as equation (3).

$$H=H_{TR}+(1-X)(H_{LD}-H_{TR})+\delta \qquad (3)$$

When : δ is depth parameter that depends on its position on the surface.

Equation of motion

There are two degree of freedom in the motion of head slider, that is force balance and moment balance, which are necessary to be balanced. The dimensionless force balance equation is

$$\int_{-\frac{1}{2}}^{\frac{1}{2}}\int_{0}^{1}(P-1)dXdY=F_0 \qquad (4)$$

The dimensionless moment balance equation is

$$\int_{-\frac{1}{2}}^{\frac{1}{2}}\int_{0}^{1}X(P-1)dXdY=X_GF_0 \qquad (5)$$

After that, finite difference and Newton-Raphson method were utilized with the boundary condition in equation (6).

$$P(0,Y)=P(1,Y)=P\left(X,\frac{1}{2}\right)=P\left(X,-\frac{1}{2}\right)=1 \qquad (6)$$

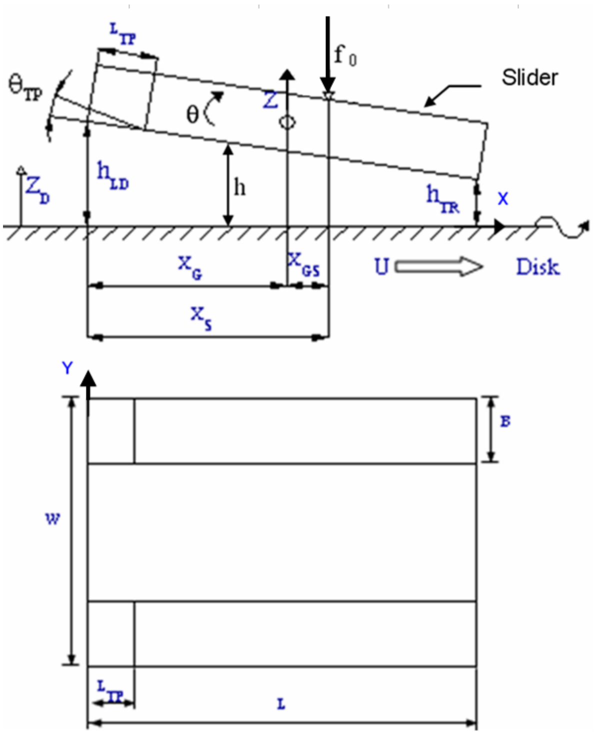

Fig. 1 Simulation model of Air Bearing Surface

3. Simulation results

In this simulation, the static characteristics of the taper flat slider are obtained theoretically. The taper flat slider is 2.025 X 1.525 (mm.) as shown in table 1

Table 1 Dimension of taper flat slider

DESCRIPTION	TAPERED - FLAT
$L(mm)$	2.025
$B(mm)$	0.5
$W(mm)$	1.525
$h_{TP}(\mu m)$	2.795
$L_{TP}(\mu m)$	0.184
$f_0(mN)$	73.5
$x_s(mm)$	1.081

3.1 Influence of the change in ambient temperature on flying characteristics of the air slider bearing.

In this study, the flying characteristics of taper flat slider were calculate for varying the slider geometry and operated at various ambient temperature conditions; 5, 25 and 45 °C as show in fig. 2, 3, 4, 5 and 6.

Fig.2 shown the flying height at leading edge and the flying height at tailing edge increased significantly when increase the rail width, disk velocity and ambient temperature.

Fig.3 shown the flying height at leading edge decreased but the flying height at tailing edge increased when increases the taper length. At low disk velocity, the flying height at tailing edge is almost constant and the flying height increased as the both disk velocity and ambient temperature increased.

Fig.4 shown the flying height at leading edge and the flying height at tailing edge decreased when increase taper angle and the flying height at the leading edge and the flying height at tailing edge increased as the both disk velocity and ambient temperature increased.

Fig.5 shown the flying height at leading edge increased but the flying height at tailing edge decreased when increases the suspension position. At low disk velocity the flying height at tailing edge is almost constant and the flying height increased as the both disk velocity and ambient temperature increased.

Flying height at leading edge and the flying height at tailing edge decreased when increase suspension preload and the flying height at leading edge and the flying height at tailing edge increased with both increasing disk velocity and increasing the ambient temperature as shown in Fig. 6.

3.2 Influence of the change in ambient temperature and current source on flying characteristics of air slider bearing.

In this study, the flying height characteristics of taper flat slider were calculate for varying the slider geometry and operated at various ambient temperature and current source condition.

Fig. 7 shown the increase of flying height at leading edge and the flying height at tailing edge when increased rail width and disk velocity. The flying height at tailing edge increased but the flying height at leading edge decreased under the supply current source at 0 mA and 13 mA at read/write device for increasing rail width and increasing the ambient temperature, the flying height significant increased.

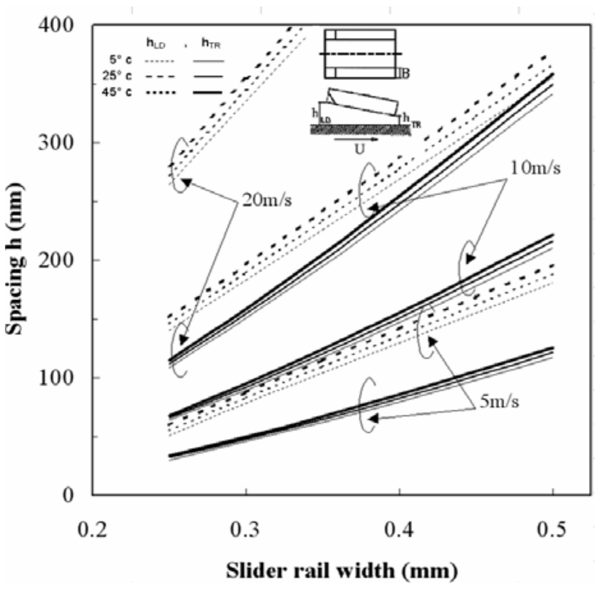

Fig. 2 Variation of flying height with varying the rail width for difference ambient temperature change

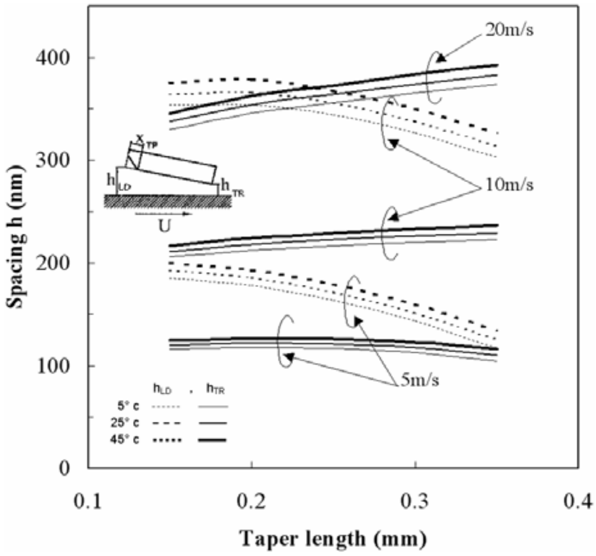

Fig. 3 Variation of flying height with varying the taper length for difference ambient temperature

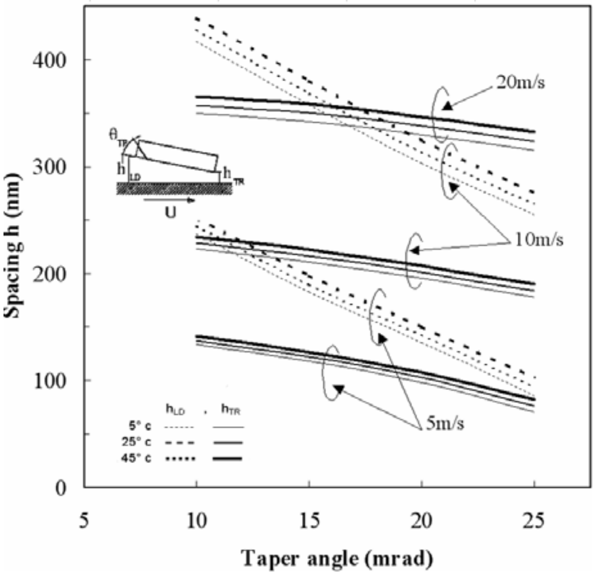

Fig. 4 Variation of flying height with varying the taper angle for difference ambient temperature change

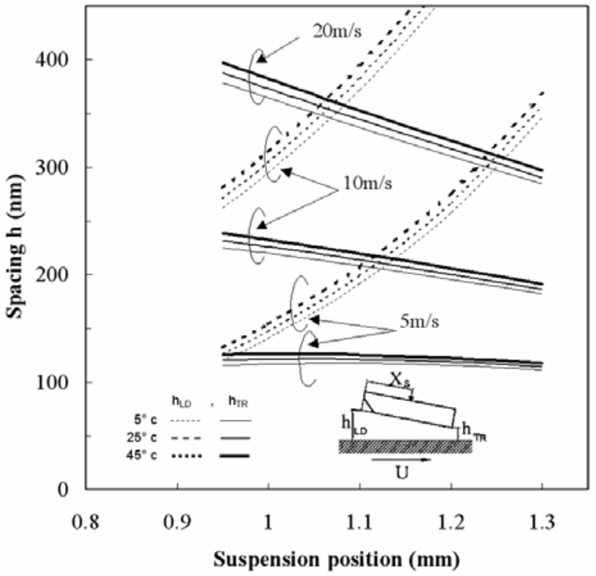

Fig. 5 Variation of flying height with varying the suspension position for difference ambient temperature change

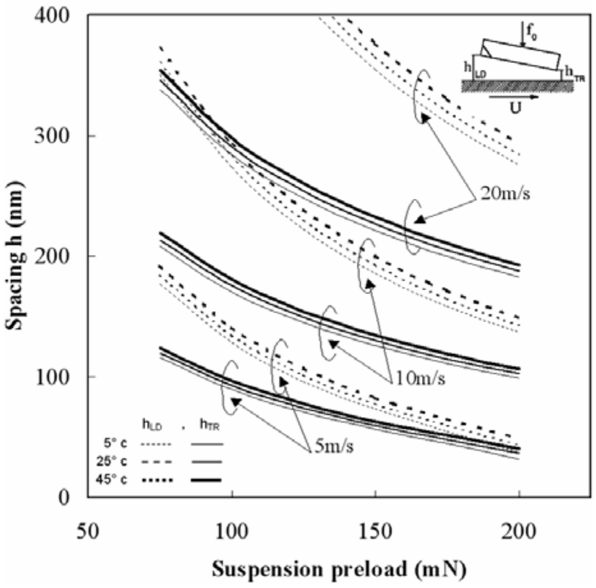

Fig. 6 Variation of flying height with varying the suspension preload for difference ambient temperature change

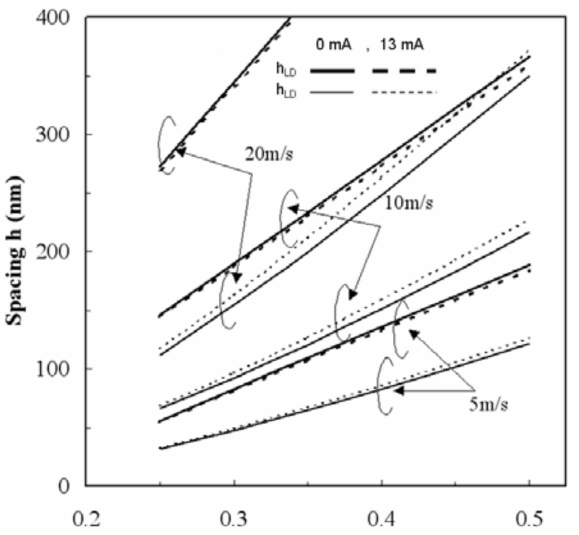

Fig. 7 Variation of flying height with varying the rail width for difference current source on read/write device at 25 °C

4. Conclusion

(a.) Numerical scheme based on the finite difference method and multi-grid multilevel technique with Newton’s method were implemented to obtain the flying characteristics of ultra-thin head sliders in steady state.

(b.) The flying height increase as the ambient temperature increased due to the increase in air viscosity.

(c.) The flying height at leading edge and the flying height at tailing edge increased with the increasing ambient temperature by 5, 25 and 45 °C

(d.) The slider geometry is the significant effect on both flying height and pressure profile.

5. Acknowledge

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6. Nomenclature

Q	Poiseullie flow factor
P	Normalized pressure, $P = p/p_a$
p	Pressure
p_a	Atmosphere pressure
λ	Length-width ratio, $\lambda = L/W$
L	Slider length
W	Slider width
Λ	Bearing number, $\Lambda = 6\mu_0 UL/p_a h_a^2$
μ_0	Gas viscosity
U	Disk velocity
h_a	Reference film thickness
X, Y	Normalized Cartesian coordinates, $X = x/L$, $Y = y/W$
x, y	Cartesian coordinates
Kn	Knudsen number, $Kn = \lambda_a/h_a$
H	Normalized film thickness, $H = h/h_a$
H_{TR}	Normalized trailing edge, $H_{TR} = h_{tr}/h_a$
H_{LD}	Normalized leading edge, $H_{LD} = h_{ld}/h_a$
h	Film thickness
h_{tr}	Trailing edge
h_{ld}	Leading edge
δ	Depth parameter
F_0	Normalized Load, $F_0 = f_0/P_a LW$
f_0	Load
X_G	Normalized support position, $X_G = x_g/L$
x_g	Support position
λ_a	Mean free molecular path of gas, $\lambda_a \approx 64\,nm$

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