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Influence of heating temperature fluctuation on flying height under EAMR conditions

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Abstract

This paper investigates the influence of heating temperature fluctuation on flying height under Energy Assisted Magnetic Recording (EAMR) conditions. During the read/write process, the effects of high temperature on the flying height have been studied under steady state condition. The modified Reynolds equation was formulated included the temperature effect on both air viscosity and density. Numerical scheme based on the finite difference method and Newton-Raphson method with multi-grid multilevel technique were implemented to obtain the flying characteristics of the slider in steady state. Under high temperature condition, the pressure gradient and flying height were calculated with varying temperature and disk velocity. The simulation results show that temperature change and disk velocity change have significant effect on the flying characteristics of the head slider in EAMR conditions.

***Keywords**:* Energy Assisted Magnetic Recording, Temperature effect, Finite difference method with Multi-grid multilevel technique, Flying characteristics under steady state condition.

1. Introduction

Energy Assisted Magnetic Recording (EAMR) is a promising technology for 1Tb/in^2 and beyond recording density after the perpendicular recording technology. With EAMR, media with very high anisotropy are used but are written suing the combination of heat produced by a laser and the field produced by a magnetic head. During the writing process, the temperature is raised in a confined region is around 500°C [1]. The temperature changes affect to the flying height and air bearing surface of the slider head due to its dependence on the motion of the air molecules [2].

The air bearing slider utilizes the combination of a thin lubricating air film theory using the finite difference method [3] and adaptive multi-grid method [4] to provide a pressure distribution and flying height. The objective of these studies is to analyze the effect of such as high temperatures on the flying height and the disk velocity of Tri pad slider 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 [5], second-order slip model [6], 1.5-order slip model [7] and Boltzmann-Reynolds model [8][9]. The governing equation for each of these models and the no-slip model can be written in the dimensionless form as equation (1) [9].

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

While $Q(P,H)=\Phi(P,H)PH^{3}$ 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 $\frac{K_N}{PH}$

$$\Phi(P,H)=A_0+A_1\left(\frac{K_N}{PH}\right)+A_2\left(\frac{K_N}{PH}\right)^{2}+A_3\left(\frac{K_N}{PH}\right)^{3} \quad (2)$$

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).

$$H_{X,Y}=H_{TR}+(1-X)(H_{LD}-H_{TR}) \quad (3)$$

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

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

The dimensionless moment balance equation is

$$\int_{-\frac{1}{2}}^{\frac{1}{2}}\int_{0}^{1}X(P-1)dXdY=X_G\left(\frac{F_0}{p_aWL}\right) \quad (5)$$

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

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

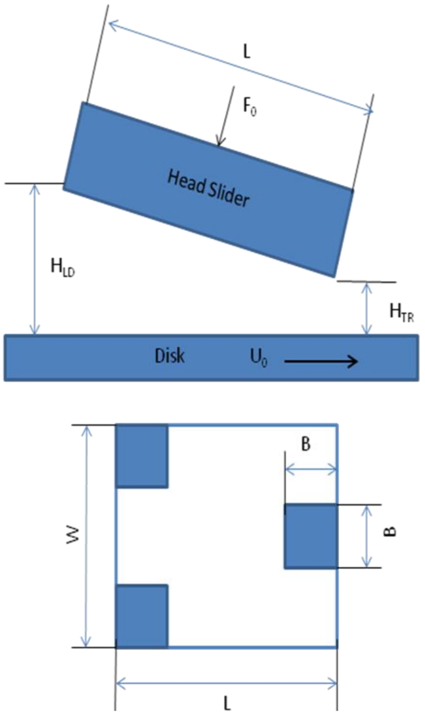

Fig. 1 Simulation model of Air Bearing Surface

3. Simulation results

The schematic diagram of the magnetic head slider considered in this paper is shown in Figure1. In this simulation, the static characteristics of the tri pad slider are obtained theoretically. The tri pad slider is 0.85 x 0.70 (mm.) as shown in Table 1.

Table 1 Dimension of Tri pad slider

SYMBOL	DIMENSION
L	0.85 mm
W	0.70 mm
B	0. 20 mm
F_0	25.0 mN

3.1 Influence of the temperature changes on statistic characteristic with Tri pad ABS design

In this study, the flying characteristics of tri pad slider were calculate for varying the slider geometry and operated at various temperature conditions; 20,60,100,300 and 500 degree C with disk velocity at 17.95, 23.94 and 33.25 m/s as show in figure 2.

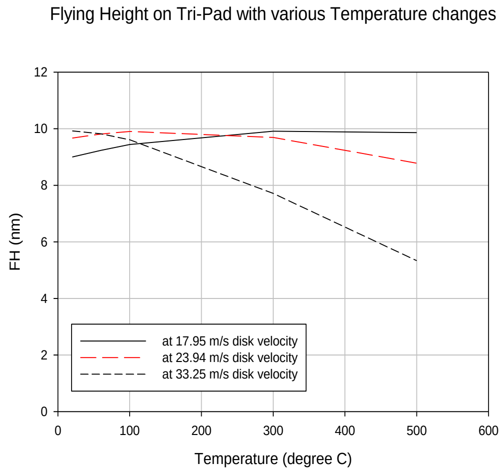

Fig. 2 Flying height comparisons with various temperatures at disk velocity changes17.95, 23.94 and 33.25 m/s

Fig. 2 shown the flying heigh changed when increased temperature. At temperature changes 300 and 500 degree C, the flying height decreased when increased the disk velocity.

3.2 *Influence of the disk velocity changes on statistic characteristic with Tri pad ABS design*

In this study, the flying characteristics of tri pad slider were calculate for varying the slider geometry and operated at various disk velocity conditions; 17.95, 23.94 and 33.25 m/s at different temperature changes as show in figure 3.

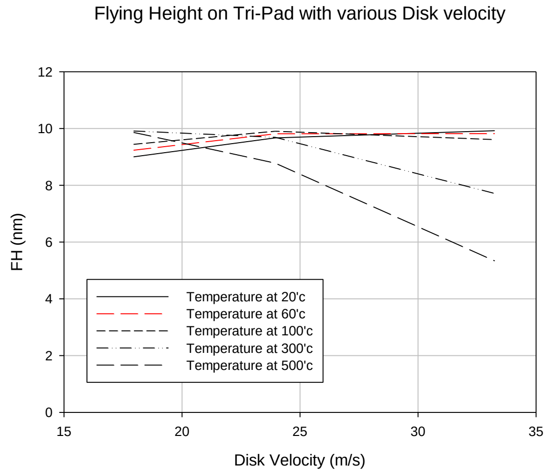

Fig. 3 Flying height comparisons with various disk velocity changes at different temperature increases

Fig. 3 shown the flying height changed when increased disk velocity. At high disk velocity 33.25 m/s, the flying height decreased when increased the temperatures.

Fig. 4 and Fig. 5 shown the pressure profile at the trailing pad with various the temperature changes at disk velocity 17.95 and 33.25 m/s. The pressure at the trailing edge area is significantly changed when the temperature increased and disk velocity increased.

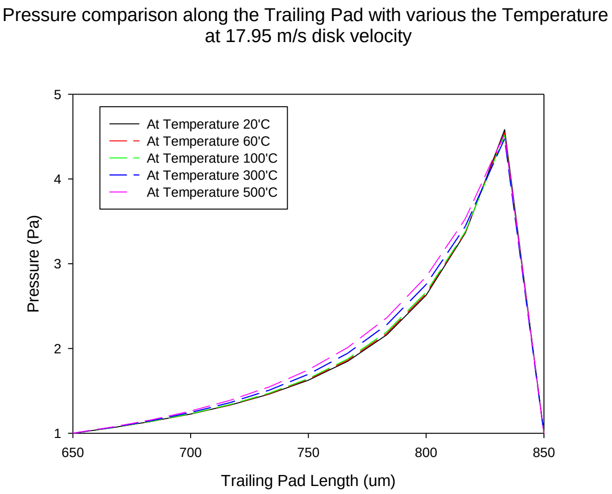
Pressure comparison along the Trailing Pad with various the Temperature at 17.95 m/s disk velocity

Fig. 4 Pressure profile at trailing pad with various temperature at disk velocity 17.95 m/s

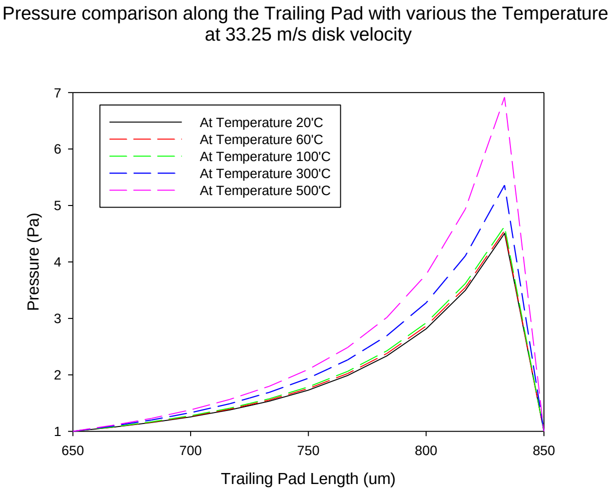
Pressure comparison along the Trailing Pad with various the Temperature at 33.25 m/s disk velocity

Fig. 5 Pressure profile at trailing pad with various temperature at disk velocity 33.25 m/s

4. Conclusion

The 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. The simulations from tri pad slider shown the temperature and the disk velocity have significant effect on both the pressure and the flying height. By increasing the temperature, the pressure is increasing when increased the disk velocity. Therefore, the flying height is changed while the temperature and the disk velocity are changing. The flying height at temperature 300 and 500 degree C is decreasing when increasing the disk velocity. The high temperature and disk velocity are the significant effect on both flying height and pressure also.

5. Nomenclature

F_0	Normalized Load, $F_0 = f_0 / P_a LW$
f_0	Load
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_a	Reference film thickness
h_{tr}	Trailing edge
h_{ld}	Leading edge
K_N	Knudsen number, $K_N = \lambda_a / h_a$
L	Slider length

P	Normalized pressure, $P = p/p_a$
p	Pressure
p_a	Atmosphere pressure
X_G	Normalized support position, $X_G = x_g/L$
x_g	Support position
X, Y	Normalized Cartesian coordinates, $X = x/L$, $Y = y/W$
x, y	Cartesian coordinates
U	Disk velocity
W	Slider width
λ_a	Mean free molecular path of gas, $\lambda_a \approx 64\,nm$
λ	Length-width ratio, $\lambda = L/W$
Λ	Bearing number, $\Lambda = 6\mu_0 UL/p_a h_a^2$
μ_0	Gas viscosity

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