Transient Response of Head Slider with the Head Geometry Change in Magnetic Storage Devices

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Abstract

In this study, the dynamic flying characteristics of the worn head sliders are investigated theoretically due to the change in head geometry caused by head and disk contact. The film shapes can be approximated as taper- truncated cycloidal-flat film. Two-dimensional time dependent modified Reynolds equation included molecular slip effect are formulated with neglected the roughness effect. The motion of head slider was assumed to have two degree of freedom in this work. Finite difference approximation with Newton Raphson iterative technique and the fourth order Runge-Kutta method were implemented to obtain the transient response of the slider head with various change in head geometry numerically and compared with the transient response of the IBM3380 type head slider.

The simulation results show the film shape has affects significantly on the static and dynamic characteristic of slider head in magnetic storage systems.

Keywords: Time dependent Reynolds equation, Runge-Kutta fourth order method, Magnetic head slider, Dynamic characteristic

1. Introduction

In the design of a high performance magnetic head slider needs to keep a very small spacing between the slider and the disk surfaces under both static and dynamic operating conditions in magnetic storage devices. Many research studies on numerical analysis of the performance characteristics of magnetic head and slider in magnetic storage devices have been done for our three decades, for examples Castelli and Pirvics [3], Ono[4], White[5,6], Nishihara et al.[7] and Bogy[8,9]. However, only few papers investigated the effects of geometry change in magnetic head surface on the flying characteristics of slider head. In this paper, the effects of film shapes due to geometry change in magnetic head surface on the flying characteristic of the self-acting taper flat type head were investigated using modified Reynolds equation with molecular slip effects base on Fukui & Kaneko model[1,2]. The IBM 3380 type slider was investigated theoretically.

2. Theoretical analysis

The generalized modified Reynolds equation for analyzing the static air film pressure between head slider and disk surface in magnetic storage systems as shown in Fig. 1 can be expressed as:

$$\frac{\partial}{\partial X}\left(Q\frac{\partial P}{\partial X}\right)+R^2\frac{\partial}{\partial Y}\left(Q\frac{\partial P}{\partial Y}\right)-\lambda\frac{\partial}{\partial X}\left(PH\right)-\sigma\frac{\partial(PH)}{\partial T}=0 \qquad (1)$$

$$Q(P,H)=\phi(P,H)\,PH^3 \qquad (2)$$

$$\lambda=\frac{6\mu UL}{P_a h_m^2} \qquad (3)$$

where $\phi(P,H)$ is the Poiseuille flow factor based on lineraized Boltzmann equation as :

$$\phi(P,H)=a_0+a_1\left(\frac{K_n}{PH}\right)+a_2\left(\frac{K_n}{PH}\right)^2+a_3\left(\frac{K_n}{PH}\right)^3 \qquad (4)$$

The boundary conditions are given as :

$$P(0,Y,T)=P(1,Y,T)=P\left(X,\frac{1}{2},T\right)=P\left(X,-\frac{1}{2},T\right)=1 \qquad (5)$$

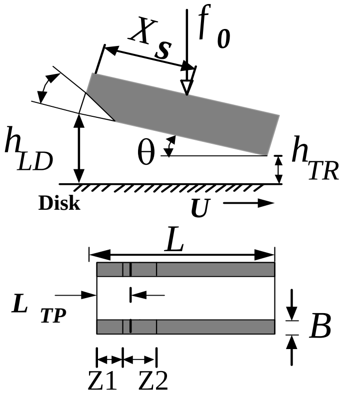

Fig. 1 Analytical model of magnetic head slider

For head slider in dynamic equilibrium condition, the force and moment balance equations can be written as :

$$M\ddot{Z}+F_s=2\int_{-1/2}^{1/2}\int_0^1\left(P-1\right)dXdY \qquad (6)$$

$$I_\theta\ddot{\theta}+M_s-F_S X_{GS}=2\int_{-1/2}^{1/2}\int_0^1\left(P-1\right)\left(X_G-X\right)dXdY \qquad (7)$$

Solving the time dependent modified Reynolds equation (1) and the force and moment balance equations (6) and (7) simultaneously, the dynamic characteristic of the head slider can be calculated. The taper-truncated cycloidal-flat film shape were investigated in this paper and can be written as :

$$h = h_{TR} + (L - L_{TP})\tan\theta + (L_{TP} - X)\tan\theta_{TP}\ ;$$
$$0 \le X \le Z1 \qquad (8)$$

$$h = h_{Z2}\left(1 + 2(\alpha - 1)\left(\left(\frac{(x - Z1)L}{2Z2}\right) - \left(\frac{1}{2\pi}\sin\frac{(x - Z1)L}{2Z2}\right)\right)\right)$$
$$;\ Z1 \le X \le Z2 \qquad (9)$$

$$\alpha = h_{Z1} / h_{Z2}$$
$$h = h_{TR} + (L - X)\tan\theta\ ;\ Z2 \le X \le L \qquad (10)$$

The air film distribution of the IBM3380 type slider and the taper-truncated cycloidal-flat film shape can be calculated from equation 8, 9 and 10 respectively.

3. Results and discussions

In this simulation, the static and dynamic characteristic of head slider with rail width b , taper length L_{TP}, taper angle θ_{TP} , suspension location X_S and suspension preload f_0 are investigated for the taper-truncated cycloidal-flat film shape due to the geometry change in magnetic head surface in magnetic storage device under head and disk contact; $Z1$ = 0.1104 mm, $Z2$ = 0.5152 mm; $Z1$ = 0.1472 mm, $Z2$ = 0.4416 mm and $Z1$ = 0.184 mm, $Z2$ = 0.368 mm.The dimension of the IBM 3380 type slider[1,2] are slider length l =4.06 mm, width w =3.05 mm, taper length L_{TP} =0.38 mm and taper angle θ_{TP} =15 mrad. And the dimension of IBM 3380 type slider is also use for the worn head slider with taper-truncated cycloidal-flat film shape.The taper-truncated cycloidal-flat film shape was calculated for three cases which ; $Z1$ = 0.1104 mm, $Z2$ = 0.5152 mm; $Z1$ = 0.1472 mm, $Z2$ = 0.4416 mm and $Z1$ = 0.184 mm, $Z2$ = 0.368 mm respectively. Fig. 2 through Fig.6 show the variation of spacing at leading and trailing edges, h_{LD} and h_{TR} .

In this study, the transient responses of the magnetic head are simulated to show the magnetic head flying over the bump. The magnetic head has two degree of freedom which are the translation in the vertical direction at the slider spacing, the center of gravity and the pitch angle of the slider head at disk velocities 20 m/s are shown in Fig. 8, 9 and 10 respectively.

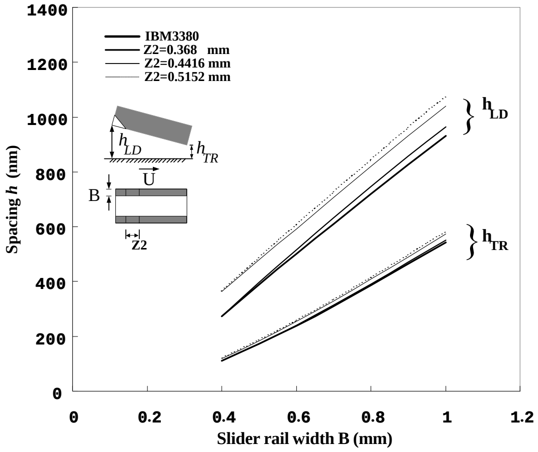

Fig. 2 Variation of spacing with slider rail width

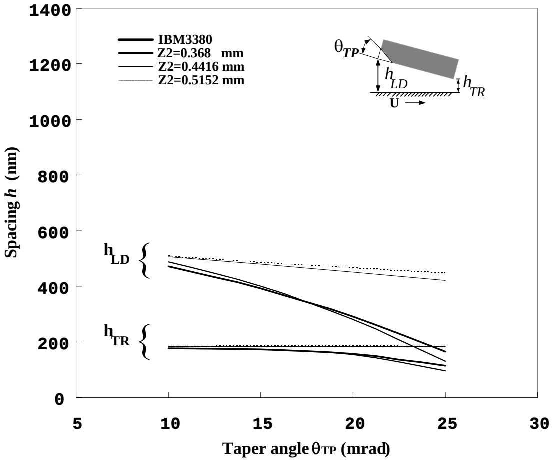

Fig. 3 Variation of spacing with taper angle

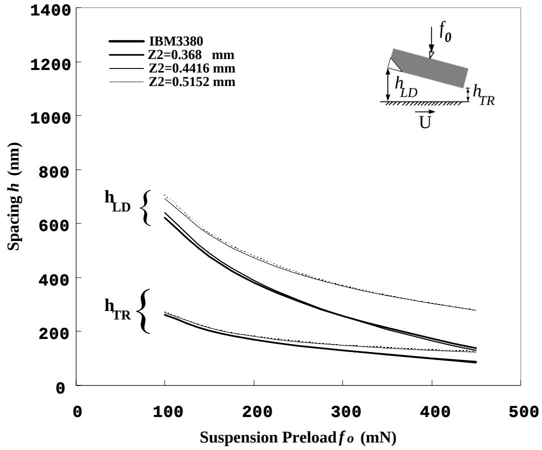

Fig. 4 Variation of spacing with suspension preload

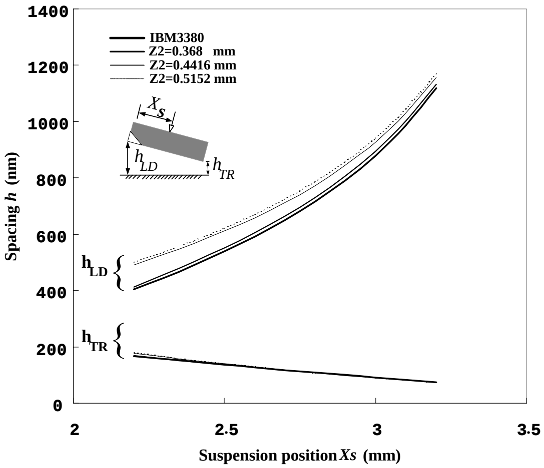

Fig. 5 Variation of spacing with suspension position

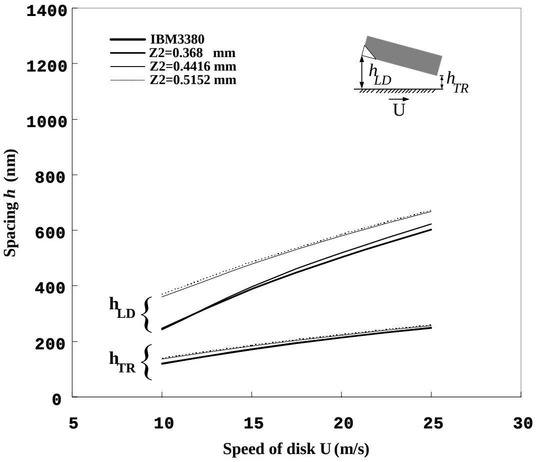

Fig. 6 Variation of spacing with disk velocity

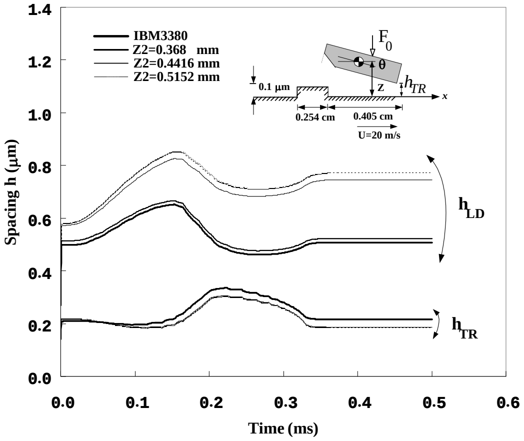

Fig. 7 Transient response of slider spacing

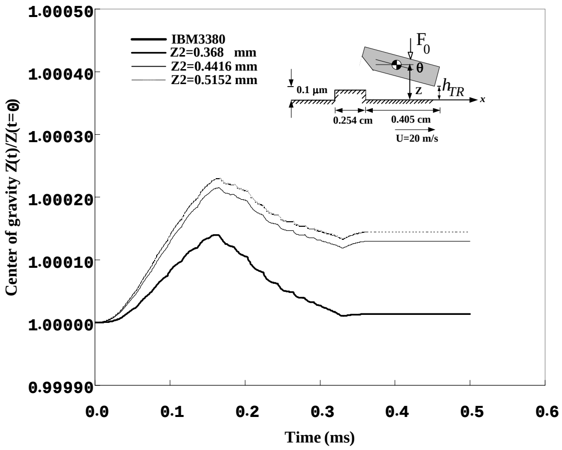

Fig. 8 Transient response of slider spacing

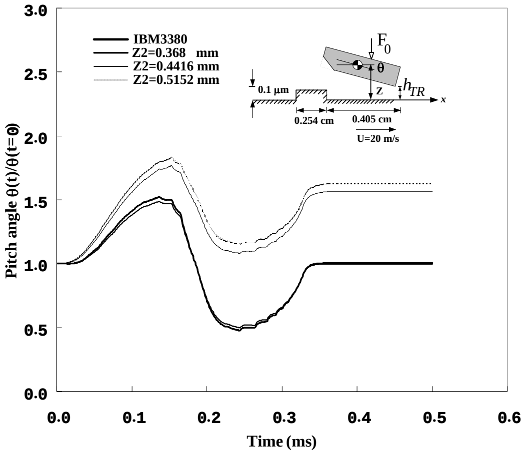

Fig. 9 Transient response of slider spacing

4. Conclusion

In this paper, the transient responses of worn head sliders with taper-truncated cycloidal-flat film shape were investigated theoretically and can be concluded as:

1. The response of spacing at leading edge is significance compared with the spacing at trailing edge for worn head head sliders.
2. The spacing at trailing edge for the worn head reach the steady state value are almost equal to the time required for the response of IBM3380.
3. Time required for the response of the worn head reach the steady state value are almost equal to the time required for the response of IBM3380 head slider within 0.32 milliseconds.

5. Nomenclature

T = normalized time

b = slider rail width (m)

H = normalized spacing $\left(h/h_a\right)$

h_a = reference spacing (m)

h_{LD} = leading edge spacing (m)

h_{TR} = trailing edge spacing (m)

h_{Z1} = film thickness at X=Z1

h_{Z2} = film thickness at X=Z2

K_n = Knudsen number $\left(\lambda_a/h_a\right)$

l = slider length (m)

I_0 = normalized slider moment of inertia about the pitch axis $\left(i_0 h_a\, \omega_0^2 / p_a l^3 B\right)$

M_z = normalized slider mass $\left(m h_a \omega_0^2 / p_a l^2 b\right)$

P = normalized pressure $\left(p/p_{a_0}\right)$

P_a = ambient pressure $\left(Pa\right)$

R = ratio of length to width of the slider

u = velocity of disk surface $\left(r\omega_0\right)\left(m/s\right)$

X_G = normalized location of center of gravity $\left(x_G/l\right)$

M_S = normalized slider moment

F_S = normalized spacing force

X_{GS} = normalized distance between the center of gravity and support position $\left(= x_{GS}\ /\ l\right)$

X_S = normalized location of support position $\left(x_s\ /\ l\right)$

X_{TP} = normalized taper length $\left(x_{TP}\ /\ l\right)$

Z = normalized translational displacement of disk surface $\left(z\ /\ b\right)$

Θ = normalized pitch angle of slider $\left(\theta\, l/h_a\right)$

6. References

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