STUDY OF CONTACT BOUNCING VIBRATION OF FLYING HEAD SLIDER IN NEAR-CONTACT REGIME

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ABSTRACT

We experimentally and analytically investigated detailed characteristics of the bouncing vibrations of a flying head slider in a near-contact regime. In the experiment, we found that the hysteresis of touch-down and take-off pressure and the rate of instability become small as the pitch angle increases. Moreover, we measured the 3-dimensional slider motion by using two laser Doppler vibrometers simultaneously and found that the bouncing vibration is a coupled vibration between translation and pitch with a small phase shift. These experimental features can be explained analytically if we consider strong shear force due to lubricant and small amount of microwaviness for the previous two-degrees of freedom slider model with nonlinear air bearing stiffness.

INTRODUCTION

The areal recording density of hard disk drives has been increased to about 100 Gb/in.$^2$ by reducing the flying height of a head slider to about 10 nm. However, we are confronted with a crucial problem such that a flying slider tends to exhibit bouncing vibration when the spacing is decreased to several nanometers. We have experimentally studied the touch-down and take-off phenomena and frequency characteristics of the bouncing vibration of a commercially available slider by changing the ambient pressure [1]. Then we analytically proved that the bouncing vibration of a slider in near-contact regime is self-excited by the combination effect of an adhesion force and a friction force at the trailing edge of the slider. Since the bouncing vibration occurs in a spacing of more than three nanometers, we attributed the destabilized adhesion force to lubricant meniscus force. On the other hand, J. Xu et al. [2] presented that the bouncing vibration is caused by the contact at the leading edge of the slider. V. Gupta and D.B. Boggy explained touchdown- takeoff hysteresis by negative condition of the elements of stiffness matrix of the slider system.

In this study, we experimentally measured more details of slider bouncing vibrations. First, we examined the effect of the pitch angle on the hysteresis phenomena of slider bouncing vibration by changing Z-height (ZH). Next, we measured the transient slider motion at the threshold of instability at just the touch-down pressure by a laser Doppler vibrometer in order to make clear the cause of an unstable vibration. Then, we measured the 3-dimensional slider behavior by using two laser Doppler vibrometers simultaneously in order to investigate the mode of slider bouncing vibration.

Then we analytically investigated slider bouncing motion by using a two-degree-of-freedom (2-DOF) slider model with nonlinear air bearing stiffness and considering a shearing force of the lubricant and microwaviness in addition to a meniscus adhesion force and friction force.

EXPERIMENTAL STUDY OF CONTACT BOUNCING VIBRATION OF THE SLIDER

The slider tested was a pico slider whose air-bearing surface is shown in Fig. 1. We changed the flying height by changing the ambient pressure, and investigated the bouncing vibration of the slider. The vertical motion of the slider at the positions of A, B, C and D was measured by one or two laser Doppler vibrometers (LDV).

First, we changed the ZH (the distance between the suspension and disk surface). As the ZH becomes large, the pitch angle of the slider increases while accompanying a slight decrease in the trailing edge spacing. Therefore, we can investigate the effect of the pitch angle on the hysteresis phenomena of the slider by changing ZH. Figure 2 shows the change of touch-down pressure ($P_{TD}$) and take-off pressure ($P_{TO}$) as a function of ZH. From Fig. 2, we note that the hysteresis between touchdown and takeoff pressures decreases.
as \( ZH \) increases. This indicates that the touchdown height is mainly influenced by the minimum flying height at the trailing edge and that the takeoff height is affected by the area of air bearing pad where the lubricant meniscus bridge forms; the meniscus bridge area decreases as the pitch angle increases.

Next, we measured the transient slider motion at point A in Fig.1 at the threshold of instability (just the touchdown pressure) by LDV. The motion of the slider at point A in Fig. 1 was measured. Figure 3 shows the typical time history at just the touchdown. In Fig. 3, Figs. (a), (c) and (b), (d) show the cases of \( ZH = +100 \) and \(-100 \, \mu m \) from standard value, respectively. Figure (ii) is the expanded time illustration of the Figs (i) at the beginning of the instability. From Figs. (b) and (d), we note that the trailing edge of the slider is attracted to the disk surface, collides with the disk and bounces, exhibiting a large vibration from the beginning when \( ZH \) is small and pitch angle is small. On the other hand, the vibration of the slider is self-excited and the amplitude grows gradually when \( ZH \) is large and pitch angle is large as shown in Fig. 3(a) and (c). From these results, it is estimated that the bouncing vibration is excited not by the leading edge contact of the slider, but by the attractive force exerted at the trailing edge due to lubricant meniscus force and associated friction force.

Next, we measured the 3-dimensional slider motion by using two LDVs. Figure 4 shows the measured displacement of the slider at points B and C, just before the takeoff pressure. In Fig. 4, we observe a small phase delay between waveforms at B and C. From the measurement of roll motion, we found that the roll motion of the slider is negligibly small.

**COMPARISON OF SIMULATION AND EXPERIMENT ABOUT HEAD/DISK DYNAMIC CONTACT BEHAVIOR**

In the analysis, we used a 2-DOD slider model with nonlinear air-bearing stiffness considering an adhesion force and viscous friction of the lubricant. The analytical results show the phase delay between displacements of trailing edge and center of mass in the time history as shown in Fig.4. Figure 5 shows the calculated transient motion of the trailing edge at the threshold of instability when viscous friction force of 50mN is taken into account in addition to the attractive force of \( f_m = 10 \) mN (Fig.(a)) and 20 mN (Fig.(b)). We note that the theoretical results in Fig. 5 correlate well with the experimental results in Fig. 3. From these results, it can be said that the validity of our theoretical analysis is confirmed.

**SUMMARY**

Detailed features of bouncing vibration were measured. By using improved 2-DOF slider model, these features of bouncing vibration can be obtained theoretically.

**REFERENCES**