Effects of Surface Energy of Thin Film Lubricant on Dynamics of a Contact Recording Head

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***Abstract*--Dynamic characteristics of a tri-pad contact recording head were analyzed considering the surface energy of thin liquid film lubricant. The head-suspension assembly was described in terms of three-degrees-of-freedom (3-DOF) model. The configuration of the contact pad, the lubricant and the disk surface was classified into four regimes, and the equations of motion for each regime considering the meniscus force and the contact force were solved. It was found that (i)there is an optimum surface energy for the perfect contact condition and (ii)the surface energy has significant effects on the dynamics of the contact slider.**

***Index Terms*--Contact slider, Surface energy, Meniscus force, 3-degrees-of-freedom model**

I. INTRODUCTION

RECORDING density of hard disk drives (HDD) becomes larger to meet the demand of larger capacity. There are several technical issues to be improved for the larger recording density, and especially the reduction of the spacing between a head and a disk surface is considered the most important. As a substitute for the flying head system, the contact head slider/disk interface (HDI) system has been proposed [1], [2].

In this study, we make a computer simulation for the contact slider motion where a three-degrees-of-freedom (3-DOF) model of a head-suspension assembly is introduced. The effects of meniscus force due to the meniscus bridge and the contact force between the slider and the disk are considered. The dynamic characteristics and design criteria of an in-contact head slider are discussed considering both bouncing vibration and wear durability.

II. THREE-DEGREES-OF-FREEDOM MODEL

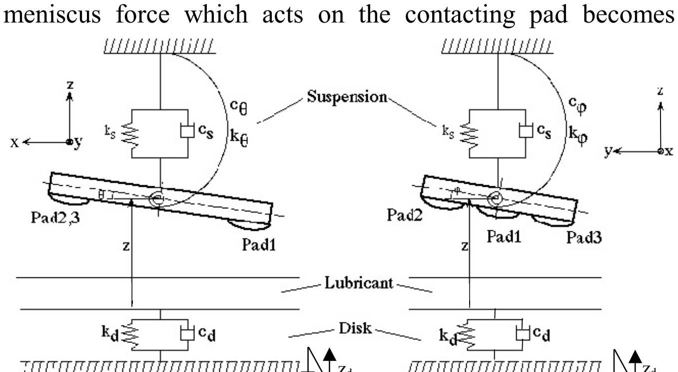
A tri-pad slider is considered in this study and the model of the head-suspension assembly is shown in Fig. 1. The axes, z, θ and φ represent bouncing, pitching, and rolling directions, respectively. The axes x and y represent the sliding and the seeking directions of the head slider, respectively. The head slider-suspension assembly has a spring and a damper structure in each direction, and the disk is assumed to be a flexible body characterized with a linear spring and a damper. The equations of motion are obtained for three directions, *i.e.*, z, θ and φ. The equations of motion and the values of the parameters are not presented here because those are written in Ref. [3] in detail.

The configuration of a pad, lubricant, and disk surface is classified into four regimes. The equations of motion with respect to each regime considering the meniscus force and the contact force are solved by the Runge-Kutta-Gill method.

III. RESULTS FOR SINUSOIDAL UNDULATION AND OPTIMUM SURFACE ENERGY OF LUBRICANT FOR PERFECT CONTACT CONDITION

In the case of the sinusoidal undulation, the contact head bounces when the frequency of the sinusoidal undulation becomes large [3], [4]. Here, the following parameters are introduced as indices of followability and wear durability; (i)critical frequency of bouncing, f_{cb}: the undulation frequency at which the pad begins to bounce, (ii)critical frequency of pressure, f_{cp}: the undulation frequency at which the contact pressure begins to exceed the allowable nominal contact pressure of the material, *i.e.*, 40 MPa [4].

Figure 2 shows the change of the both critical frequencies, f_{cb}, f_{cp}, for the surface energy of the thin film lubricant. It is found that the critical frequency of bounce, f_{cb}, increases while the critical frequency of pressure, f_{cp}, decreases according to increase in the surface energy. This is because the attractive meniscus force which acts on the contacting pad becomes



(a) Side view (b) Front view

Fig. 1. Three-degrees-of-freedom model of a head-suspension assembly.

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larger when the surface energy is higher. Four regions are seen in Fig. 2 and the state in each region is the followings: (I)no bounce and no wear, (II)bounce but no wear, (III)no bounce but wear, (IV)bounce and wear. The region (I) indicates safety design region for perfect contact condition. It is found that there exists an optimum surface energy in the region (I) at which the critical frequency becomes the highest. The optimum surface energy γ_{opt} in the present case is found to be $\gamma_{opt} \approx 25$ mJ/m^2. The surface energy of PFPE diol, is measured to be about 24 mJ/m^2, which is close to the value of the optimum surface energy obtained in this study.

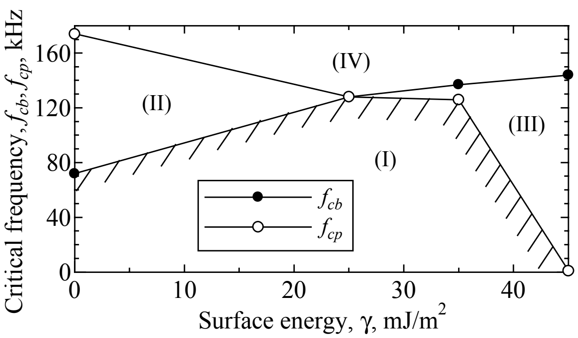

Fig. 2. Change of the critical frequency of bounce, f_{cb}, and the critical frequency of pressure, f_{cp}, for the surface energy of the lubricant.

IV. Results for Random Undulation and Multiple Regression Coefficients

The random undulation is generated by the moving average method [5] which has two parameters, *i.e.*, RMS value of amplitude and nondimensional correlation length, λ^*.

The relation between the nondimensional correlation length, λ^*, and the maximum bouncing height of the trailing pad, Z_{1max}, is shown in Fig. 3. Negative values of Z_{1max} indicate perfect contact condition. The nondimensional correlation length, λ^*, means the inverse of the undulation frequency, f, and small λ^* gives minute undulation. As shown in Fig. 3, therefore, the maximum bouncing height, Z_{1max}, becomes large according to decrease in λ^*. It is found that the maximum bouncing height, Z_{1max}, becomes relatively small according to increase in the surface energy of lubricant, γ, because the attractive force by the liquid meniscus increases.

The multiple regression was carried out with respect to the bouncing height and contact pressure in order to investigate the effects of each parameter. The absolute values of the

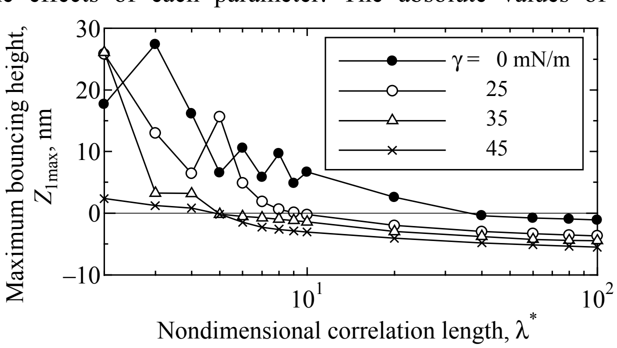

Fig. 3. Maximum bouncing height of the trailing pad for the nondimensional correlation length varying the surface energy of lubricant.

multiple regression coefficients are shown in Fig. 4, in which the bright bars and the dark bars show the coefficients with respect to the maximum bouncing height and the contact pressure, respectively. Note that the coefficients are normalized by the maximum value. It is found that the RMS value of the undulation amplitude influences the maximum bouncing height the most significantly and the next is the surface energy. In the case of the contact pressure, the surface energy has the most significant effect. Therefore, it is very important to take the surface energy of lubricant into account in order to design the contact HDI system.

V. Summary

Dynamic characteristics of a tri-pad contact recording head over sinusoidal and random undulation disk surface were analyzed considering the surface energy of thin liquid film lubricant. It was found that (i)there is an optimum surface energy for the perfect contact condition and (ii)the surface energy has significant effects on the dynamics of the contact slider.

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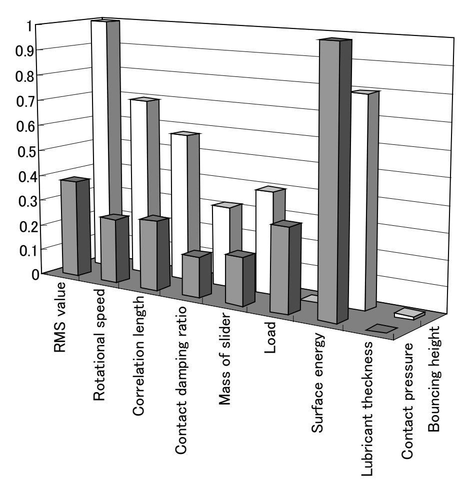

Fig. 4. Absolute values of the multiple regression coefficients which are normalized by the maximum value.