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플라스틱 디스크상의 부상형 광헤드의 부상안정성에 관한 연구

A Study on the Flying Stability of Optical Flying Head on the Plastic Disks

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Key words: Optical flying head(OFH: 부상형 광헤드), Plastic disk(플라스틱 디스크), Slider(슬라이더), Air bearing surface(ABS:공기베어링표면), Flying stability(부상안정성), Load/unload(로드/언로드)

ABSTRACT

착탈식의 플라스틱 디스크와 부상형광헤드를 사용하는 광드라이브에서 부상형 광헤드의 부상안정성 문제는 고밀도 표면기록의 신뢰성확보를 위해 매우 중요한 요소로 고려되어야 한다. 플라스틱 디스크와 광헤드의 포커싱 제어를 위해 부상형광헤드의 광학적 조립오차와 플라스틱디스크의 보호층의 오차를 보상해주는 추가적인 엑츄에이터의 몇 가지 설계방안에 대해 검토한다. 또한 본 논문에서는 부상형 광헤드의 부상안정성을 위하여 디스크의 굴곡에 대한 부상특성과 안정성을 해석하고, 특히 로드/언로드 시의 부상안정성에 대해서도 검토해 본다.

In the optical drive system, adopting the optical flying-type head (OFH) flying on a removable plastic disk, the flying stability of the small OFH should be carefully considered to ensure the reliability for first surface recording. Additional micro actuators for focus servo are discussed for better interface of optical flying head on thin cover layered plastic disk to eliminate focus error due to the non–uniformity of cover layer thickness and the tolerance of lens assembly. This study gives two simulation results on the flying stability of the OFH. One is the dependence of the flying height and pitch angle variations on the wavelength and amplitude of disk waviness. The other is the flying stability of the slider and suspension system during the dynamic load/unload (U/UL) process.

I. INTRODUCTION

Recently, the optical disk drives using various types of an OFH system have been studied. The OFH unit on a small form factor plastic disk have been developed by Kim et al.[1-2]. The OFH technology on a thin cover layered plastic disk requires not only uniformity of the cover layer thickness of the disk media and precise mechanical tolerance in the OFH assembly, but also the flying stability of the OFH on the plastic disk surface with low flying variation. Therefore we study the characteristics of flying stability related with various disk parameters, such as the disk waviness and flutters. In general, a dynamic load/unload mechanism is adopted to improve the reliability of the optical drive using the OFH. The loading and unloading motions should be carefully controlled to avoid the possibility of contact and permanent damage. In this study, a ramp loading mechanism is considered to ensure the reliability of the OFH during load/unload operation. To achieve stable flying characteristics on the L/UL mechanism, an optimal design of the OFH is carried out based on previous design methods[3-5].

II. FLYING STABILITY VARIATION

A. Focus actuator design

In case of the OFH with high NA objective lens interfaced with a cover layered plastic disk, additional focusing actuator is needed to focus a laser beam exactly onto the recording layer due to various focusing errors as shown in Fig.1. In general, the types of actuators depend on design requirements of servo bandwidth and geometrical layout such as total drive height limitation. Based on the location of actuator, three different designs of actuators such as "A", "B" and "C" are shown in Fig. 2.

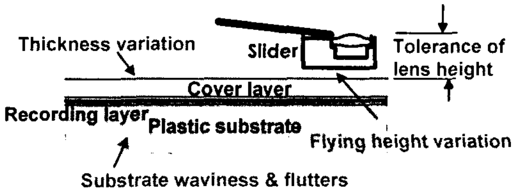

Fig. 1 Various focusing errors in the optical flying head system interfaced with a plastic disk

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Design "A" is an integrated actuator inside the slider for actuating objective lens fabricated by micro machining technology. The design model is required to reduce the size of actuator within the volume of the slider, but small and robust actuator should be precisely equipped inside the slider for actuating objective lens. Design "B" actuates a collimator instead of objective lens and has more flexible room for designing the shape and size of actuator. Design "C" allows a relatively large actuator that can move a collimator, but the servo bandwidth for tracking is limited by the increased inertia of the actuator.

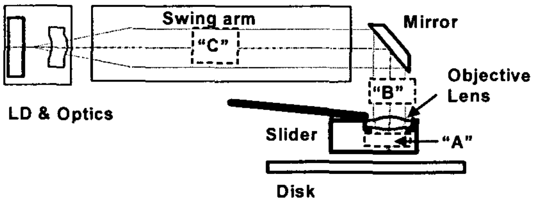


Fig. 2 Schematic of different locations of actuator in the swing arm type optical pickup head

B. ABS(Air Bearing Surface) optimization

To achieve stable flying characteristics on a plastic disk and L/UL mechanism, we have developed a new optical flying head system. The optimized air bearing surface (ABS) configuration of the OFH is shown in Fig. 3. The dynamic characteristics of the optimized model are numerically investigated when the parameters of disk waviness are changed. Figure 4 shows the variation gain, which is an amplitude ratio of the flying height modulation (FHM) over the disk amplitude, with respect to the wavelength of the disk waviness. The amplitude of the waviness is ±100 nm and the wavelength varies from 0.1 times the slider length to 10 times. The simulation result of the original model before the optimal process shows that the flying variation gain rapidly increases as wavelength approaches the slider length. However, the simulation result using the optimal design model shows more stable flying motion than the original one over all disk wavelengths (Fig. 4). It is noted that the FHM of both sliders can be larger than the amplitude of the disk waviness when the wavelength is less than the slider length.

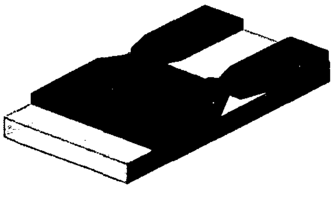


Fig. 3 An optimized ABS design of the OFH[1]

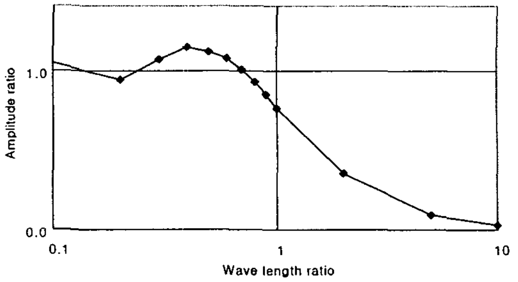
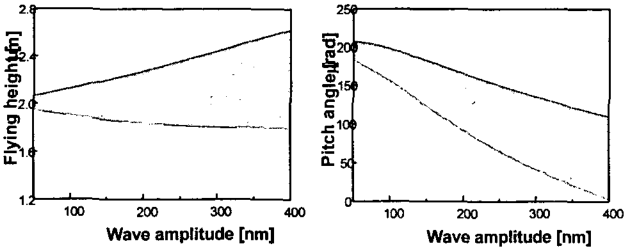


Fig. 4 Flying stability on disk waviness[2]

C. Flying stability due to various disk parameters

To obtain high stability on flying height, it is important to achieve a high air-bearing stiffness and to reduce the flying height fluctuation. Kim et al. [2] investigated that the FHM can be larger than the amplitude of the disk waviness when the wavelength is less than the slider length. The wavelength of the plastic disk should be larger than around 2 mm in order to keep the variation of flying height within 2±0.1 μm, as shown in Fig. 5. Here, its dark area represents the variations of the flying height and pitch angle with respect to the wave amplitude. The flying height variation of the slider linearly increases in proportion to the wave amplitude while the mean value slightly increases. However, its pitch angle shows the opposite trend. The slider is likely to have negative pitch motion at large wave amplitudes.

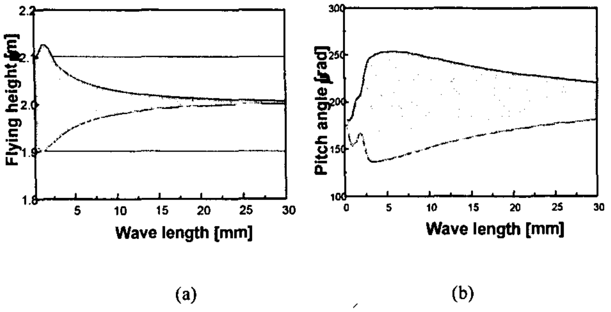


(a)

(b)

Fig. 5 Flying stability with respect to wave amplitude :
(a) Flying height , (b) Pitch angle

As shown in Fig. 6, the variation of pitch angle considerably increases with increasing wavelength, although the variation of flying height is reduced. There exists a specific value of wavelength to maximize the flying height and pitch angle. On the other hand, the effect of the rotational speed of the disk on the flying stability is evaluated. Both the flying height and the pitch angle increase in proportion to the rotational speed. However, the magnitude of the variation is nearly uniform.

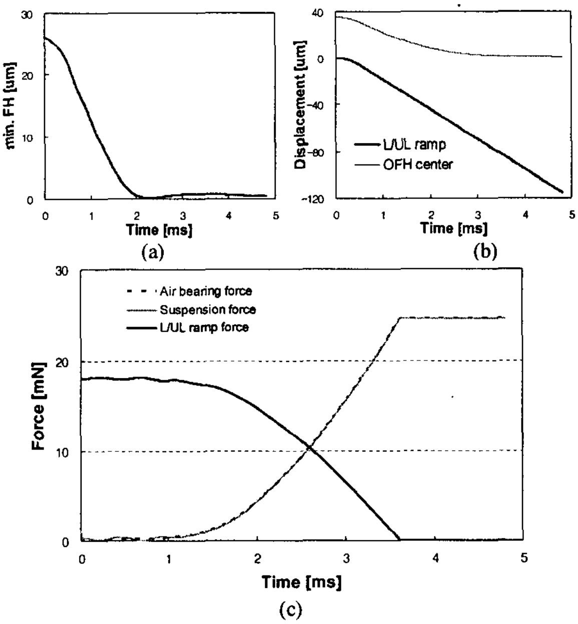


(a) (b)

Fig. 6 Flying stability with respect to wave length: (a) Flying height , (b) Pitch angle

D. Flying stability on L/UL applications

The L/UL mechanism, which has been employed for achieving better shock resistance and lower power consumption, is also necessary in portable and removable disk drives. To investigate the flying stability of slider and suspension during the L/UL process, the dynamic L/UL simulation is implemented, based on Zeng and Bogy[6], where the suspension is modeled as a 4-DOFs system.

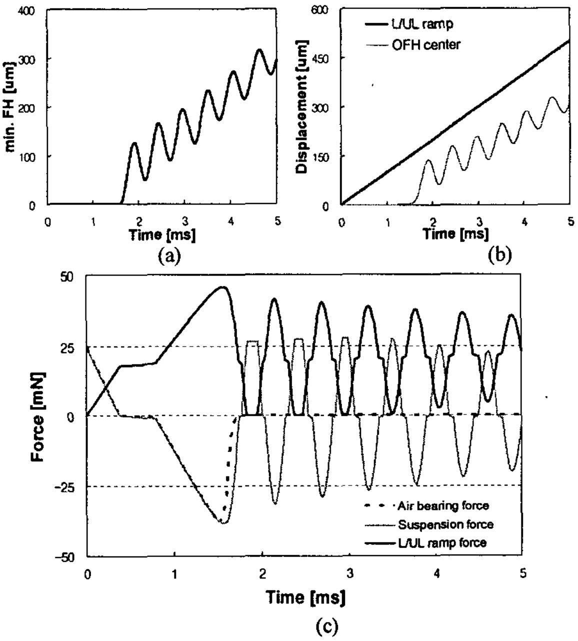


(a) (b)

(c)

Fig. 7 Flying stability during the loading process: (a) minimum flying height, (b) displacements, (c) forces

For the loading process, the displacement and force histories are shown in Fig. 7. These results show that the OFH incorporated with the suspension is smoothly loaded onto the rotating disk. Fig. 7(a) shows the minimum of flying heights have positive values during the loading process. This means the OFH doesn't contact the disk. It is noted that the relatively high flying height of the OFH reduces the effects of the suction force in the loading process. Figure 7(b) plots the displacement profiles of the L/UL ramp and the center of the OFH. Both displacements of the ramp and the OFH linearly decrease at the initial loading stage, but the air bearing force starts to affect and the OFH profile becomes different about 1 ms. In Fig. 7(c), the suspension force is nearly identical with the air bearing force and the L/UL force applied by the ramp runs against the air bearing and the suspension forces during the loading process. The loading process is finished within about 3.6 ms, and then the OFH gradually settles down.



(a) (b)

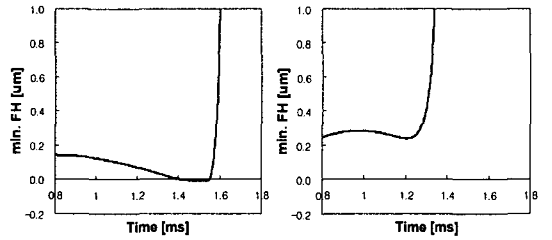
(c)

Fig. 8 Flying stability during the unloading process: (a) minimum flying height, (b) displacements, (c) forces

On the other hand, Fig. 8 shows the effects of the unloading process on the flying stability. The unloading results show that the average of the OFH motion follows the ramp profile, but a relatively large oscillation occurs during the unloading motion. Figure 8(c) shows that a large lift-off force also occurs during the unloading process, which can lengthen the settling time of the unloading process as well as the slider oscillation. From about 0.8 to 1.5 ms, the dimple is open and the limiter is closed. The air bearing quickly disappears between 1.5 and 1.7 ms. The unloading process is finished in only about 2 ms by employing the suspension limiter. Therefore, the optimal design to reduce the lift-off force is strongly desired to improve the unloading performance of the OFH.

From Fig. 8(a), it seems that there is a slider/disk contact during the unloading process. In order to check the possible contract, we zoom the plot around 1 ms. Fig. 9(a) shows that the minimum flying height over the air bearing surface has a negative value at about 1.5 ms, confirming the occurrence of a slider/disk contact. The contact phenomenon seems to be due to large inertia effects of the OFH, as well as high squeeze effects of the air bearing. However, our simulation is performed at a low rotational speed of only 1800 rpm. If the rotational speed of the disk increases, the OFH can be smoothly unloaded without a head/disk contact. The simulation result at 3600 rpm is plotted in Fig. 9(b).

Further parameter studies show that the slider motion during load/unload is very sensitive to the initial conditions in the pitch direction and loading/unloading velocity. Using the U/UL simulation model, we can determine the optimized parameters to meet design requirements and show stable and robust performances.



(a) (b)

Fig. 9 *Investigation of slider/disk contact: (a) 1800 rpm* (current), (b) 3600 rpm

III. SUMMARY AND CONCLUSIONS

In high NA pickup system interfaced with a cover-layered plastic disk, the flying height variation between the OFH and the recording layer of disk media should be carefully compensated for first surface recording. In the optical disk drive using the OFH and a flexible plastic disk, the shape optimization of slider is very helpful to obtain stable flying stability with respect to the critical disk parameters such as disk waviness and flutter. The variations of flying height and pitch angle of the slider linearly increase in proportion to the amplitude of disk waviness. However, both variations are reduced with increasing the wavelength of disk waviness.

For mechanical reliability during load/unload operation, the flying stability of the OFH during the L/UL process is investigated by dynamic L/UL simulation. The optimal design is strongly required to avoid the unwanted contact of slider/disk and reduce the lift-off force in order to improve the unloading performance of the OFH.

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