INFLUENCE OF SLIDER AIR-BEARING DESIGN ON DISK EFFECTIVE TAKE-OFF HEIGHT

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ABSTRACT

The disk take-off height (or glide avalanche) is a commonly used property of the disk in disk drives. Typically, the take-off height is defined as a pure disk property, influenced by the disk surface morphology and topography. However, at increasingly low slider flying heights, the take-off height also is strongly coupled with the slider air-bearing design. The flying height at which the interference exceeds a certain threshold is called the effective take-off height of the head-disk interface. We have determined that, the width of the slider trailing edge and slider dynamic pitch have a strong influence on the effective take-off height. We show that the head-disk durability is directly proportional to the effective take-off height. Therefore, the effective take-off height must be considered as one of the critical parameters in designing reliable disk drives.

1. INTRODUCTION

It is well known that the slider flying height in hard disk drives (HDDs) has been decreasing exponentially with the areal density. This is a direct consequence of the relationship between the read-back signal amplitude and the linear recording density. The Wallace spacing loss portrays this relationship in a simple form:

\[ A_d / A_r = \exp(-2\pi (d - d')/\lambda) \]

(1)

where \( A_d \) and \( A_r \) are the read-back amplitudes when the magnetic spacing is \( d \) and \( d' \) respectively. The signal wavelength (sinusoid signal is required) is \( \lambda \).

The development of higher HDD capacities and hence, higher linear densities, have resulted in slider flying heights that are currently below 10 nm. At these flying heights the disk take-off height is not solely a function of the disk morphology and surface properties. In fact, the effective disk take-off height will now be defined as the flying height for a given air-bearing surface (ABS) design where the interference between slider and disk becomes significant. Significant interference between slider and disk can result in air-bearing flying height modulation including bouncing of the slider on the disk, or in off-track motion. If these conditions can be avoided by the design of the head-disk interface, the effective take-off height can be defined as the plane below which the slider flying height cannot be reduced. The latter case also describes the disk effective take-off height in case of contact recording.

2. MEASUREMENTS

Head-disk interface clearance and durability are measured with distinctly different techniques. The head-disk clearance (and therefore the effective take-off height) is measured quantitatively. The interface durability is qualitatively measured through accelerated testing.

2.1 Effective take-off height

Based on the Wallace spacing loss, the change in the spacing in a magnetic recording interface can be quantified. This method requires instrumentation that allows measuring the change in amplitude with changing spacing. The effective take-off height is then defined as the difference between the slider flying height at starting conditions and before significant head-disk interaction occurs.

For the ABS designs in this study, adjusting the ambient pressure is an effective method to change the flying height while keeping the recorded wavelength, \( \lambda \), constant. The change in spacing is measured in an HDD by monitoring the change in the read-back amplitude, which translates directly into a quantifiable change in the flying height.

2.2 Durability

The durability of a head-disk interface is difficult to quantify. Qualitative differences reveal themselves easily through stress testing. In our stress tests, low flying sliders are kept on a single track until interface failure is observed through monitoring the acoustic emission. It is important to keep in mind that many interface properties influence this measure of durability (e.g. disk roughness, lubricant, humidity, etc). However,
relative comparisons of different ABS designs can be made by keeping these factors constant.

3. RESULTS

Two different ABS designs were used to demonstrate the importance of the design on the effective take-off height and the durability of the head-disk interface. Both ABS designs have a nominal flying height of 7 nm. The only difference pertinent to this study is the dynamic pitch. The dynamic pitch is defined as the angle between the disk plane and the ABS surface of the flying slider at ambient conditions.

3.1 Effective Take-off Height

As stated before, the effective take-off height is the difference between the slider flying height and the head-disk clearance. The sliders in the HDDs fly at about 7 nm as measured by flying height tester before the HDDs were assembled.

Figure 1 shows the flying height change for 8 heads built into drives of the same model with the same type of disks. When the pressure is reduced from 1 atm, the sliders gradually lose flying height. At about 0.6 atm, the sliders suddenly seem to increase in flying height. This is the point where the slider comes into significant contact with the disk. This point defines the effective take-off height of the head-disk interface. Averaging over the slight differences between the individual sliders (8 each), the clearance is about 2 and 4 nm for the lower and higher dynamic pitch designs, respectively. Therefore, the effective take-off height for the lower pitch design is 5 nm, while it is 3 nm for the higher pitch design.

3.2 Durability

Figure 1 also shows that the pressure sensitivity of these ABS designs is not identical. The lower pitch design drops less in altitude than the higher pitch design. Therefore, the stress-testing is performed under ambient conditions. Sliders with comparable and very low flying heights were selected. Time to failure in Fig. 2 is defined as the time where acoustic emission indicates interface failure, i.e. head crash.

The failure for the lower pitch design occurs after less than 100 minutes. The higher pitch design does not show failure in the allowed testing time.

3. CONCLUSIONS

Two different ABS designs are compared. Quantitatively, the higher pitch design has a significantly lower effective take-off height. Qualitatively, the higher pitch design shows much higher durability. The improved performance is due to the proportional decrease in the contact area between the slider and disk at the same spacing. Therefore, the slider "sees" the disk take-off height later, and at the same flying height, much less frictional energy is dissipated in the interface, translating in significant durability gains.