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Investigation of Head-Disk Interactions at Ultra-low Flying HDI

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Abstract: In this work, head-disk interactions are studied when flying height becomes lower than laser bump height on the landing zone of a disk. With the reduction of the spinning speed in a spin stand, the flying height is decreased under the height of laser bumps. Conventional and padded pico sliders sweep between landing zone and data zone and, then, the dynamic behavior of the pico sliders and head-disk impacts are investigated using AE and stiction/friction signals. After 20000 cycle-sweep tests, bearing analysis and AFM analysis indicate that there are some signs of wear and plastic deformation in the landing zone of a disk, although AE and stiction/friction signals are not significantly changed during the sweep tests. The experimental results of this paper suggest that in CSS tests at component level, more rigorous examination methods of wear and plastic deformation might be necessary as flying height becomes getting lower.

Key words: Head-disk interface, flying height, laser bump, contact stat-stop (CSS), hard disk drive

Introduction

Magnetic hard disk drive is continually being pushed to reduce magnetic spacing for higher recording densities. In contact start-stop (CSS), a slider has been designed to fly above laser bumps in a laser textured disk. The demand for lowering flying height requires a continuous decrease in laser bump height of a laser textured disk. On the other hand, further decrease in the bump height could lead to stiction problem [1-3]. This paper suggests an alternative approach of contact start-stop (CSS) for further reduction of magnetic spacing. At present, the sum of laser bump height and flying height above laser bumps is on the order of a few nm. If a slider could fly below laser bumps, magnetic head-disk spacing would be reduced as much as some portion of laser bump height in addition to flying height above laser bumps.

In this work, it is investigated if flying height could be lowered under the height of laser bumps [4]. This study is the preliminary investigation with emphasis on identifying interactions and degradation in head-disk interface during head-disk contacts at flying heights under laser bump height. With the reduction of the spinning speed, the flying height is decreased under the height of laser bumps. When conventional and padded pico sliders sweep between laser textured zone and data zone, head-disk contacts are monitored using AE and friction signals. After sweep tests of 20000 cycles, disks are examined with bearing analysis and AFM. Friction and AE signals of contact-start tests are monitored to investigate the effect of head-disk contacts on the performance of CSS tests at component level.

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Experiments

Fig. 1 shows a spin stand that measures stiction/friction and AE-rms during CSS tests at flying height under laser bump height. Conventional and padded pico sliders of 1 mm × 1.235 mm × 0.305 mm are used. On the data zone of disk A and B, surface roughnesses are 6.5 ± 2.0 Å, 5.5 ± 2.0 Å and at the landing zone, laser bump heights are 165 ± 20 Å, 115 ± 20 Å. The test pairs are a conventional pico slider on disk A, and a padded pico slider on disk B.

All the CSS tests are performed at temperature of 25 ± 3°C and relative humidity of 50% in a clean room of class 1000. Two kinds of CSS tests are carried out at flying height under laser bump height. First, in the seek tests, interactions between a slider and a disk are investigated based on stiction/friction and AE-rms signals. Second, in sweep tests, effects of head disk impacts on CSS tests at component level are studied.

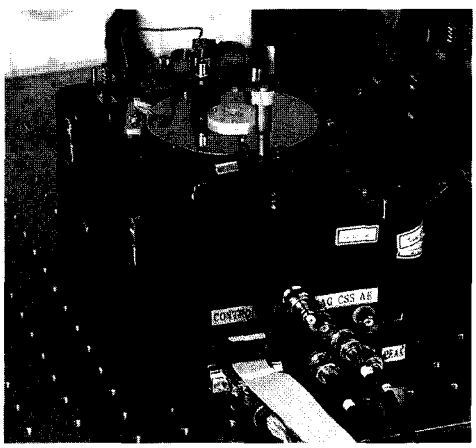
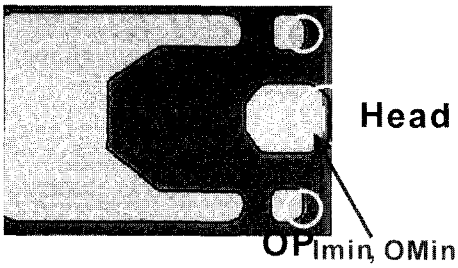
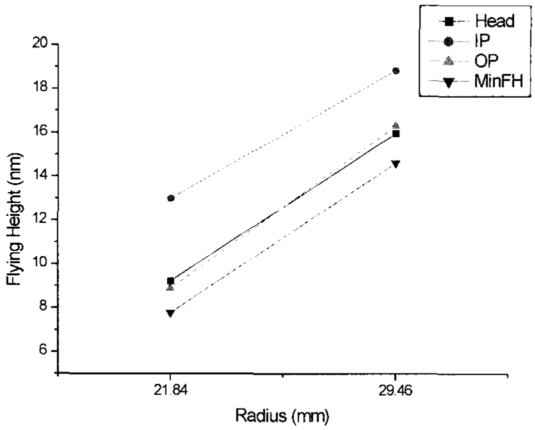


Fig. 1. Contact start-stop (CSS) tester at component level.

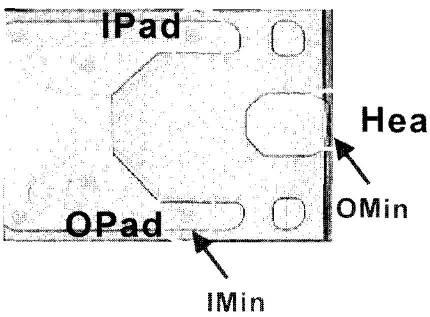


(a)

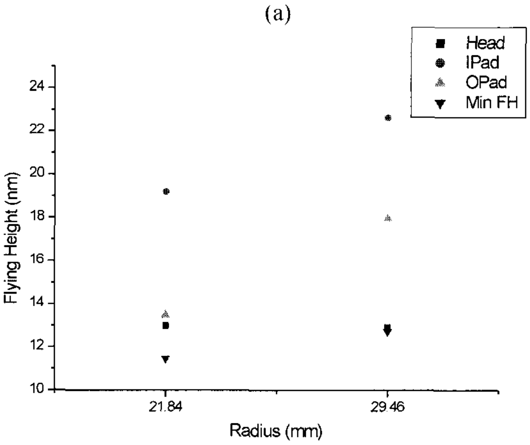


(b)

Fig. 2. (a) Head, IP, OP, IMin, OMin and (b) flying heights of a conventional pico slider.



(a)



(b)

Fig. 3. (a) Head, IPad, OPad, IMin, OMin and (b) flying heights of a padded pico slider.

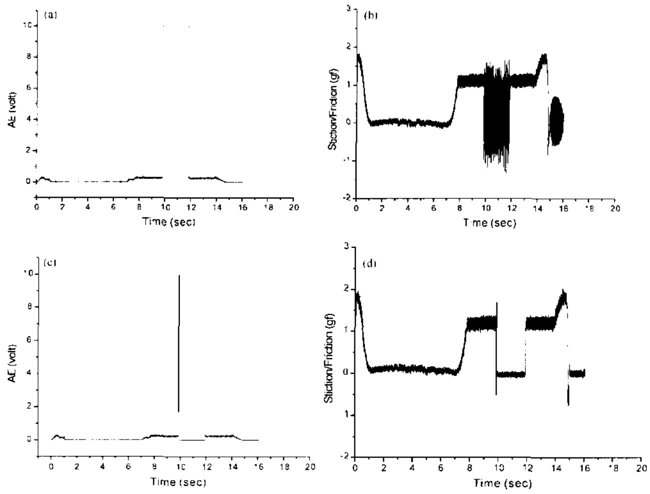


Fig. 4. AE and stiction/friction signals in the seek tests of 2.54 mm stroke (a), (b) and 10.16 mm stroke (c), (d) for the conventional pico slider and disk A.

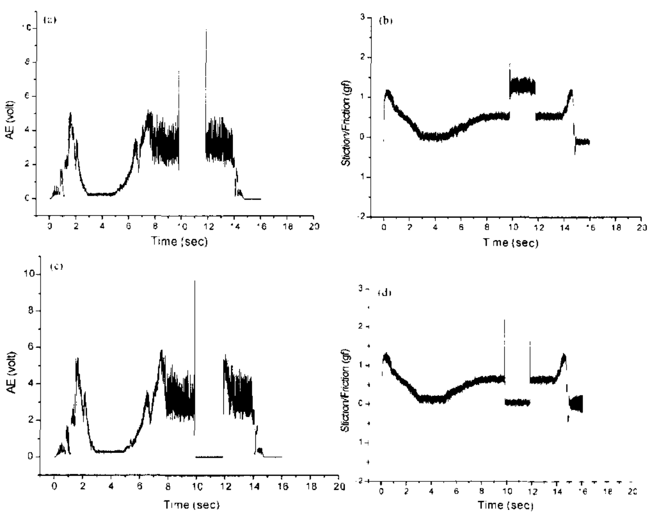


Fig. 5. AE and stiction/friction signals in the seek tests of 2.54 mm stroke (a), (b) and 10.16 mm stroke (c), (d) for the padded pico slider and disk B.

At seek tests and sweep tests, flying height should be lowered than laser bump height on the data zone of a disk. From ABS simulation, it is found that flying heights of conventional and padded pico sliders become lower than laser bump height at 900 rpm and 2700 rpm, as shown in Fig. 2 and 3.

The sequence of a seek test is 3 sec-acceleration until 5400 rpm, 2 sec-dwell, 3 sec-deceleration until 900 rpm or 2700 rpm, 2 sec-dwell, seek to data zone for 2.54 mm or 10.16 mm, 2 sec-dwell, seek to landing zone for 2.54 mm or 10.16 mm, 2 sec-dwell, 1 sec-deceleration and 1 sec-dwell. The sequence of a sweep test is 3 sec-acceleration until 5400 rpm, 1 sec-dwell, 3 sec-deceleration until 900 rpm or 2700 rpm, 2 sec-dwell, 20000 cycle-sweep between disk radius 19.3 mm and 21.8 mm at 15 Hz or 45 Hz, 7 sec-deceleration and 1 sec-dwell. Before

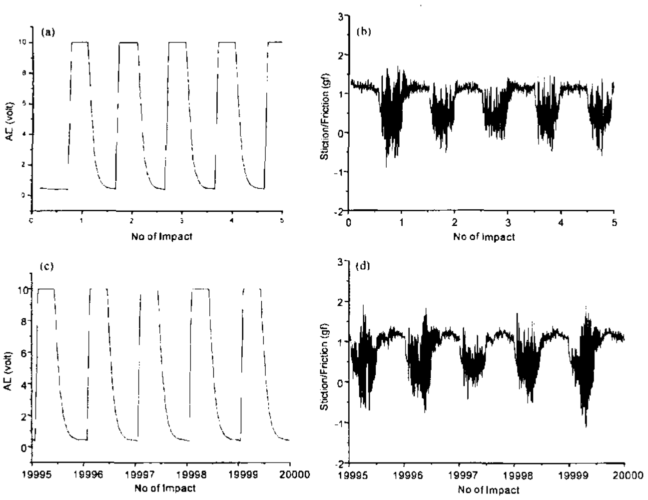


Fig. 6. AE and stiction/friction signals in the beginning and ending cycles of the 20000 cycle-sweep test of 2.54 mm stroke for the conventional pico slider and disk A.

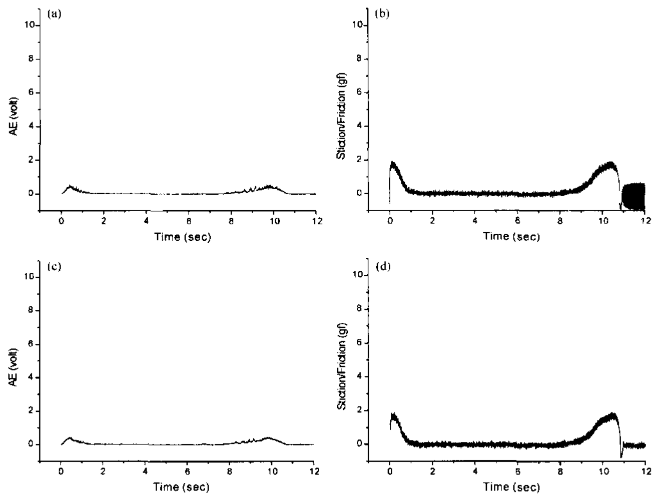


Fig. 8. AE and stiction/friction signals versus time during contact start/stop before and after the 20000 cycle-sweep test for the conventional pico slider on disk A.

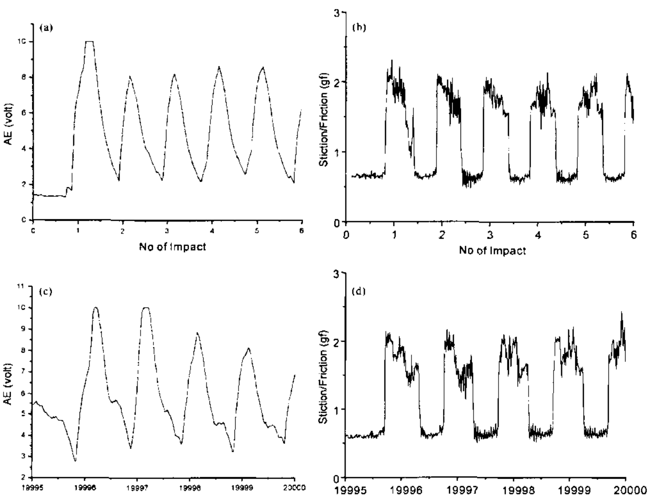


Fig. 7. AE and stiction/friction signals in the beginning and ending cycles of the 20000 cycle-sweep test of 2.54 mm stroke for the padded pico slider and disk B.

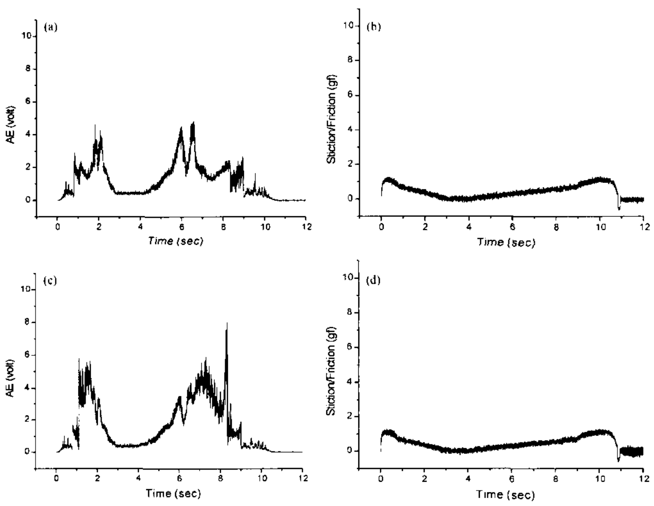


Fig. 9. AE and stiction/friction signals versus time during contact start/stop before and after the 20000 cycle-sweep test for the padded pico slider on disk B.

and after the sweep tests, CSS tests of 3 sec-acceleration, 1 sec-dwell, 7 sec-deceleration, 1 sec-stop are carried out to examine the effect of 20000 cycle-sweep tests on characteristics of CSS tests at component level.

Results and Discussions

Fig. 4 and 5 show AE and stiction/friction signals during the seek tests of 2.54 mm and 10.16 mm strokes. It is observed that there are dings, *i.e.* head disk interactions, when pico sliders move over the transition region of landing zone and data zone of a disk. During dwell procedure at the data zone, pico sliders contacts disks for the 2.54 mm-stroke seek, but for the 10.16 mm-stroke seek, there is no contact between pico sliders and disks. The reason could be flying height at the outer diameter of a disk is higher. Fig. 4 shows that the contact of a conventional pico slider and landing zone of disk A is stable and friction is low due to the reduction of stiction by laser bumps on landing zone. The contact of the pico slider and the data zone of disk A shows stick-slip process. In Fig. 5, the contact of a padded slider and landing zone of disk B shows relatively low stiction/friction due to reduction of contact area by micro-pads on the pico slider surface as well as minor fluctuating behavior caused by continuous hits between the micro-pads and laser bumps. In Fig. 5 (a) and (b), the contact of a padded slider and data zone of disk B shows stable stiction/friction due to reduction of contact area by the micro-pads. In Fig. 6 and 7, AE and stiction/friction signals indicate dynamic behavior of conventional and padded pico sliders during 20000 cycle-sweep tests of 2.54 mm stroke. It is shown that during the sweep tests, there are contacts between pico sliders and data zone of disks and dings happen at the

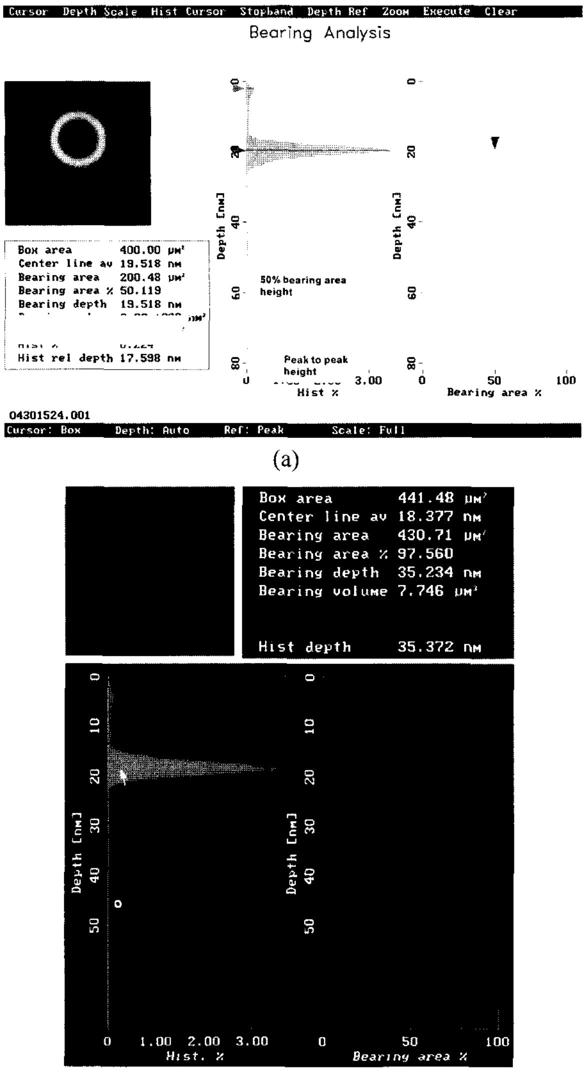


Fig. 10. (a) Before and (b) after the 20000 cycle-sweep test, bearing analysis of a laser bump on disk A.

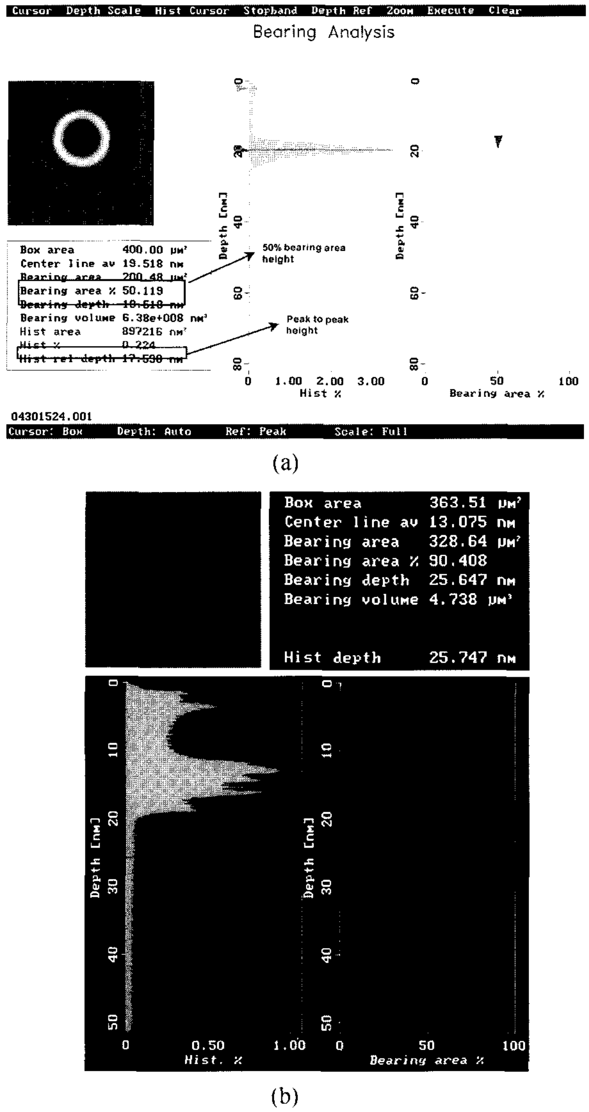


Fig. 11. (a) Before and (b) after the 20000 cycle-sweep test, bearing analysis of a laser bump on disk B.

transition region of landing zone and data zone. From Fig. 3, 4, 5 and 6, the behavior of conventional and padded pico sliders are similar for seek tests and sweep tests. In Fig. 8 and 9, there is no significant change of AE and stiction/friction signals before and after 20000 cycle-sweep tests. Fig. 10 and 11 show the results of bearing analysis and AFM analysis of a laser bump on landing zone of disk A and B before and after 20000 cycle-sweep tests. In Fig. 10 (b) and 11 (b), Center Line Average (CLA) becomes lower due to wear and plastic deformation after 20000 cycle-sweep tests. In Fig. 11 (a), deformation of a laser bump is observed in the AFM image. It can be concluded that laser bumps can be worn and plastically deformed during 20000 cycle-sweep tests, although AE and stiction/friction signals are not apparently changed during the sweep tests. The current contact start-stop test at component level is mainly based on the monitoring of AE and stiction/ friction signals. There is no rigorous criteria about examination of wear and plastic deformation of disks. The result of this work suggests that more detailed criteria of wear and plastic deformation should be set up in CSS tests as the flying height become getter lower.

Conclusions

This paper presents experimental investigation of head-disk interactions at flying height lower than laser bump height. For a conventional pico slider, the contact with landing zone is very stable and stiction/friction is low, but that with data zone shows stick-slip process. For a padded pico slider, the contact with landing zone shows minor fluctuation due to impacts of micro-pads against laser bumps and that with data zone shows stable and low stiction/friction due to the reduction of contact area by the micro-pads. Regarding the interaction with landing zone and data zone of a disk, the contact behavior of a padded pico slider is, in general, better compared with that of a conventional pico slider. After 20000 cycle-sweep tests, both bearing analysis and AFM analysis show some signs of wear and plastic deformation, although there is no apparent change in AE and stiction/friction signals. As flying height becomes getting lower, it is critical to establish more rigorous examination methods of wear and plastic deformation in CSS tests at component level.

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