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Accelerated wear testing of head-disc interfaces

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Abstract

To better assess wear characteristics of head and media combinations under conditions that approximate drive operation, we describe an accelerated wear test in which the *z*-height is increased so that the trailing edge of the air bearing surface makes contact. Using this test, we find that the wear rate for a particular head-media combination decreases as time$^{1/2}$ and we document the effect of media wear on the head wear rate. These experimental findings are combined with numerical modeling of head-disc interface wear that correlates well with our results and predicts a shift in wear mechanisms as surface deformation shifts from dominantly plastic to elastic.

Keywords: Wear; Hard disk drive; Head-disk interface

1. Background

Historically, development of head and disc wear-resistant overcoats was guided by the performance of materials in a variety of tests, including nanoindentation hardness, nanoscratch resistance, drag tests, and contact-start stop tests [1,2]. Each test methodology results in a particular measure of overcoat properties and each had varied success in predicting ultimate performance in drive usage. Some reasons these do not always correlate to drive usage performance is that stresses may be orders of magnitude higher, shear rates many orders of magnitude lower, and the contacting surfaces different. With increasing attention to head-disc interfaces operating in near-contact regimes in data zones, there is a need for an in-situ accelerated wear test to quantify differences in interface designs.

We describe a test that induces contact at the trailing edge of the center pad of the air bearing and enables one to quantify wear rates for a given combination of heads and media. The primary benefit of this method is that the test conditions (e.g. stresses, shear rates, and contacting surfaces) are very similar to those encountered in normal operation. Moreover, this method can be utilized on tribology test spinstands commonly used in the industry and is adaptable to different test environments.

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2. Test conditions

To force contact at the trailing edge, we increase the *z*-height until the slider pitch angle is sufficiently high that contact occurs. Modeling of the test conditions were performed using the CML air bearing simulation code [3]. Two effects of changing the *z*-height were modeled: a reduction in the gram load and an increase in the pitch torque. To estimate the decrease in the gram load, we modeled the suspension as having a spring rate of 38 gmf/in. The effect of changing pitch torque was modeled by calculating the change in suspension angle with a change in *z*-height and then calculating the effect of a changing angle on the pitch torque using the pitch stiffness. The suspension length was taken as 9.65 mm and the pitch stiffness was 1.5 μNm/degree. The air bearing chosen for this study is from a Seagate 30 Gbpsi product that utilizes a central trailing edge pad that has a width of approximately 170 μm.

The results of the modeling indicate that as the *z*-height is increased, the minimum fly height decreases and the pitch angle increases. Details of these trends are shown in Fig. 1. As the *z*-height is increased to 0.889 mm 0.035′, the minimum fly height is reduced to zero and the pitch angle increases to 760 μrad. The combination of these two changes forces the contact point to be the trailing edge of the air bearing surface. In addition, the normal force applied by the suspension is reduced from 2.5 to 1.5 gf.

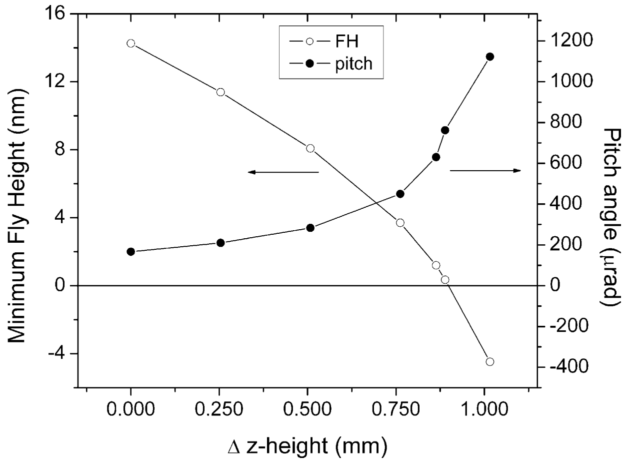

Fig. 1. Predictions of minimum fly height and pitch angle for the air bearing used as the *z*-height is increased from its designed value. Trailing edge contact begins once the *z*-height is raised by approximately 0.889 mm, which is the condition used for accelerated wear testing.

It is important to emphasize that by doing this, we are forcing the trailing edge to be in contact with the media. Under normal operating conditions, wear lowers head-disc interference and lowers the contact force, while in this mode, wear has a negligible effect on the contact force.

Testing was conducted on TTi, Inc tribology spinstands at a linear velocity of 7 m/s at 0° skew while acoustic emission (AE) and laser doppler vibrometry (LDV) were used to monitor contact and HGA dynamics. The circumferentially textured media had a glide avalanche of 12 nm, an AFM roughness (measured over 10 μm) of 0.7 nm, and was coated with a CHN overcoat and 1.8 nm of Z Dol (MW = 4000).

3. Head wear

The primary metric for interface wear in this study is the volume of material worn from the head. In our studies, this wear occurred at the trailing edge of the center pad, which consists of carbon coated sputtered alumina. To obtain a measure of head wear over a given time interval, a virgin HGA was flown over a virgin disc at the conditions described above for the given test interval. The volume of material worn from the head was estimated by combining optical with atomic force microscopies and interferometry. The area exhibiting wear on the air bearing surface was measured using optical microscopy and the wear depth was measured using either interferometry or AFM. An example of a head that has been worn using this method is shown in Fig. 2. The lower portion of the image is the slider body, made of an alumina-TiC composite (AlTiC), while the upper portion is the alumina basecoat, recording devices, and encapsulation layer. The air bearing surface has been defined with rounded corners and to extend 24 μm from the AlTiC-alumina break. There can be seen a darker band near

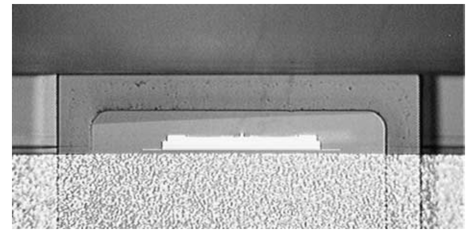

Fig. 2. Optical image of a portion of the air bearing surface used in the study. The darker section near the trailing edge of the air bearing surface resulted from wear.

the trailing edge of the alumina that corresponds to worn alumina. The area of this portion of the surface was measured using post-processing software and was combined with depth information from profilometry to give the wear volume.

The results of head wear volume measurements confirm that flying at an exaggerated *z*-height create conditions ideal for an accelerated wear test. Fig. 3 depicts measurements of average wear volume for a span of test times ranging from 15 to 3600 s. Note that the data is plotted on a log–log scale and the increase in wear volume can be fit with a line that increases with test time as $t^{1/2}$.

To understand wear rates, the same data was normalized by the test length to give the average wear rate as a function of test duration, as shown in Fig. 4. It should be emphasized that this is not the instantaneous wear rate but rather the average wear rate for an entire test. These data decay with test length as $t^{-1/2}$, as depicted by the dotted line.

4. Media wear

As opposed to pseudo-contact or near-contact recording schemes in which the head makes intermittent or infrequent contact, the accelerated wear test forces the head to make contact and thus induces significantly more media wear.

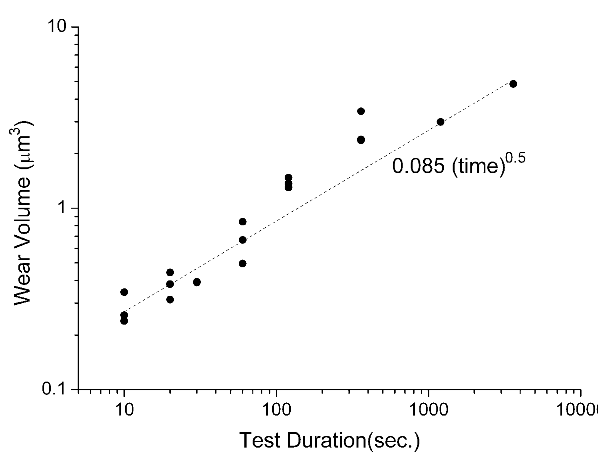

Fig. 3. Measurements of head wear volume as function of test duration. The fitted line illustrates how the head wear rate increases according to $t^{1/2}$.