

FRETTING WEAR BETWEEN A HOLLOW SPHERE AND FLAT SURFACE

Bart Raeymaekers^{1*}, Sebastian Helm¹, Ralf Brunner¹, Edmund B. Fanslau², Frank E. Talke¹

¹Center for Magnetic Recording Research
University of California, San Diego
9500 Gilman Drive, #0401
La Jolla, CA 92093
*bart@talkelab.ucsd.edu

²NHK International Corp.
2350 Mission College Blvd.
Santa Clara, CA 95054

ABSTRACT

Wear particles in a hard disk drive may cause the head/disk interface to fail. We have experimentally investigated wear particle generation resulting from fretting wear between the dimple on the suspension and the gimbal spring. We have found that increasing the normal load as well as using a low friction coating reduces the formation of wear particles.

INTRODUCTION

Examination of failed hard disk drives has shown that wear particles are partly responsible for hard disk drive failure [1]. One source of wear particles in a hard disk drive is fretting wear between the dimple and the gimbal of a hard disk drive suspension. Figure 1 a) shows a top view and Fig 1 b) shows a side view of a typical hard disk drive suspension assembly. The slider, which contains the magnetic read/write element, is connected to the gimbal spring. The gimbal spring is attached to the suspension. A dimple is pressed in the suspension surface to allow roll and pitch motion of the gimbal with slider, during operation of the hard disk drive.

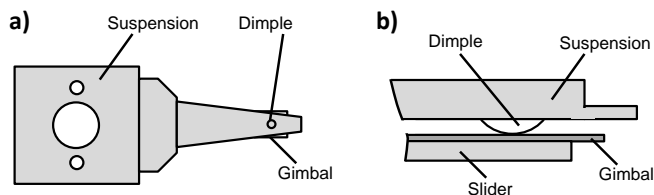


Figure 1: a) top view and b) side view of suspension assembly

The contact between the dimple and the gimbal top surface is equivalent to the contact between a hollow spherical protrusion and a flat surface. During the operation of the hard disk drive, the suspension arm positions the slider over the recording

tracks. This radial motion of the suspension arm creates a reciprocating contact between the surfaces of the dimple and the gimbal spring, which can cause wear or fatigue and may produce wear particles in the hard disk drive.

FRETTING

Fretting is defined as a cyclic relative motion between two surfaces at small displacement amplitude [2, 3]. Experiments have shown that cyclic motion at the contact interface between two bodies can be divided into four different regimes of sliding: stick, partial slip, gross slip and reciprocal sliding [4, 5].

Varenberg et al. [6] introduced the so-called “slip index”, a criterion to determine different fretting regimes defined as

$$\delta = \frac{A_d S_c}{N} \quad (1)$$

where A_d is the displacement amplitude, S_c is the slope of the friction hysteresis loop and N is the normal load. The slip index δ can be determined from a friction hysteresis loop measurement as illustrated in [6, 7]. This paper experimentally investigates the fretting wear between the dimple and the gimbal spring during hard disk drive operation.

EXPERIMENTAL SET-UP

Figure 2 a) shows a schematic of the experimental set-up, which is similar to several fretting testers documented in the literature [e.g. 8]. A suspension is attached to a strain gauge based load cell. The suspension is positioned parallel to the gimbal material and rests with its dimple on the gimbal material, which is attached to a shear mode piezo (PZT) actuator. A normal force N is applied to the dimple. The shear mode PZT actuator is fed with a triangularly shaped input voltage signal from a signal generator to create a reciprocating

motion. The displacement of the PZT actuator is measured with an optical displacement sensor. The load cell measures the friction force F_t , created between the dimple and the gimbal material, as illustrated in Fig. 2 b).

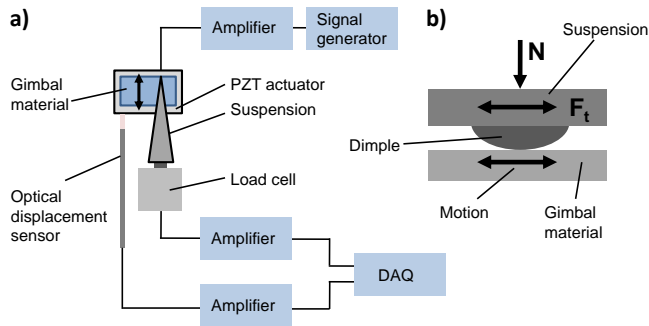


Figure 2: a) Schematic of experimental set-up and b) detailed side view of dimple/gimbal interface

TEST PROCEDURE AND SAMPLES

We have used commercially available, stainless steel hard disk drive suspensions. The dimple on the suspension measures 300 μm in diameter and the suspension has a thickness of 30 μm .

Table 1 summarizes the surface roughness (R_a and R_{RMS}) values of the dimple on the suspension (D1) as well as different gimbal materials we have used (G1, G2 and G3).

Table 1: Material samples

Sample	D1 stainless steel	G1, stainless steel	G2 stainless steel	G3 gold coated
R_a	76.5 nm	72.5 nm	89.5 nm	27.8 nm
R_{RMS}	92.6 nm	88.1 nm	116.8 nm	35.1 nm

Each experiment was conducted five times and the results were averaged over all experiments. For each test a new suspension was used. The suspension is connected to the load cell, and mounted parallel to the gimbal surface. The gimbal material is attached to a shear mode piezo crystal that makes a reciprocating motion, with amplitude 3 μm . We have used discrete frequencies of 1, 2 and 5 Hz for the reciprocating motion of the gimbal material. A normal load is applied to the suspension by adding a calibrated weight to the suspension surface, directly over the dimple. We have used a normal load ranging between 10 and 50 mN, while state-of-the-art hard disk drive suspensions typically operate under a normal load of 30 mN.

Plotting the friction force data (from load cell) versus the displacement data (optical sensor) visualizes the friction hysteresis loop. The surface enclosed by this loop represents the dissipated energy during one fretting cycle. Summing up the energy over all cycles yields the total dissipated energy

during the experiment. The friction hysteresis loop also provides all parameters to calculate the slip index, as defined in eq. (1).

RESULTS

The combination of D1/G1 serves as benchmark, since it represents the standard case of a stainless steel dimple on a stainless steel gimbal, without lubrication. Figure 3 shows the slip index versus the normal load for different frequencies, for the D1/G1 case. We observe that the slip index δ decreases with increasing normal load, and is almost independent of the frequency. A horizontal line at $\delta = 0.8$ indicates the transition from gross slip fretting regime to partial slip. It seems that in our experiments, the transition between both regimes occurs at a normal load of approximately 40 mN. Figure 3 also shows a typical friction hysteresis loop (friction force as a function of displacement) for the cases of 10, 20 and 50 mN. We observe that the slip amplitude (displacement at constant friction force) decreases for increasing normal load. Almost no slip occurs in the case of 50 mN normal load, and, thus, almost no energy is dissipated. The surface contained within the hysteresis loop is almost equal to zero. The optical microscope images provide a rough idea of the shape and magnitude of the wear scar created by the fretting experiment. We observe that for the experiments with 10 mN and 50 mN normal load, the wear scar is smaller than for the experiment with 20 mN normal load. This suggests that more energy is dissipated in the latter case than in the case of 10 and 50 mN normal load.

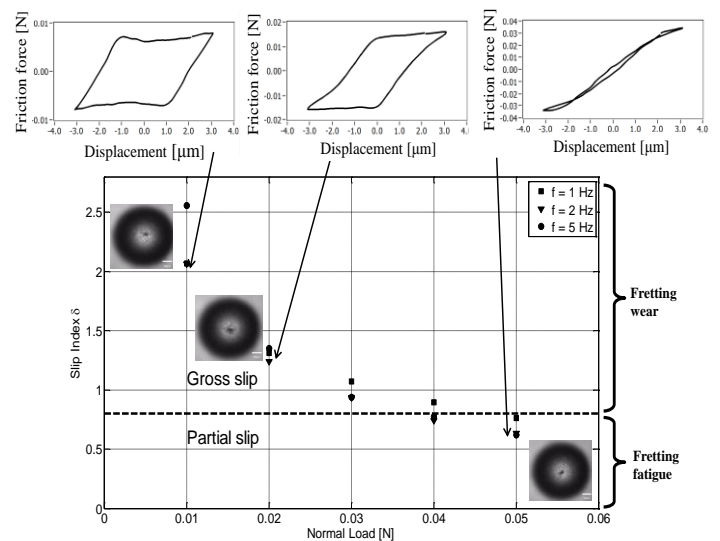


Figure 3: Slip index versus normal load (D1/G1)

Figure 4 shows the dissipated energy as a function of the normal load, for different frequencies. We observe that the energy dissipation in the case of a 20 mN normal load is higher than in the case of the 10 mN and 50 mN normal load, as suggested by the optical microscope images in Fig. 3. The interaction of two parameters is important; normal load and

the type of fretting regime (slip index). When increasing the normal load, the contact area between the dimple and the gimbal increases. At normal loads of 10 - 20 mN, the dimple/gimbal interface operates in the gross slip regime, i.e., the entire dimple is sliding over the gimbal. Thus, more energy is dissipated for increasing normal load, and more wear occurs. However, at a normal load of 40 mN, only a portion of the dimple is sliding over the gimbal, because the fretting regime transitions from gross slip to partial slip (see Fig. 3). The other portion of the dimple remains in “stick” contact with the gimbal. Therefore, despite increased contact area, less energy will be dissipated, and, accordingly, less wear will be generated. We also notice from Fig. 4 that the effect of the frequency on the dissipated energy and the slip index seems small.

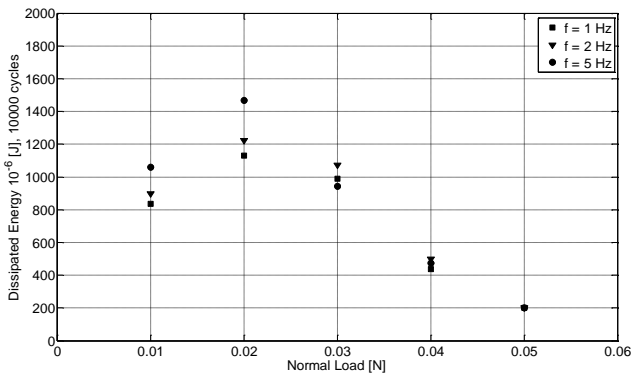


Figure 4: Dissipated energy versus normal load (D1/G1)

Figure 5 shows the dissipated energy after 10,000 cycles, for a normal load of 10 mN and 50 mN, for different gimbal materials. We observe that during the experiments with the gold coated gimbal (D1/G3) under a normal load of 10 mN, less than half of the energy was dissipated compared to the experiments with the stainless steel gimbal material (D1/G1 and D1/G2). Less dissipated energy indicates a smaller amount of wear [9].

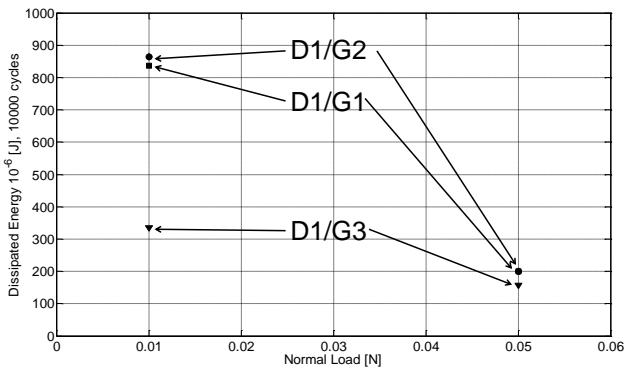


Figure 5: Dissipated energy versus normal load for different gimbal materials

The R_a and R_{rms} roughness values for the gold coated gimbal (G3) are approximately three times smaller than for gimbal material A (G1). The R_a and R_{rms} roughness values for gimbal material A (G1) are approximately 20% lower than for gimbal material B (G2). The lower surface roughness of the gold coating compared to the stainless steel samples could thus explain the reduced energy dissipation and wear. The friction coefficient (measured at 10 mN normal load, 1 Hz) shown in Table 2, also points in that direction.

Table 2: Friction coefficient

Sample	D1/G1	D1/G2	D1/G3
Friction coefficient	0.6	0.75	0.2

CONCLUSION

1. Wear and wear particle generation seem to be function of the normal load between the dimple and the gimbal, and the surface roughness of the gimbal.
2. Increasing the normal load on the dimple could reduce wear particle formation, because the dimple gimbal interface would operate under the partial slip fretting regime rather than the gross slip regime.
3. Covering the gimbal with a low surface roughness coating also reduces wear, by lowering the friction coefficient.

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