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TRANSIENT SLIDER-DISK CONTACTS IN THE PRESENCE OF SPHERICAL CONTAMINATION PARTICLES

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Introduction

A number of investigations have been published that deal with tribological failure and erasure of information in magnetic recording disk drives due to particles being trapped in the head-disk interface [1-3]. In the above studies, the following situations were treated: mechanical contact [1], soft-particle contact [2], and sliding of a large particle in the head-disk interface [3]. In all studies steady state conditions were assumed.

No studies have been published, however, on transient slider-disk contacts in the presence of contamination particles. The goal of the present work is to investigate this latter situation and study the tribological failure of the head disk interface and the erasure of information during transient contacts in the presence of contamination particles.

Numerical Model

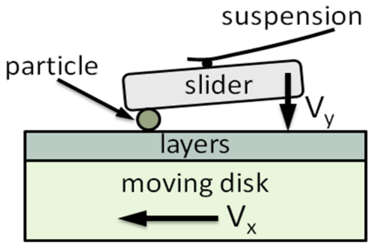

Fig.1 Schematic model of particle trapped in HDI.

Figure 1 shows the head-disk interface during a transient contact in the presence of a contamination particle. The impact velocity of the slider is denoted by V_y while the disk velocity is denoted by V_x. The particle is assumed to be spherical in shape with radius R, adhering solidly to the surface of the rotating disk during a transient contact.

Figure 2 shows the finite element model of the particle-disk contact for a magnetic recording disk with aluminum substrate. This model "lumps" the carbon overcoat, the magnetic layer, and all sublayers into one layer on the substrate [4]. The top surface of the spherical particle is assumed to be rigid and has a constant initial temperature identical to that of the disk to which the particle adheres. Three typical materials were used to represent contamination particle, namely, stainless steel (SS), polyoxymethylene (POM), and alumina (Al_2O_3). The mechanical and thermal material properties of these particles are summarized in Table 1. The material properties for the layered disk structure with aluminum and glass substrates are given in Ref. [4].

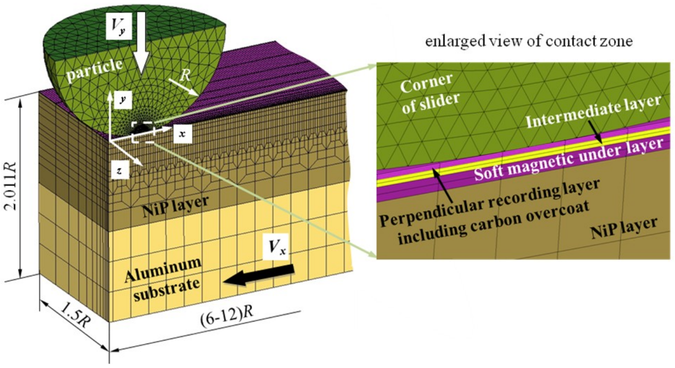

Fig.2 Finite element model of particle-disk contact for layered disk with aluminum substrate.

Table 1. Material properties of contamination particles.

Property	Symbol [units]	SS Particle	POM Particle	Al_2O_3 Particle
Young's modulus	E [GPa]	195	3	400
Yield strength	Y [GPa]	0.48	0.03	6.40
Poisson's ratio	ν [-]	0.276	0.40	0.30
Density	ρ [kg/m^3]	7840	1450	4300
Specific heat	c [$J\ kg^{-1}K^{-1}$]	498	1470	860
Thermal conductivity	k [$W\ m^{-1}\ K^{-1}$]	15.20	0.21	24.00
Thermal expansion	α [$10^{-6}K^{-1}$]	17.6	60.0	7.5

Results and Discussion

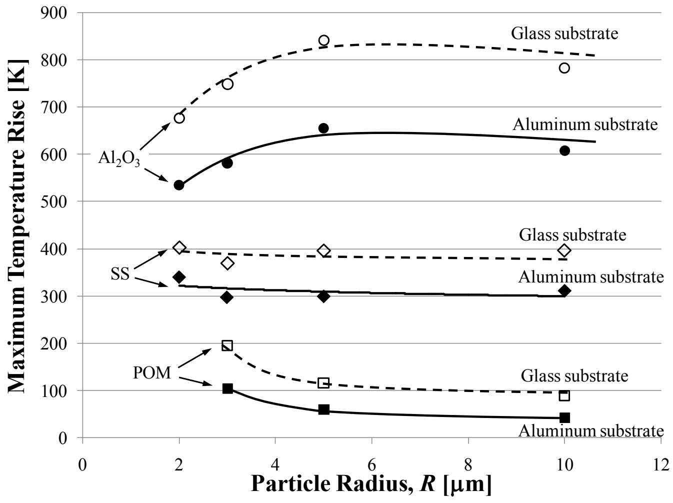

Fig. 3 Maximum temperature rise on the surface of the recording layer caused by contamination particles for glass and aluminum substrate.

Figures 3 - 5 show the maximum temperature rise, the plastically deformed area, and the maximum residual penetration on the disk surface, respectively, for stainless steel, polymer and alumina contamination particles as a function of the particle radius for both glass and aluminum substrate disks. The numerical results were obtained for typical impact conditions of a slider on a disk, namely, a slider vertical initial velocity of $V_y = 0.2$ m/s, a disk circumferential velocity of $V_x = 10$ m/s and a coefficient of friction of $\mu = 0.2$. We assume that the slider has a mass of 0.5 mg.

We observe from Fig. 3 that glass substrate disks results in a higher maximum temperature rise in comparison with Ni-P/aluminum substrate, which is consistent with findings in Ref. [4]. We observe that alumina particles lead to a higher maximum temperature rise than semi-hard stainless steel or soft polyoxymethylene particles due to the larger contact pressure resulting in higher frictional heating. We also observe that the maximum temperature rise becomes independent of particle size for particle radius larger than 5 mm. However, the maximum temperature rise is a function of the particle size as the radius becomes small.

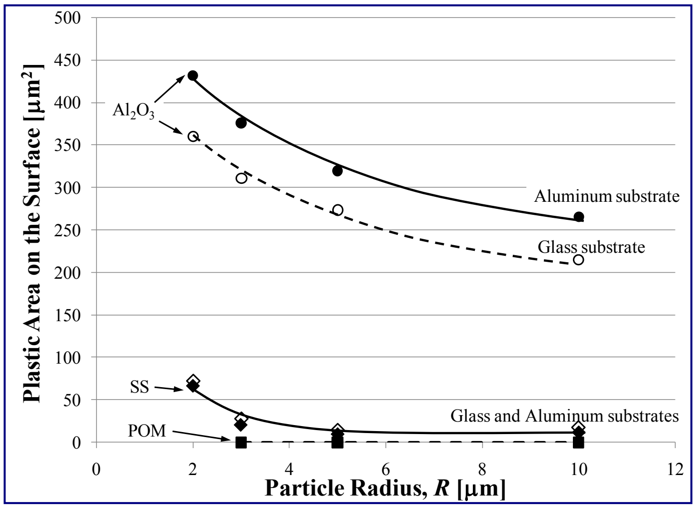

Fig.4 Plastic area on the surface of the recording layer caused by contamination particles for glass and aluminum substrate

Figure 4 shows that for hard alumina particles, glass substrate results in a smaller plastically deformed area in comparison with aluminum substrate due to the higher yield strength of glass [4]. However, for the softer stainless steel contamination particles we observe nearly the same values of the plastically deformed area. We also note that soft polyoxymethylene particles do not cause any plastic deformation on the surface of the recording layer. The plastic area on the surface of the recording layer tends to decrease with larger particle radius since contact pressure decreases.

Figure 5 shows that the maximum residual penetration is significant for hard particles such as alumina, and is larger for aluminum substrate than for glass substrate. The latter is in agreement with numerical results shown in Fig. 4. Stainless steel and soft polyoxymethylene particles do not result in any residual penetration on the disk surface for either substrate.

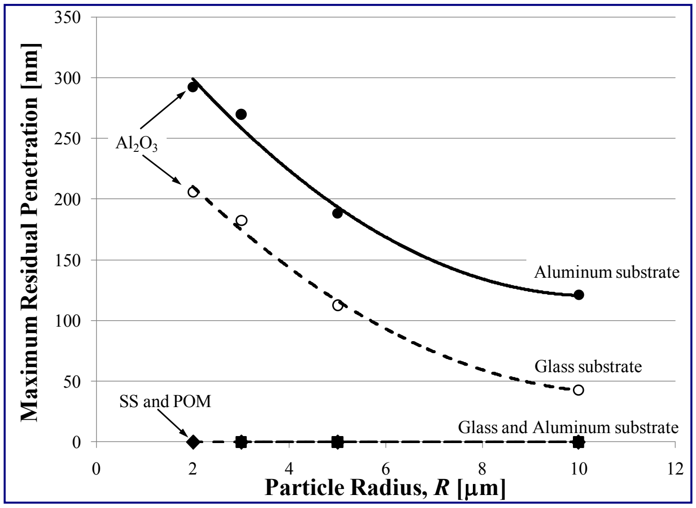

Fig.5 Maximum residual penetration on disk surface caused by contamination particles for glass and aluminum substrate.

Numerical simulations of particles with radii less that 2 μm were also performed. Depending on the material properties of the contamination particles, we observed that small particles are either pushed deep into the substrate (alumina) or are flattened out on the surface of the disk (SS and POM). Further investigations will be presented to elucidate the combined effect of inverse magnetostriction and frictional heating on the thermal erasure of magnetic information.

Conclusion

Soft particles such as polyoxymethylene do not show plastic deformation of the magnetic recording layer during transient slider disk contacts. Temperature increases on the order of one hundred degrees of Centigrade are predicted, indicating that thermal erasure may be a possible tribological failure mechanism. Semi-hard particles such as stainless steel particles seem to cause little physical damage (residual plastic deformation) of the recording layer, but result in a temperature rise of several hundred degrees of Centigrade, which could lead to thermal erasure. Hard particles such as alumina are predicted to result in significant plastic deformation combined with high temperature rise which can lead to loss of data in a similar way as “conventional” slider-disk contacts [4]. It is apparent that hard contamination particles represent the most severe problem for the tribological integrity of magnetic recording disk drives.

References

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