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SIMULATION AND TESTING OF THE HEAD DISK INTERFACE FOR DISCRETE TRACK MEDIA

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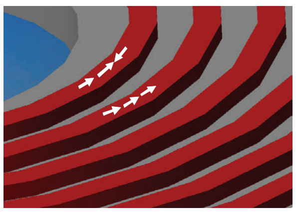
Introduction

Magnetic recording has become the main technology for the storage of digital data. It is believed [1] that perpendicular recording allows an increase in storage density to approximately 500Gbit/in^2 before the so-called super paramagnetic limit will be reached. To increase the storage density beyond 500Gbit/in^2, patterned media recording [2] is being considered. In bit patterned media recording, magnetic bits are recorded on individual "island-like" regions (bit patterned media, BPM). In discrete track recording, the magnetic information is stored on discrete tracks that are physically separated from each other (discrete track recording, DTR). In bit patterned media magnetic transition noise is eliminated completely (BPM), while in discrete track media the transition noise is confined to noise in the circumferential direction (DTR) [3]. However, the air bearing domain in patterned media is highly influenced by the existence of surface structures on either disk or head. "Island" like structures or circumferential grooves in the disk surface change the air bearing pressure distribution of the head/disk interface compared to non-structured head/disk interfaces. A number of researchers have investigated the effect of local spacing variations of the air bearing as a result of roughness [6] or surface texture on the head [7, 8] and disk [9].

The effect of discrete track disks on the flying characteristics of sub-ambient pressure sliders is investigated as a function of discrete track media parameters. A finite-element-based air bearing simulator [10] (CMRR simulator) was used to account for the characteristics of the grooved disk surface. The steady state flying behavior of typical proximity recording sliders over discrete track disks is studied and the influence of discrete track media parameters such as groove depth, groove width, and groove pitch is investigated with respect to the flying behavior of five types of sub-ambient pressure slider. Groove depths from zero to 40nm and groove widths from 500nm to 1000nm were evaluated. Flyability testing of sliders on patterned media was also conducted, with a significant variation in flyability observed as a function of groove depth.

Mathematical Modeling

Figure 1a) shows a schematic of a typical discrete track disk. Individual bits are stored along the circumferential ridges on the disk surface (white arrows in Figure 1a). In Figure 1b) the parameters defining discrete track media are shown. We note that w denotes the groove width, p the groove pitch, and d the groove depth, respectively.

a) 

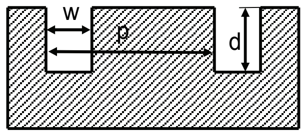
b) 

Figure 1 a) discrete track disk b) discrete track disk parameter

The air bearing pressure over the slider is calculated based on the Reynolds equation [11], given by

$$\frac{\partial}{\partial x}\left(\bar{Q}ph^3\frac{\partial p}{\partial x}\right)+\frac{\partial}{\partial y}\left(\bar{Q}ph^3\frac{\partial p}{\partial y}\right)=6\mu\left(U\frac{\partial ph}{\partial x}+V\frac{\partial ph}{\partial y}\right) \qquad (1)$$

where Q denotes the Boltzmann correction for rarefied gas flow [12, 13], $p(x,y)$ describes the pressure field of the air bearing slider, μ is the dynamic viscosity of air, while U and V are the velocity components in the x and y directions, respectively. The spacing between slider and disk is represented by h.

Simulation Results

In Figure 2, the pressure distribution for the trailing edge center region of a pico slider is shown for a) a smooth head/disk interface, b) an interface with 15nm groove depth, and c) an interface with 75nm groove depth, respectively. A coarse track pitch of 10µm and a groove width of 7.5µm were chosen, resulting in a groove width to pitch ratio of three to four (0.75).

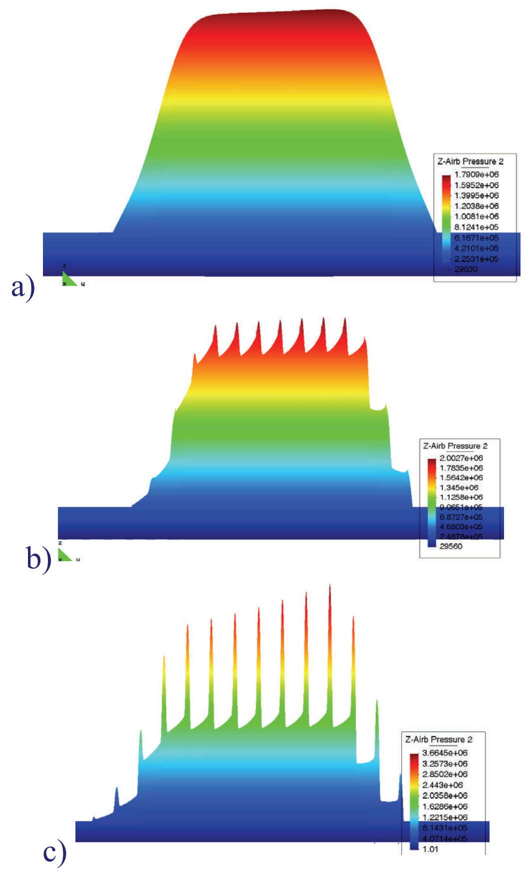


Figure 2 trailing edge center pressure distribution for a) smooth disk, b) 15nm groove depth, c) 75 nm groove depth

The trend in the pressure distribution of the air bearing surface for increasing groove depths can clearly be observed. With increasing groove depth, the pressure distribution over a land region approaches more and more the shape of a delta function, i.e., increasingly higher pressure values over the land regions are observed, accompanied by a decrease in pressure over the groove regions. As the pressure over a land region increases, side flow from the land areas into the grooves increases. Increased side flow results in a reduction of the maximum achievable load carrying capacity of the air bearing. Clearly, side flow and maximum pressure are important parameters that need to be considered in the air bearing design process for discrete track disk interfaces.

Experimental Testing

A spin-stand test system was used for testing the flyability of sliders on patterned media . Pico-type standard sliders (11 nm flying height) and DTR-specific sliders were used on the spin stand with integrated laser Doppler vibrometer (LDV) and acoustic emission (AE) signal capability for contact detection at the head/disk interface. To characterize the dynamic behavior of the sliders on the varying media, we have determined the standard deviation σ of the flying height variation. In Figure 3, the results of this calculation are shown for both standard and DTR sliders on each patterned media that was investigated.

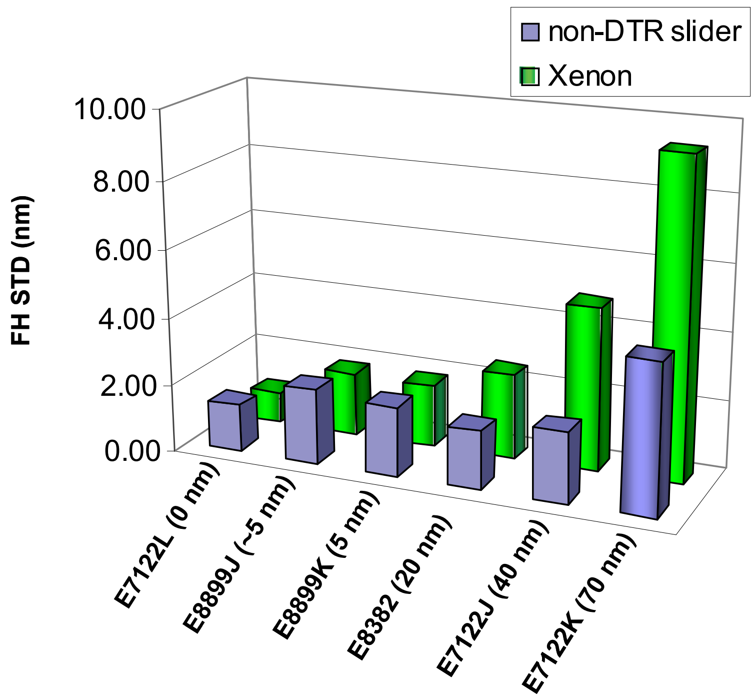


Figure 3 Comparison of σ of flying height variation for sliders.

As can be seen from Figure 3, there is a clear trend towards increasing variation in flying height with an increase in DTR groove depth. Since flying height variation should be less than 10-15% of the total flying height, the flying height variation as a function of groove depth appears to be a critical design parameter for discrete track media. Magnetic SNR tends to improve with increasing groove depth, but a groove depth that is too large may cause non-optimal variations in the slider flying height. Clearly, further research is necessary to fully understand how the flying height is affected by the DTR topology.

Summary and Conclusion

The influence of discrete tracks on the steady state flying behavior of sub-ambient air bearing designs was investigated. It was found that the maximum pressure in a discrete track media head/disk interface increase with increasing groove depth and increasing ratio of discrete track groove width to discrete track groove pitch. Also, experimental tests showed that increasing groove depth was found to increase the variation in slider flying height, indicating that groove depth is a critical design parameter for patterned media. It is likely that there is an optimal groove depth that yields an optimal SNR for magnetic recording and is acceptable from the point of view of flying height variations.

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