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Investigation of HDD Ramp Unloading Processes with an Efficient Scheme

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Abstract. Ramp load/unload (L/UL) mechanisms are widely used to rest sliders in hard disk drives (HDDs). Loading/unloading a slider swiftly and smoothly is crucial in a HDD design. A novel, efficient simulation scheme is proposed to investigate the behaviors of a head disk interface (HDI) in ramp unloading processes. A dual scale model is enabled by decoupling the nano-meter scale change of an air bearing and the micro- or milli-meter scale deformation of a suspension. A modified Reynolds equation governing the air bearing was solved numerically. The slider design was characterized with performance functions. Three stages in an unloading process were analyzed with a lumped parameter suspension model. Key parameters for the model were estimated with a comprehensive finite element suspension model. Finally, simulation results are presented for a commercial HDI design.

AMS subject classifications: 65P40

Key words: Hard disk drive, ramp, unloading, head-disk interface, suspension, Reynolds equation, performance surfaces.

1 Introduction

Hard disk drives (HDDs) provide a major form for data storage. To address the serious tribological problems caused by the direct contact between the disk and the head, floating sliders are designed to suspend the heads above the disk surfaces as the disks passed by underneath. Nowadays, minimum flying height of a magnetic slider is approaching 5nm and even below. When a HDD is powered off, the rotational speed of the disks slows down to stop, and therefore the dynamic air bearing supporting the slider disappears. To avoid the direct slider-disk contact, the sliders should land on

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a non-data zone before the air bearing breaks down. Load/unload (L/UL) mechanisms are widely adopted to resist wear and tolerate more start/stop cycle by resting a slider on a ramp [1,2]. A typical ramp L/UL mechanism is shown in Fig. 1. Currently, L/UL zone at the outer disk diameter is not used for data storage due to potential loss of magnetic information caused by head-disk contact. If the slider can be loaded/unloaded smoothly and swiftly, the L/UL zone can be minimized or even be used for data storage, and then a larger storage area is available.

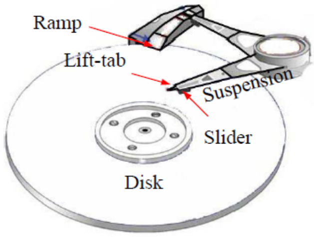

Figure 1: A typical load/unload mechanism in HDD.

Simulation provides an economical approach for a HDI design. In a conventional dynamics analysis, the instantaneous attitude of a slider was calculated by solving a modified Reynolds equation which was coupled through the air bearing force and the moment with the dynamics of the suspension [3–5]. The historical behaviors in an unloading process were obtained by solving the coupled equations repeatedly. Despite its precision, the traditional way is limited to examining only typical, individual cases because of the intensive computation requirements.

In this work, an efficient scheme is proposed to analyze the behaviors of subambient pressure sliders in unloading processes. The studies on the sliders and the suspensions are decoupled with a dual-scale model. The numerical solutions for a modified Reynolds equation were fitted to characterize the performance of an air bearing design. A simplified lumped parameter model was constructed to study the behaviors of a suspension in unloading processes. Key parameters of the suspension were estimated with a comprehensive finite element model and checked with experiments. With the efficient scheme, an unloading simulation can be worked out with a very short computation time [6,7].

2 Analysis of an unloading process

2.1 Three stages in an unloading process

In modern HDDs, a head-gimbal assembly (HGA) is designed with several pieces as shown in Fig. 2(a). The load beam helps position the slider. The gimbal allows the flying slider to rotate about the dimple to accommodate surface variations. The limiter is designed to limit the separation between the load beam and the slider. The lift tab