ON THE TOUCHDOWN-TAKEOFF HYSTERESIS OBSERVED AT THE HEAD-DISK INTERFACE IN HARD DISK DRIVES

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ABSTRACT

The touchdown-takeoff velocity hysteresis observed in hard disk drives during CSS or L/UL tests is analyzed using an experimental approach. Tests similar to L/UL were conducted for different slider-disk combinations at different humidities. Factors affecting the touchdown and takeoff velocity were identified on the basis of their domain of operation. It is concluded that the intermolecular forces and meniscus forces are contributing factors to hysteresis, which is also influenced by disk topography and slider dynamics.

INTRODUCTION

In order to achieve higher areal recording density, the head-disk spacing has to be reduced below 3 nm at which intermittent contact will be unavoidable. It has been experimentally observed that at such spacing there exists operational instability at the head-disk interface [2]. It has been shown through modeling that the stability of the head depends on phenomena such as the intermolecular forces (IMF) [2] and meniscus forces [3,4]. In order to achieve operational stability, it is important to identify and characterize these phenomena experimentally.

One of the methods by which we can experimentally determine the contribution of these phenomena is by studying the touchdown-takeoff hysteresis. The touchdown and takeoff velocities are a measure of slider stability as they indicate how soon the slider loses its stability and how soon it regains it respectively. Thus the hysteresis is a measure of recovery of the slider from contact to a stable flying regime. Hence, to increase the stability at the head-disk interface, it is desirable to reduce the touchdown velocity, takeoff velocity and the resultant hysteresis.

During the touchdown-takeoff sequence, the slider loses its fly height during the touchdown leg, as the disk velocity decreases. In this case, the slider is affected by proximity phenomena as well as the uneven disk topography, thus reducing its stability. When it comes into contact with the disk the slider-suspension system starts vibrating with much higher amplitudes due to the impact forces, which in turn adds more energy into the vibrating system. As a result, there are sustained high amplitude vibrations during contact. When the velocity starts increasing again, the mean fly height of the slider starts increasing and the high vibrations due to impact are resisted by a stiffer air-bearing. This tends to stabilize the system and decrease the vibration as experimentally seen using a Laser Doppler Vibrometer (LDV). But the stiffer air-bearing now required to curb these vibrations requires a higher disk velocity; i.e. more energy has to be expended now to stabilize an unstable system as compared with that required to maintain the system stability in the absence of contact or high vibrations which was the case during the touchdown leg. Hence, the slider dynamics during contact may be seen as an inherent reason for the hysteresis observed.

Thus, to determine the other factors influencing the hysteresis, we need to consider the individual variation in the touchdown and takeoff velocities due to these factors based on the domain of operation of each of the factors [5]. For example, IMF are a non-contact phenomenon. Hence, the IMF influence can only be studied on the touchdown velocity, before which there is no slider-disk contact. Upon contact, the contact phenomena, such as slider-lubricant interactions (causing meniscus forces) also have their influence, which makes it difficult to discern the influence of IMF. Similarly, being a contact phenomenon, the influence of meniscus forces can be studied only on the takeoff velocity, during which the contact phenomena are dominant.

EXPERIMENTS

Tests similar to L/UL tests were conducted at different humidities and for different slider-disk combinations on a CETR tester equipped with an acoustic emission sensor for detecting contact [1]. It was found that the touchdown velocity decreases when there was an increase in the lubricant thickness on the disk (Fig. 1). This trend was opposite to that predicted by the meniscus forces. Multilayer modeling of intermolecular forces explained the trend, and hence it was concluded that IMF influence the touchdown velocity and the slider dynamics at proximity [1]. Thornton and Bogy [2] showed through modeling that inclusion of IMF in a dynamic model indicates a touchdown-takeoff hysteresis. Thus, we can conclude that IMF are one of the factors causing hysteresis.
During these experiments it was also observed that the takeoff velocity increases when there is lubricant picked up by the slider (Fig. 2), thus increasing hysteresis. (In Fig. 2, the AE signal is plotted against the disk rpm. The time axis folds back on itself so that the hysteresis is evident.) Subsequent tests were conducted on a Tti spinstand. LDV and an acoustic emission sensor were used to study the slider dynamics and detect contact respectively. In these experiments it was found that when the slider picks up lubricant its flying stability decreases [5]. The lubricant contaminated slider has higher touchdown and takeoff velocities. This can be explained by the increase in the adhesion between the slider and the disk due to lubricant pickup, making a case for lube-lube adhesion at the head disk interface. From these results, we see that the meniscus forces (which may not be seen as a conventional meniscus forming, but as acting through lube-lube adhesion) are also a factor influencing the hysteresis and a contributor to dynamic instability.

CONCLUSIONS:

From the experiments it was seen that the touchdown-takeoff hysteresis is a complex phenomenon that depends on many interactions. The slider dynamics itself during the touchdown-takeoff process introduces a hysteresis. In addition, intermolecular forces and meniscus forces contribute to the hysteresis. The long range IMF are mainly attractive in nature and increase the adhesion between the slider and disk [2]. Meniscus forces act through lubricant mediated adhesion which occurs when a flying slider or a slider in partial contact picks up lubricant on the disk. Rough or contaminated disks can also cause early touchdown, though burnishing during contact can help regain the slider stability.

REFERENCES: