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The pulse width effect on the shock response of the hard disk drive

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Abstract

A finite element model (FEM) of the ST drive from Seagate is developed in ANSYS to investigate the shock response of the hard disk drive (HDD). The FEM includes the pivot bearing, the head stack assembly (HSA) and the disk. The free state of the HSA is determined by an iterative procedure to produce the prescribed preloading force at the head–disk interface. The FE model is then verified by conducting a modal analysis over the HSA. The obtained mode shapes and resonant frequencies are compared with the modal testing results. An acceleration pulse is applied to the shaft and the whole disk surface at the same time to study the shock response of the HDD. The head slap behavior is examined at the slider–disk interface. The effect of the pulse width on the head slap behavior is studied. The duration of the acceleration pulse varies from 0.3 to 1 ms. It is found that the lift-up height of the slider reaches a peak value at different pulse widths when the amplitude of acceleration pulse changes. This is due to the nonlinear behavior introduced by the contact surfaces.

Keywords: HDD; Shock analysis; Modal analysis; Head slap behavior; Pulse width effect

1. Introduction

In recent years, hard disk drives (HDDs) have received wide applications in portable consumer electronics such as, MP3 players, digital cameras, etc. As these HDDs work in more vulnerable circumstances compared with desktop and laptop HDDs, their shock resistance capability becomes more demanding. The failure of the HDD usually takes place at the head–disk interface when it is subjected to a shock loading. A phenomenon called head slap may take place at the head–disk interface in the non-operating or operating state of the HDD.

For most traditional HDDs, the sliders rest at the central zone of the disk in the non-operating state. When the HDD is subjected to a shock loading, the inertia force of the suspension may overcome the preloading force and the slider is thus lift off the disk surface. As the bending mode shape of the suspension switches phase, the suspension springs back and the slider slaps over the disk surface. The head slap behavior can

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generate particles on the disk and cause contamination problems. It should be strictly avoided in the design of the HDD. One approach to avoid the head slap is by increasing the preloading force of the suspension. But too large preloading force may introduce tribology problems to the head–disk interface. Another approach is to design more shock-resistant head stack assembly (HAS) and HGA. The dynamics of the head slap behavior must be fully understood to guide the design of these structures. The head slap behavior can also take place in the operating state [1]. When the acceleration pulse is strong enough, the air bearing at the slider–disk interface may collapse which is followed by severe contacts between the slider and the disk caused by the head slap.

For HDDs designed for non-traditional applications, the slider of these HDDs usually rests on the ramp in the non-operating state. Thus the head slap is no longer a threat to the safety of the HDD. However, as the head slap behaviors in the non-operating (slider rests on the disk surface) and operating state are similar and it is more convenient to study the shock response of the HDD in the non-operating state either by experiments or by numerical simulations, the head slap behavior of the non-traditional HDDs in the non-operating state (the sliders rest on the disk) is also of great concern. The resistance to the head slap behavior in the non-operating state has become an important index to assess the shock resistance capability of the HDD. In this paper, the shock excitation is simulated with a half-sine acceleration pulse. The effect of the pulse width on the head slap behavior is investigated for the non-operating state of the ST drive from Seagate.

It is has been shown by Shu et al. [2] that when a linear SDOF system is subjected to a half-sine acceleration pulse, a correlation exists between the natural frequency of the system and the critical pulse width at which the response of the SDOF reaches a peak value. Suppose that the natural frequency of the system is given by ω_n and the characteristic frequency of the shock pulse is given by $\omega = \pi/t_0$, where t_0 is the pulse width. While $\omega \approx 0.66\omega_n$, the shock response of the SDOF system reaches the peak value. When the head stack assembly (HAS) rests on the disk, several resonant modes can be found for the HSA. The objective of this paper is to study which mode dominants for the head slap. It is very important to identify which mode dominants the head slap behavior in order to improve the design of the HDD. When the HDD is dropped to a ground surface, it is subjected to a reaction acceleration pulse from the surface. The harder the ground surface, the sharper the reaction acceleration pulse (a sharper pulse means the duration of the pulse is shorter while the amplitude of the pulse is larger). It is important to study how the pulse width influences the head slap behavior of the HDD and what relationship exist between the pulse width and the resonant modes of the HDD to improve the shock resistant capability of the HDD.

Finite element model (FEM) is a robust tool to evaluate the overall mechanical performance of the HDD. Due to the complexity of the structures of the mechanical components inside the HDD, simplified theoretical models are usually not sufficient to study the complex dynamics of the HDD at the system level. Allen and Bogy [3] studied the shock effect on the head–disk interface both numerically and experimentally. The model considered only the effects of the disk and suspension arm on the magnetic head for the case of a linear shock. Edwards [4] developed a complete FE model of HDD to study the non-operating shock event when the HDD is dropped from a constant height for three different contact surfaces. Zeng and Bogy [5] studied the response of the head–disk interface in the operating state to a shock impulse. A FEM was used to find the structure response of the HDD. Then the response of the air bearing was studied by using the structure response as the input. Jayson et al. [6] studied the head slap behavior of operational and non-operational HDDs for linear drop test and tilt drop test. A correlation between linear drop test and tilt drop test was set up. Lin [7] developed a two-head HDD model in ANSYS. A semi-sine acceleration pulse is applied to the base of the HDD, the duration of the semi-sine pulse, the thickness of the disk and the stiffness of the bearing were studied for the non-operating shock. However, in all the above simulations, the pulse width effect is not investigated.

In this paper, a FE model of the HDD is developed in ANSYS. The FE model includes the pivot bearing, the HSA and the disk for the ST drive from Seagate. A semi-sine acceleration pulse is applied to the shaft and the disk surface at the same time. In this paper, we apply the acceleration pulse to the whole disk surface. This is to cancel the influence of the disk modes. It has been shown by Luo et al. [8] that the vibration of the disk modes also contributes to the head slap behavior. In this study, in order to identify the role of the suspension modes in the head slap behavior, the vibration of the disk is not considered. The head slap behavior under non-operating state is then simulated with the implicit to explicit analysis function of ANSYS. The pulse width effect of the acceleration pulse is studied. It is found that when the amplitude of the acceleration pulse