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2014

Huang, X. Y., Min, H., & Zhang, Q. D. (2013). Feedback control of flow-induced vibrations on head gimbals assembly inside hard disk drives. Lecture Notes in Mechanical Engineering, Proceedings of the 2nd Symposium on Fluid-Structure-Sound Interactions and Control, pp.405-411.

<https://hdl.handle.net/10356/85376>

https://doi.org/10.1007/978-3-642-40371-2_58

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Feedback control of flow-induced vibrations on head gimbals assembly inside hard disk drives

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Abstract. High speed flows in working hard disk drives (HDDs) can induce off-track vibrations on a head gimbals assembly (HGA), which limit positioning accuracy of the slider magnetic head on the tip of the HGA for high magnetic storage density in disks. This paper presents experimental studies and numerical simulations on the flow-induced vibrations (FIV) of the HGA inside an HDD and active control of such vibrations. Firstly, the HGA off-track vibration and the airflow pressure fluctuations around the HGA are measured to characterize the FIV of the HGA. Secondly, we propose an active control strategy for such FIV of the HGA, in which feedback acoustic pressures are employed to suppress pressure fluctuations in turbulence around the HGA. Numerical simulations have been carried out on this issue by introducing virtual sensors into the close regions around the HGA. Finally, by using the FIV on the HGA as feedback error signals through the laser Doppler vibrometer, the feedback control of FIV on the HGA has also been demonstrated.

Keywords: active control, flow-induced vibration, acoustic pressure, hard disk drive, head gimbals assembly

1.1 Introduction

Vibration of a head gimbals assembly (HGA) induced by high speed circumferential airflows in working hard disk drives (HDDs) limits the positioning accuracy of slider magnetic head on the HGA tip, and is therefore receiving much attention associated with the development of high magnetic storage density in disks, such as 10 Tb/in². Aerodynamic pressure fluctuation around the HGA plays an important role in the flow-induced vibration (FIV) on the HGA [1]. Passive methods such as modification on the HDD inner structures have proved to be difficult for the fine control on this issue [2]. The previous work on active control of disk flutter inside working HDDs by Huang *et al.* [3, 4] suggested a possible active control strategy on the FIV of the HGA through suppressing unsteady airflows around the HGA by acoustic pressure disturbance. In this paper, the turbulence fluctuations and the

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FIV on the HGA are measured to show the correlations between them. Then, a possible active control architecture is proposed based on numerical simulations. Finally, experimental demonstration was carried out to demonstrate the proposed active control strategy on the FIV of the HGA.

1.2 Measurement of FIV on HGA in HDDs

The setup for simultaneous measurements of pressure fluctuations and HGA-OTV inside a working 3.5 inch Seagate HDD is illustrated in Fig. 1.1. The HDD can operate at different rotation speeds driven by an HC6250B-PT motor driver. During the measurements, the HGA was fixed at middle track following position and a PCB 103B12 pressure transducer was used to measure the pressure fluctuation through a hole of diameter 3 mm drilled on the HDD cover right above the HGA. The HGA off-track (horizontal) vibrations were measured through a laser Doppler vibrometer (LDV) typed Polytec PSV300.

Fig. 1.1 Setup of measurements on pressure fluctuations around an HGA and the HGA off-track vibration (HGA-OTV) in a 3.5 inch Seagate HDD.

Fig. 1.2 (Color online) Spectra of (a) pressure fluctuation around the HGA and (b) the HGA off-track vibration displacement at HDD different rotation speeds.

In the measurements, the HDD was working under three different rotation speeds and the corresponding results are presented in Fig. 1.2. It is shown that the pressure fluctuations inside the HDD are highly associated with the HGA off-track vibration in terms of principal peaks in the spectra, and the spectrum magnitudes of both the pressure fluctuation and the HGA off-track vibration increase with the HDD rotation speed. This reveals the correspondence of the turbulence fluctua-

tions around the HGA to the FIV on the HGA, and suggests that an active control may be applied on the HGA vibrations by suppressing the turbulence fluctuations around the HGA.

1.3 Control architecture and experimental demonstration

Based on observations in measurements above, we conducted numerical simulations to understand the fluid fluctuations closely around the HGA and the possible control system architectures for HGA flow-induced vibrations. This work can be reviewed in [5] and are not presented in this paper for succinctness. From such numerical understanding on the control architectures, an experimental demonstration has been conducted to further validate the proposed active control solution of the FIV on the HGA. Fig. 1.3 is a schematic diagram on the experimental setup. The feedback control close-loop consisted of a LDV, a narrowband frequency filter, a signal conditioner, an in-house made phase shifter, and a piezoelectric (PZT) disk mounted on the inner surface of the HDD cover. The HGA off-plate (vertical) vibrations detected by the LDV were used as feedback error signals, and the signals were then phase shifted and amplified to drive the PZT disk to generate feedback acoustic pressure around the HGA. The phase shift and gain of the feedback loop were adjusted such that the HGA off-plate vibrations were reduced.

Fig. 1.3 Schematic diagram of the experimental setup.

By setting the center frequency of the narrow band filter, experiments have been conducted by focusing the active control separately on several principal peaks in the HGA off-plate vibration spectrum. In this paper, only the results from control focused on the principal peak around 1256 Hz in the HGA vibration spectrum are presented in Fig. 1.4 for succinctness. It is shown that positive suppression up to 13 dB has been achieved at the principal peak around 1256 Hz. The results demonstrate the physical validity of the active control strategy on the FIV of the HGA by acoustic pressures.

Fig. 1.4 (Color online) Spectra of the HGA off-plate vibration before and under active control focused on the principal peak around 1256 Hz.

1.4 Conclusion

Experimental and numerical studies were conducted on active control of the FIV on the HGA in working HDDs through suppressing turbulence fluctuations around the HGA. The correspondence was found between the pressure fluctuations around the HGA and the FIV on the HGA. Numerical results show that the FIV on the HGA can be successfully controlled when the airflow pressure fluctuations in close regions around the HGA can be actively suppressed, which has been further demonstrated in experiments by using an analogue feedback loop.

1.5 Acknowledgments

This project (No. 092-156-0128) is funded by A*STAR of Singapore.

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