Active control on flow-induced vibration of the head gimbals assembly in hard disk drives

Min, H.; Huang, X. Y.; Zhang, Q. D.

2012

Min, H., Huang, X. Y., & Zhang, Q. D. (2012). Active Control on Flow-Induced Vibration of the Head Gimbals Assembly in Hard Disk Drives. 2012 Digest APMRC, pp.1-2.

<https://hdl.handle.net/10356/85296>

© 2012 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works. The published version is available at: [Article URL: <http://ieeexplore.ieee.org.ezlibproxy1.ntu.edu.sg/xpl/articleDetails.jsp?reload=true&arnumber=6407536&content>]

Downloaded on 26 Apr 2023 15:40:21 SGT

Active Control on Flow-Induced Vibration of the Head Gimbals Assembly in Hard Disk Drives

H. Min, *Member, IEEE*, X. Y. Huang, and Q. D. Zhang

Abstract--A feedback active method is proposed to control the flow-induced vibration (FIV) of the head gimbals assembly (HGA) through suppressing the pressure fluctuations around the HGA. Firstly pressure fluctuations and FIV measurements are carried out around the HGA in a working hard disk drive, and the results show a high correlationship between the spectra of the HGA's FIV and the pressure fluctuations. Secondly numerical simulations are conducted to investigate the control effect on the HGA's FIV by the proposed feedback active method with a pressure virtual sensing architecture. The numerical results show that the HGA's FIV can be successfully controlled through suppressing the pressure fluctuations with virtually sensing pressure in the wake zone of the HGA.

Index Terms--Active control, flow-induced vibration, pressure fluctuation, virtual sensing.

I. INTRODUCTION

High speed flows in working hard disk drives (HDDs) can induce off-track vibration of a head gimbals assembly (HGA), which limits positioning accuracy of the slider magnetic head on the tip of the HGA for the future 10 Tb/in² magnetic storage density. Passive methods such as HDD interior geometry modifications have been applied to control such HGA flow-induced vibration, but seem hard for further fine control to meet the super-high slider positioning accuracy demand in swift growth of storage density [1,2]. Active control methods may be good alternative for this bottleneck.

Huang *et al.* [3,4] applied active control technique to control the rotating disk flutter in

HDDs. Their study suggests a useful active control strategy for the HGA off-track vibration by employing active pressure disturbance to suppress the unsteady airflows around the HGA inside the working HDDs.

II. EXPERIMENTAL RESULTS

The simultaneous measurements of pressure fluctuations and the HGA's off-track vibration inside a working 3.5 inch Seagate HDD have been carried out. The HDD operates at rotation speeds of 7200, 9000, 10800 rpm driven by an HC6250B-PT motor driver. A PCB 103B12 pressure transducer right above it was used to measure the pressure fluctuation, through a hole of diameter 3 mm drilled on the HDD cover. The direct HGA's off-track vibration signals were measured through a LDV typed Polytec PSV300. The measured spectrum results of pressure fluctuations at three HDD rotation speeds of 7200, 9000 and 10800 rpm are presented in Fig. 1. Figure 2 resents the simultaneous spectrum results of the HGA's off-track vibration at these three HDD rotation speeds. Comparison between Figs. 1 and 2 indicates a clear causal nexus from the pressure fluctuation to the HGA's off-track vibration. That is, change of the pressure fluctuation around the HGA may correspondingly result in the simultaneous change of the HGA's off-track vibration.

III. NUMERICAL SIMULATIONS

Two-dimensional numerical simulations are conducted to investigate the control effect on the HGA's off-track vibration by suppressing the pressure fluctuations around it. Turbulent model based on the large eddy simulation (LES) is applied through the commercial code of FLUENT.

A feedback control architecture with pressure virtual sensing at a point right in the wake zone of the HGA, CP₁, is implemented as shown in Fig. 3. A pressure actuator chip with 10 mm width is assumed on the HDD cover inner surface in the upstream of the HGA, and a physical pressure sensor is assumed to pick up the pressure disturbance on the cover inner surface right above the wake zone of the HGA through a hole on the

Manuscript received 7 Sept, 2012 (date on which paper is submitted for review). This project (No. 092-156-0128) is funded by A*STAR of Singapore.

H. Min is with the School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore 639798 (phone: +65-67906204; fax: +65-67924062; e-mail: hqmin@ntu.edu.sg).

X. Y. Huang is with the School of Mechanical and Aerospace Engineering, Nanyang Technological University, Singapore 639798 (e-mail: mxhuang@ntu.edu.sg).

Q. D. Zhang is with the Data Storage Institute, DSI Building, Singapore 117608 (e-mail: ZHANG_Qide@dsi.a-star.edu.sg).

HDD cover. Given that a relationship function can be explicit between the spectra of pressure fluctuations at the physical and the virtual sensing position, the direct cancellation point for pressure fluctuations in the feedback control system can be moved from the physical sensing position onto the virtual sensing one [5].

The simulation results of pressure disturbance contour at frequency of 1480 Hz before and under control are presented in Figs. 4(a) and (b). It is shown that successful suppression of pressure fluctuations in the wake zone and other close regions of the HGA with virtual sensing.

The drag coefficient of the HGA block is used to evaluate the HGA's off-track vibration in simulations. The spectrum results of the drag coefficient of the HGA block before and under control of this feedback control system are presented in Fig. 5. It is shown that most of the peaks in spectrum of the HGA off-track vibration become well suppressed with this feedback control system, especially for the maximum peaks around frequencies of 1480 Hz and 2940 Hz. These results indicate that the feedback control system with the virtual sensing of pressure disturbance at the wake zone of the HGA can provide good suppression on the flow fluctuations around the HGA and then enable the successful control on the HGA off-track vibration.

Fig. 1. Spectra of pressure fluctuation around the HGA at HDD rotation speeds of 7200, 9000, 10800 rpm respectively.

Fig. 2. Spectra of the HGA off-track vibration displacement at HDD rotation speeds of 7200, 9000, 10800 rpm respectively.

Fig. 3. Schematic architecture of the feedback active control loop with virtual sensing at CP₁ in the wake zone of the HGA.

Fig. 4. Contour of pressure disturbance around the HGA at the frequency of 1480 Hz, (a) before control, (b) under control with CP₁ as the pressure fluctuation cancellation point in the feedback architecture.

Fig. 5. Spectrum results of the drag coefficient of the HGA block before and under the feedback control with pressure virtual sensing.

REFERENCES

- [1] Q. D. Zhang, C. S. Tan, K. Sundaravivelu, M. A. Suriadi, G. L. Chin, T. H. Yip, E. H. Ong and N. Y. Liu, "Mitigation of flow induced vibration of head gimbals assembly," *Microsyst Technol.*, vol. 16, pp. 213-219, Mar. 2010.
- [2] H. Min, X. Huang and Q. Zhang, "Aerodynamic pressure fluctuations associated with flow-induced vibration of the head gimbals assembly inside a hard disk drive," *IEEE Trans. Magn.*, vol. 48, pp. 101-106, Jan. 2012.
- [3] X. Y. Huang, X. Wang and F. F. Yap, "Feedback control of rotating disk flutter in an enclosure," *J. Fluids Struct.*, vol. 19, pp. 917-932, Aug. 2004.
- [4] X. Y. Huang, M. E. Hoque and X. Wang, "An experimental study on feedback control of rotating disk flutter," *J. Fluids Struct.*, vol. 20, pp. 71-80, Jan. 2005.
- [5] S. J. Elliott, *Signal Processing for Active Control*, London, UK, Academic Press, 2001.