VIBRATION SUPPRESSION OF HARD DISK DRIVE MECHANISM USING INTELLIGENT ACTIVE FORCE CONTROL

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ABSTRACT

One of the key performances of a Hard Disk Drive (HDD) system is its ability to control or suppress the vibration occurred. The fast development of HDD technology such as in the aspect of high transfer rate, large amount of stored data and the emerging of portable HDD have giving a great challenge to researchers to come up with new solutions and effective techniques to control such a non-linear mechanical system accurately and robustly. This study focuses on the implementation of Active Force Control (AFC) scheme together with intelligent control technique which employing Fuzzy Logic (FL) and Iterative Learning Control (ILC) applied to the linear Voice Coil Motor (VCM) actuator in the HDD dynamics. This type of active control technique and vibration model was done through simulation study using MATLAB and Simulink. The performance of the Intelligent Active Force Control (IAFC) system was compared to the traditional proportional-integral-derivative (PID) control system in terms of tracking performance and system robustness in countering the disturbances, particularly the vibration and friction. The external vibration was modeled as sinusoidal and random form whereas the friction was modeled based on Coulomb friction. Sensitivity analysis of the system output response was conducted with respect to some variations in operating and loading parameters involved in the HDD system dynamics. The simulation results for each type of proposed controllers as well as from what had been discussed in comparative study part affirm the superiority of the proposed control techniques over its counterpart.

ABSTRAK

Salah satu kunci prestasi sistem ‘Hard Disk Drive (HDD)’ adalah kemampuannya untuk mengendalikan getaran yang berlaku. Perkembangan pesat teknologi HDD seperti dalam aspek kadar pemprosesan data yang cepat, sejumlah data yang besar yang disimpan dan munculnya HDD mudah alih telah memberikan cabaran besar kepada penyelidik-penyelidik untuk datang dengan penyelesaian-penyelesaian baru dan teknik yang berkesan untuk mengawal sistem mekanik dengan tepat dan kukuh. Penelitian ini memfokuskan pada pelaksanaan ‘Active Force Control (AFC)’ skim bersama-sama dengan teknik kawalan bijak yang menggunakan ‘Fuzzy Logic (FL)’ dan ‘Iterative Learning Control (ILC)’ diterapkan pada aktuator ‘Voice Coil Motor (VCM)’ dalam dinamik HDD. Jenis teknik kawalan aktif dan model getaran dilakukan melalui kajian simulasi menggunakan MATLAB dan Simulink. Prestasi ‘Intelligent Active Force Control (IAFC)’ adalah sistem yang dibandingkan dengan sistem kawalan tradisional ‘Proportional-Integral-Derivative (PID)’ dalam hal pelacakan prestasi dan ketahanan sistem dalam melawan gangguan, khususnya getaran dan geseran.Getaran luaran dimodelkan sebagai bentuk sinusoidal dan rawak sedangkan gesekan dimodelkan berdasarkan geseran ‘Coulomb’. Analisis sensitiviti respon sistem telah dilakukan dengan memperhatikan beberapa variasi dalam pelaksanaan dan ‘loading parameter’ yang terlibat dalam sistem HDD. Keputusan simulasi untuk setiap jenis kawalan dicadangkan daripada apa yang telah dibincangkan dalam bahagian kajian perbandingan seterusnya menegaskan keunggulan teknik kawalan yang dicadangkan berbanding teknik kawalan yang lain.

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AFC	Active force control
AFCAFL	Active force control and fuzzy logic
AFCAIL	Active force control and iterative learning
FL	Fuzzy logic
HDD	Hard disk drive
ILC	Iterative learning control
PCB	Printed circuit board
PID	Proportional-Integral-Derivative
PZT	Piezoelectric
VCM	Voice coil motor

CHAPTER 1

INTRODUCTION

1.1 General Introduction

The development of Hard Disk Drive (HDD) is getting faster nowadays. The industry competes with each other to produce a HDD which is able to store up to Gigabytes of data, transfer the data faster as well as to make the HDD portable and light in weight. Consequently, these factors have created numerous engineering studies such as academic research in order to investigate and improve the performance of HDD. One of the big areas in this research is to study on the vibration affect to HDD and its effective method to suppress the vibration occurred so that the performance can be increased. Vibration is one type of disturbance which is common to any mechanical system like HDD. In HDD, vibration may comes from the contact of its mechanical components during the read and write operation of data. Besides, the air gap between the end of the suspension (head slider) and disk during writing data onto the very high speed spinning disk also create the vibration in HDD. In addition, some external vibrations such as shock to a fixed or portable HDD may cause failure to the positioning mechanism of HDD. As a result, these sources of vibration will degrade the performance of HDD and cause significant error during its data track registration. To solve this discrepancy, the design development of each electromechanical component and control techniques applicable to HDD have been studied through various research.

1.2 Research Background and Contribution

Vibration suppression control in HDD becomes a significant area to be solved these several years. Research done to reject disturbance either internal or external vibration can be found in many literatures [1-6]. Through literatures, the controller's design has been the most important part to be developed and improved. The common control techniques used by others are servo control, feedforward control and optimal control. Many research also incorporated smart device like PZT as the actuator and sensor to enhance the servo performance of HDD. However, PZT does have some limitations for certain applications. For instance, it may produce error in reading the signal when the PCB where PZT is mounted deflected [7-9]. This could happen due to strain sensitivity of PZT. Hence, in this study, the research work was focussed on the implementation of new control algorithm to HDD positioning system. A novel control method known as AFC which never been applied to HDD system was proposed. The advantages of AFC method which is robust to disturbance of a dynamics system is expected to eliminate vibrations occur in HDD. The most challenging part of this research was to tune the value of estimated mass in the AFC loop. This estimation need to be properly approximated since the estimated mass will determine the estimated disturbance force to the system that is significant in achieving disturbance rejection [10]. Therefore, two control methods which AFC and ILC were embedded to the AFC loop in order to indentify the appropriate estimated mass of the system. On the other hand, comparative study with Anti Wind-up vibration control in HDD done by Hermann *et. al* [11] was conducted for validation purpose of the simulation results.

1.3 Problem Statements

In this study, the importance of vibration suppression is highlighted to ensure accurate positioning of head slider during read and write of data in HDD. There are two major things which going to be solved in this study. In the first part of this research, the AFC method is implemented to HDD positioning system. AFC is widely used in robotics system where research was done for trajectory of robot's arm. The implementation of this AFC has been improved the trajectory of the robot's arm successfully. One new area which using AFC technique was vehicle active suspension system done by Priyandoko *et. al* [10]. His work was to isolate the disturbances experienced by a vehicle suspension system. Thus, this study is important to use this advantageous AFC method to another new application that is HDD positioning mechanism system.

Secondly, this study focuses on one of the important criteria of AFC loop which is the estimation of mass matrix. A good estimation of the estimated mass is crucial when the system dynamics keep changing. As in HDD positioning system, this problem need to be solve since it involves with highly non-linear system. The dynamics of this system change whenever the loading parameters vary and hence produce different operating parameters. In this case, the crude approximation technique is not practical and effective to be applied to the HDD system.

Thus, other control method using fuzzy logic and iterative learning are embedded to the AFC loop in order to estimate the mass matrix intelligently.

1.4 Research Objective

The main objective of this study is to suppress the vibration phenomenon generated in HDD mechanism using intelligent AFC technique.

1.5 Research Scope

The scope of this study is:

i. Theoretical study on head positioning mechanism of HDD, control methods and Artificial Intelligence (AI) technique.
ii. Consider one degree of freedom (DOF) HDD mechanism actuated using linear Voice Coil Motor (VCM).
iii. Implement Proportional-Integral-Derivative (PID) controller and AFC methods in simulation by using Simulink.
iv. Consider Fuzzy Logic (FL) method and Iterative Learning Control (ILC) to be embedded into the AFC loop.
v. The main disturbance element considered is at low frequency vibration of the mechanism.
vi. Comparative study.

1.6 Research Methodology

This research is divided into several parts of study. Initially, some critical literature reviews were done related to HDD actuation system and find out the gap of knowledge in the previous research. After done with the literature, the dynamics of the HDD actuation mechanism was modelled based on linear VCM. Next, it was followed by the controller design stage and tested the controller by giving disturbance with variation in its parameters. The simulation part was applied in MATLAB/Simulink to obtain the response of the system. Finally, the results were analysed and validated by conducting comparative study.

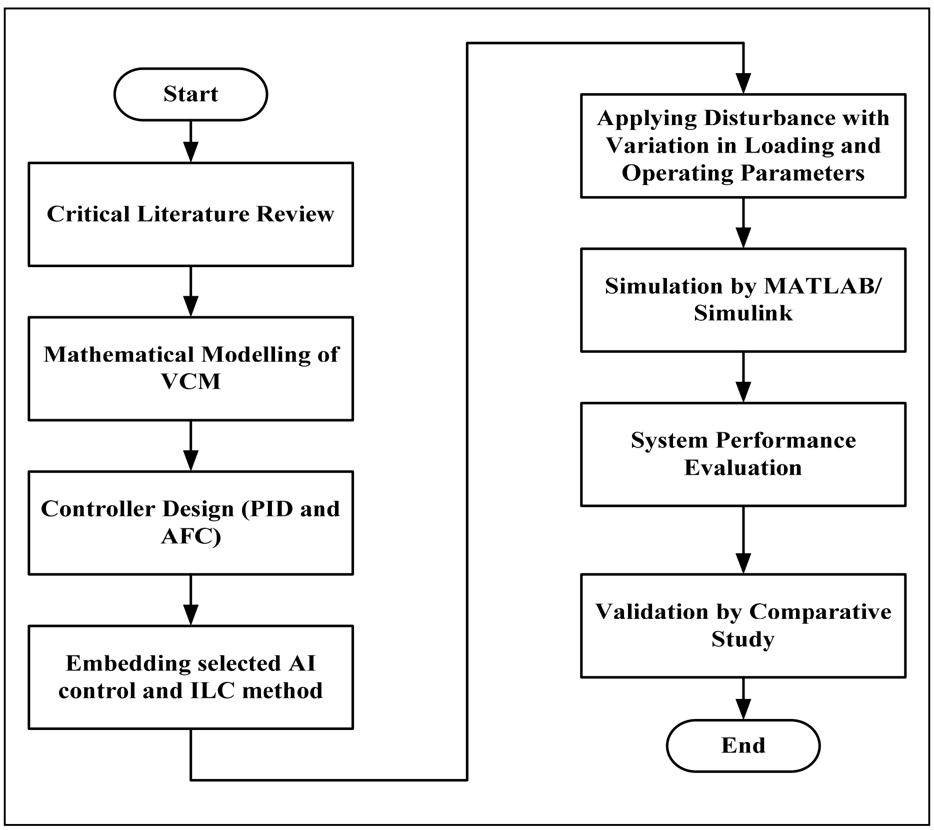

Figure 1.1: Research methodology

1.7 Outline of The Project Report

This thesis is organized into seven chapters. The critical literature reviews of related previous studies and all the theoretical frameworks used in this study are explained in Chapter 2. It also included the comparison of some related studies by previous researchers in vibration control of HDD system and the fundamental knowledge of control strategies to be used in this study. In Chapter 3, the significant starting part of this research is discussed which are the mathematical modelling and design of the controller. The modelling of linear VCM actuator as the dynamics system of HDD positioning mechanism is illustrated as it is required for the simulation of the control system. Besides, the control system block diagram of each proposed control methods is also represented in this chapter.

Meanwhile, Chapter 4 and 5 are dedicated for the simulation of HDD actuation mechanism by using the modelled linear VCM. Chapter four covers the simulation part of the conventional PID control and AFC whereas chapter five covers the simulation part of the intelligent control techniques embedded to the AFC loop. The intelligent control techniques applied in this study are the fuzzy controller and iterative learning control. In both chapters, the MATLAB Simulink models are shown together with the list of the control parameters used. The graphical approach of the parameters tuning followed by the simulation results are finally end the chapters.

The comparative study of all the simulation results is presented in Chapter 6. This comparative study is important due to the validation of the simulated results. The simulated results are discussed with respect to several operating and loading parameter conditions in order to meet the objective of this study. The transient performance characteristics and its frequency response are explained in detail which lies on the control techniques to estimate the mass matrix and trajectory track performance of proposed control schemes.

Lastly, Chapter 7 summarizes the research done and provides some possible future works that can be explored to improve and validate this study on vibration control of HDD positioning system.

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