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POSITIONING PERFORMANCE IMPROVEMENT OF A SERVOMECHANISM OF HARD DISK DRIVE IN A COMPUTER

Njoku O. Donatus [*1], Ejem Agbaeze [2], Nwandu C. Ikenna [2], Amaefule I. A.[3], Uka K. Kizito[3], Madu K. Andrew[4]

[*] Computer Science Department, Federal University of Technology, Owerri, Nigeria
[2]Computer Science Department, Federal University of Technology, Owerri, Nigeria
[3] Computer Science Department, Imo State University, Owerri, Nigeria
[4] Computer Science Department, Federal Polytechnic Nekede, Owerri, Nigeria

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ABSTRACT

This paper has presented positioning performance improvement of a servomechanism of hard disk drive (HDD) in a computer. It is desired to improve the transient response performance of servo positioning system of an HDD in computer. In order to do this, the mathematic equations representing the dynamics of the servomechanism were obtained and later transformed into transfer function representing the plant. A proportional integral derivative (PID) compenstaor was designed so as to meet the performance specifications of the HDD, PID tuning was used as the design method and a robust response time tuning method was employed subject to automatic (balance performance and robustness) design mode. The compensator is integrated with dynamic of an HDD to form a control loop. The simulation results obtained indicated that the designed controller largely improved the positioning performance of the system as well as its stability. This ensured improved track seeking and track following.

KEYWORDS: Hard disk drive, Servo positioning, Compensator, PID

I. INTRODUCTION

Despite the improvement in hard disk drive (HDD), the basic functional principle has remain unchanged [1]. There has been enormous improvement in the storage capacity, data access time and miniaturization of HDD in the last decade [2]. Today, there is a high rate of demand for storage capacity of HDD and this can attributed to the improvement witnessed so far its design. The continuous demand for improved hard disk drive has led to ever improving performance by data storage industry.

A hard disk drive (HDD) as a hardware component of is refer to non-volatile storage device. Data is stored in the hard disk in a digitally encoded form on a rapidly rotating rigid platters with magnetic surfaces. As the name implies, an HDD is a motorized mechanical system that uses the rotational principle of electric drives to carry out its storage function. A typical Figure of a hard disk drive is shown in Fig.1.

There are four major elements of a hard disk drive. The elements which are the platters, the circular discs in the hard disk where data a stored; the spindle, which keeps the platters at a specific distance of separation from one another so as to enable the read/write (R/W) arm to gain access; the read/write (R/W) heads, whose movement is controlled by the R/W arm and carry out the actual reading and writing function on the disk platters; and the actuator, also referred to as head actuator, is an electric motor that provides the servomechanism to control the R/w arm and direct data transfer to and from the platters.

The objective functions of the read/write head servo positioning system in HDD are track seeking and track following. In the track seeking function, the servomechanism moves the R/W head from initial track to a new

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defined destination track within the shortest possible time using a control strategy. The track following function ensures that the R/W head is maintained as close as possible to the destination track centre as data or information is being read from or written to the hard disk drive. Tracks are tightly packed concentric circles of each platter division. Information stored in hard disk are recorded in tracks. The track density of a hard disk drive is given as the reciprocal of the track width. This shows that an inverse relationship exists between the track density and its width and hence a closely spaced track will mean increased track density. Hence, has disk drive are being reduced in size but with increase in storage density, which also translate into increase in the track density, a more restrictive allowable variations of the R/w heads servo positioning from the actual track centre [3].

The recent trend in hard disk design is geared towards having miniaturized HDD with increasing storage capacities. This invariably means reduction in track width which results to lower error tolerance in the read/write head positioning [3]. Hence the servo positioning control required for track following must be able to handle such strict control in small hard disk drive. Many control strategies have been implement in literature and industries for improving the performance of the servomechanism in hard disk drive.

Fig.1: A typical hard disk drive servo system

Goh et al [3] presented a paper on design and implementation of a hard disk drive servo system using robust and perfect tracking approach. A robust perfect tracking (PRT) controller was implemented and the results obtained were compared to those of a proportional integral derivative (PID) controller. The results indicated that the designed PRT controller had much better performance than the PID for the servo system. Paulinus et al [1] presented servo position control in hard disk drive of a computer using MRAC integrating PID algorithm. A model reference adaptive control (MRAC) integrating a proportional integral derivative (PID) controller was developed to give the so called MRAC PID controller. The controller was combined with a model dynamic of a servo position of hard disk read/write (R/W) head. The results obtained indicated that the system response was largely improved with the adaptive gain chosen for the controller. Oldham et al [4] conducted a research on design and control of a dual-stage disk drive servo system with a high aspect ratio electrostatic microactuator. The design technique employed a multi-rate, multivariable control to evaluate the performance of the closed loop of a disk drive system with microactuator and a sensing position. The simulation results indicated that proposed structure was able to reduce off-track position error. Aysha et al [5] in their work on discrete PID control scheme for a hard disk drive servomechanism proposed a discrete time PID controller. A continuous time PID controller was designed initially and then converted to its equivalent value in discrete time so as to precisely move the read/write head of a hard disk with minimum overshoot and settling time. Christian et al [6] presented a compensator for optimum hard disk drive read/write head positioning and control. A compensator that ensured an optimum control of a hard disk drive read/write head 0.1 percent overshoot, 0.2 second settling time and a rise time of less than 5second to a unit step input was proposed. Uwe et al [2] presented a paper on Modeling and control of a dual stage actuator hard disk drive. A data-base approach was used for modeling and controller design of a dual-stage servo actuator in a hard disk drive. Discrete-time models of a voice coil motor

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(VCM) and a piezoelectric actuator were estimated using a weighted Hankel matrix based realization algorithm that employed frequency domain data. Classic and H_∞ loop shaping methods were used to design different dual-stage track-following controllers. Implementations were performed in real-time in the studied HDD. The obtained result seemed promising for data based modeling and control. Conway et al [7] presented a robust track-following controller design in Hard disk drives based on parameter dependent Lyapunov functions. Kaitwanidvilai and Nath [8] investigated the design and implementation of high performance hard disk drive servo controller using genetic algorithm (GA) based 2DOF robust controller. A technique for designing a robust controller for HDD with VCM actuator was proposed which employed GA to solve the control problem of H_∞ loop shaping with structured controller. Farrokhi et al [9] presented a paper on hard disk drive vibration damping using disturbance observer.

In this paper, a robust PID compensator is developed and implemented using MATLAB software to improve the positioning performance of a hard disk drive servo system. The objective is to design a controller that is implementable in software and integrated into a hard disk drive servo positioning system so as to ensure improved track-following performance.

II. MATERIALS AND METHODS

Dynamic Equation

The rotational dynamic equation of an HDD servomechanism can be obtained by considering the effective turning force of position assembly produced the electric current applied to the servomotor.

$$J\ddot{\theta} + C\dot{\theta} + K\theta = K_m i(t) \tag{1}$$

were J = the inertial of head servomechanism, C = the viscous damping coefficient of the bearings, K = the return spring constant, θ = the angular position (or displacement) of the head, K_m = the torque constant of the disk drive motor, and i = the supply current.

Taking a Laplace transform of Eq. (1) gives:

$$Js^2\theta(s) + Cs\theta(s) + K\theta(s) = K_m I(s) \tag{2}$$

Equation (2) further yields Eq. (3) as the transfer function defined as the ratio of the angular position θ of the disk drive head to the supply current I .

$$G(s) = \frac{K_m}{Js^2 + Cs + K} \tag{3}$$

The values of the parameters of the dynamic equation of a typical hard disk drive (HDD) R/W head servomechanism are stated in Table 1 below, and are taken from [10].

Table1: Values of the Parameters of a HDD R/W head model

Parameter	Unit	Value
J	Kgm^2	0.01
C	$Nmrad^{-1}s^{-1}$	0.004
K	$Nmrad^{-1}$	10
K_m	$Nmrad^{-1}$	0.05

Substituting these values into Equation (3) yields:

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$$G(s) = \frac{0.05}{0.01s^2 + 0.004s + 10} \tag{4}$$

Design Specifications

The HDD servo-positioning system is required to achieve the following specifications stated below to a unit step input:

I. Peak value less than 5%
II. Settling time less than 0.2s
III. Rise time less than 5s

Compensator Design and System configuration

In order to design the proposed compensator so as to meet the performance specifications of the HDD, PID tuning was used as the design method and a robust response time tuning method was employed subject to automatic (balance performance and robustness) design mode. The proposed controller designed using single input single output (SISO) of the MATLAB control tool is presented in Eq. (5).

$$C = 2.2537e + 05 \times \frac{(1 + 0.0093s)(1 + 0.29s)}{s(1 + 7.2e - 06s)} \tag{5}$$

The compensator is integrated with the servomechanism of the HDD drive to form a closed loop control system as shown in Fig.2.

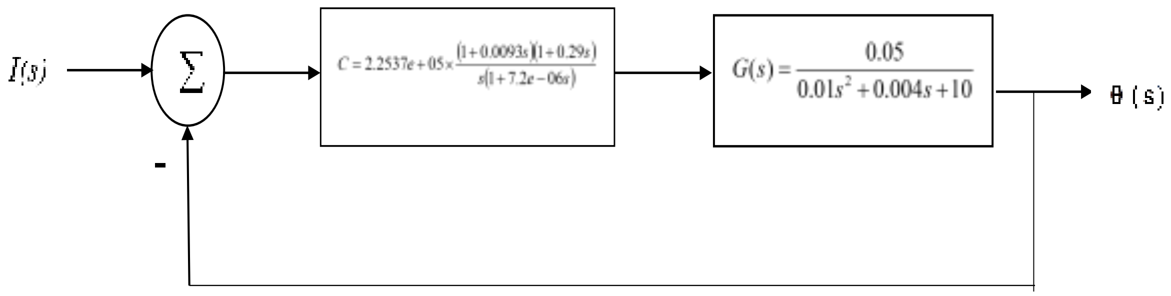

Fig. 2: Configuration of the servo positioning control loop

III. Simulation Results and Discussion

The simulation results obtained from the simulation performed using MATLAB software is presented in this section. Figures 3 and 4 represent the output responses of servo positioning system of the hard disk drive in uncompensated and compensated states. Figure 5 is the Bode plot showing the stability performance analysis of the system.

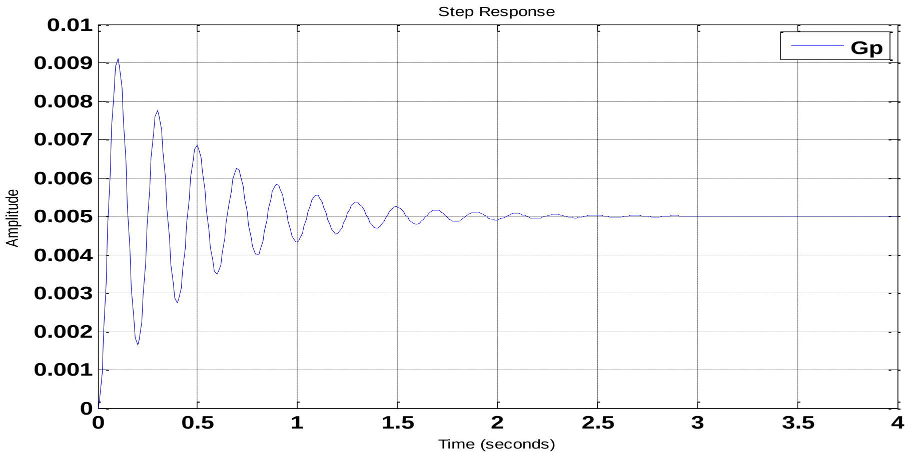

Fig.3: Output response of uncompensated system

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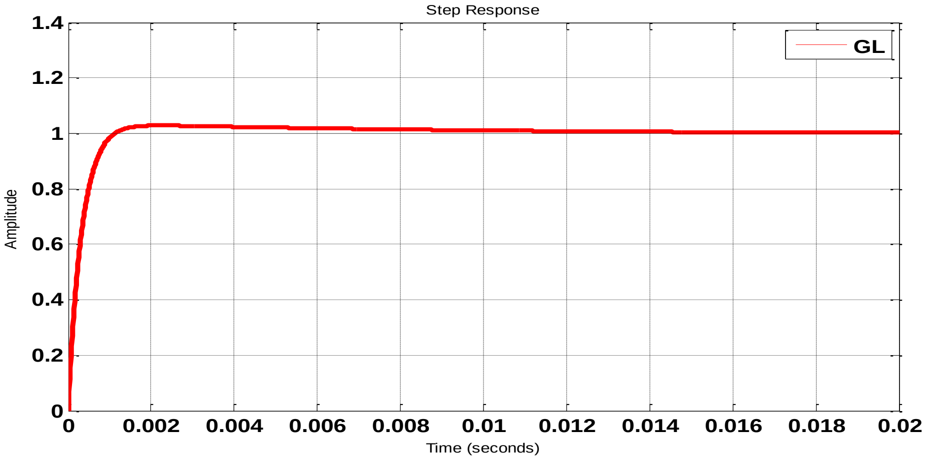

Fig. 4: Output response of compensated system

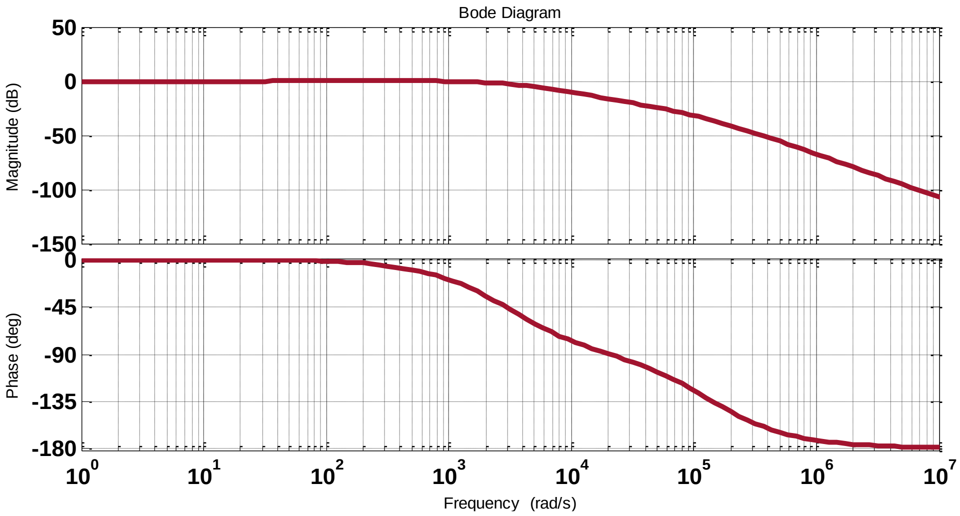

Fig. 5: Bode plot for the servo positioning system

Figure 3 shows the transient response performance of servo positioning system when the designed compensator has not been integrated with the plant. The simulation performance of the system show a cycling response of an overshoot of 82%, settling time of 1.9 seconds, and rise time 0.0345 seconds. The cycling show that the system is unstable and as such its performance needs to be compensated. In Fig. 4 the compensated response shows that the system performance has been improved with an overshoot of 2.84%, settling time 0.00537 seconds, and 0.000636 seconds. This shows that the system transient response performance and stability have been largely improved. The stability of the system is demonstrated in the Bode plot in Fig. 5.

It can be seen that in this paper a proportional integral deerivative (PID) compenstaor which improves the positioning performance of a hard disk drive (HDD) servo system has been presented. The model dynamic of an HDD in a computer is obtained. A PID compensator is designed using MATLAB software. The compensator is integrated with dynamic of an HDD to form a control loop. The simulation results show that with the compensator in the loop, the track seeking and track following of the disk drive is well improved.

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