Model Reference Adaptive Control Based PID Controller for Hard Disk Drive Read/Write Head Servo Posistioning System

Chisom Ifunanya Onyekwelu[1], C. A. Nwabueze[1], C. N. Muoghalu[1] , B. O. Ekengwu[2]

[1]*Department of Electrical and Electronic Engineering, Chukwuemeka Odumegwu Ojukwu University*
Uli, Nigeria
2Department of Electronic Engineering, University of Nigeria Nsukka, Nsukka, Nigeria

***Abstract**: This paper presents improving the head position servo control system of hard disk drive using adaptive mechanism. In order to carry out this task, the mathematical equation of hard disk drive servomechanism was presented as a transfer function to describe the dynamic behaviour of the R/W head position servo of hard drive in a computer system. A Model Reference Adaptive Control (MRAC) system was designed based on modified Massachusetts Institute of Technology (MIT) rule to determine the adaptive gain of the controller. The MRAC was enhanced with the addition of Proportional-Integral-Derivative (PID) control algorithm. Simulation analysis was conducted for uncompensated state of the R/W head positioning of the HDD. The performance of the system is largely influenced by cycling which results in instability and therefore maintaining accurate track for efficient read and write operation was not realizable. Despite the low rise time of 0.0373 s, the step response performance of the uncompensated system indicated high overshoot of 95.4% and prolonged settling time of 9.13 s. Furthermore, the system in this condition was not able to track the desired position, which in this case, is represented by a step input such that a final value of 0.0113 that resulted in steady state error of 0.9887. With the introduction of the proposed MRAC, the performance of the system was largely improved using the different adaptive gains tagged (MRAC1, MRAC2 and MRAC3). The adaptive controller in terms of MRAC1, MRAC2 and MRAC3 yielded different rise time of 0.0894 s, 0.0415 s and 0.0066 s; overshoot of 0.85%, 1.1%, and 1.15%. However, the settling time, final value and steady state error were all the same for the three adaptive gains. Simulation conducted assuming step in put disturbance after 5 s revealed that system position was deviated but this was quickly corrected immediately after 0.75 s for each gain of the adaptive controller. Performance comparison of the MRAC and PID controller showed that it provided better performance than the PID including handling the effect disturbance. Furthermore, the simulations conducted in terms optimal performance indices such as Integral Square Error(ISE), Integral Absolute Error (IAE) and Integral Time Absolute Error (ITAE) showed that the MRAC controller regardless of the adaptive gain significantly give finest error handling capability than PID controller by ensuring that more accurate track keeping is achieved by the R/W head positioning system. Generally, the MRAC with adaptive gain 6 (MRAC3) provided the minimum error and as such would be the best option to achieve the most desired optimal performance for the HDD positioning operation.*

Keywords— Controller, Hard disk drive, MRAC, PID, Servo positioning

1. INTRODUCTION

A huge improvement in the hard disk drive (HDD) regarding storage capacity, data access time and miniaturization has been achieved in the last decades, although its basic functional principle remains the same [1]. The HDD is regarded as the most preferred device for data storage because of its excellent scalability, low cost, and because it has highest areal density, biggest capacity, highest rate of data transfer and highest access speed compare to other data storage devices. There has been dramatic increase in data storage areal density of HDDs with respect to rapid development in magnetic recording technologies. The areal density of HDD is referred to the amount of data that can be stored within a given amount of physical space on its platters.

As a mechatronic system, the HDD has several parts that can be classified as mechanical components, electromechanical components, magnetic components, and electronics [2]. The media and the head are magnetic components of HDD system and are the parts of the disk responsible for storing and retrieving of data (binary information) [3]. The HDD system uses the read/write (R/W) head to record and retrieve information since data are stored in concentric tracks on a rotating magnetic coated disk. The R/W operation forms the two main functions of the head positioning servomechanism in HDD. This is called track seeking and track following. However, to practically achieve such non-volatile storage and retrieval of data involves several vital components such as a motor to rotate the disk, which serves as an actuator that enable the R/W head access the desired data. The HDD's R/W head is moved from the present track by the track seeking to a specified destination track in minimum time using a bounded control effort [4]. The head is maintained closely to the destination track centre by the track following as information is being read or written to the HDD. The inverse of the track width is known as the track density. The tracks on the surface of a HDD are expected to be written as closed but spaced as possible to reduce the HDD surface usage.

The working principle of HDD is such that information can be stored and retrieved from it using a magnetic R/W head. Information is actually arranged on concentric tracks. A control problem arises when it is desired that the R/W head be positioned over the appropriate track. This has an appreciable impact on the HDD performance.

The HDD servo-system uses servo patterns created by disk platters to identify the data tracks and servo sectors; and to determine the read head relative position to the track centerline, that is, Position Error Signal. The servo patterns are written on disk and serves as a reference point to the HDD servomechanism when no reference is on or inside the disk. This servomechanism produces the feedback positioning signal using the servo patterns. Several conventional mechanisms exist for providing the reference as the servo writing is carried out.

A HDD will need access to different tracks during normal operation. The rate at which information can be stored or retrieved from the HDD depends on how fast the read/write head can move between tracks. This paper focuses on improving the head positioning servomechanism of HDD using adaptive control mechanism.

2. READ/WRITE HEAD POSITIONING CONTROL SCHEME

In this section some of the recent studies related to the current study are presented to provide literature background. Aysha et al. [5] designed a discrete time PID controller to improve the performance of a HDD servo mechanism in terms of minimum overshoot and settling time. The controller was shown to outperformed discrete PI controller. Discrete time compensator was introduced into feedback control system of HDD device for accurate read/write (R/W) head operation in Mbaocha et al. [6] and Ezeobi et al. [7]. Model Reference Adaptive Control (MRAC) based PID (MRAC-PID) controller was implemented to improve the transient response performance of HDD by Eze et al. [1].The mathematical model of modern multi-actuator for head positioning system of HDD was carried out so as to enable the design of new control systems [8]. A feedback resonant controller was designed to suppress the resonance of piezoelectric micro-actuator made from lead zirconatetitanate (PZT) by Rahman et al. [9]. The transient response of HDD was improved including its stability using PID tuned compensator by Njoku et al. [10]. Sliding model control was applied to servo position system of dual stage actuator (DSA) hard disk drive (HDD) in Sonkham et al. [11]. Two typical kinds of head-positioning systems with nonlinearities of HHD that combined the improved event-triggering reset condition and an optimal reset law design problem were achieved using feedback-based optimal control scheme by Wang et al. [12]. Three actuation systems with different combinations of proportional plus integral (PI), proportional plus derivative (PD), and proportional plus integral plus derivative(PID) controller, lag-lead controller, lag filter, and inverse lead plus a PI controller were designed and analyzed through simulation to achieve high-precision positioning were proposed for triple-stage actuator HDD servo system by Hossain and Rahman [13]. A discrete time MRAC for head loading of HDD so as to decrease the effect of head striking was proposed in Boonpranchoo et al. [14]. A tracking controller for dual stage-actuator HDDs based on a frequency domain data-driven feedback control design technique was implemented to ensure stability and disturbance rejection [15]. Head positioning control for HDDs with dual-stage actuator was achieved using stroke controller, which was reduced the stroke of the piezo actuatorby 65% while the stability and positioning accuracy of the head positioning control system were nearly the same as that of decoupling filter system [16]. Robust control system for triple-stage actuator HDDs to achieve minimum position error signal (PES) while maintaining sufficient margins of stability was proposed by Pan et al. [17].

Despite the fact that a good number of studies has been carried out on HDD head servo positioning, the use of Model Reference Adaptive Control (MRAC) with PID control algorithm has not been largely considered. Where it was considered in Eze et al. [1], the effect of disturbance was not considered and this is the same for most of the previous studies. In this paper, an improved MRAC with PID control scheme is proposed to achieve faster read/write head movement between tracks including accurate head positioning for HDD system. The proposed Adaptive control is expected to provide reduced overshoot (or oscillation during operation), settling time and rise time including general control system performance in terms of error performance optimization.

3. METHODOLOGY

The method for the system design involves the mathematical description of hard disk drive (HDD) servo system and the development of an adaptive control scheme. Hence, this section is divided into three basic subsections namely, proposed system, dynamic model of HDD head positioning system and Model reference adaptive control (MRAC) with Proportional-Integral-Derivative (PID) controller.

3.1 Proposed System

The essence of the HDD head positioning servo system control developed in this paper is to ensure that an accurate head position is maintained along the centre of the track and fast head movement from one track to another selected. Consequently, an adaptive control system based on MRAC algorithm is implemented for HDD servo system using modified Massachusetts Institute of Technology (MIT) rule. The block diagrams of the HDD position servo system with conventional PID and the closed loop control system proposed in this work based on MRAC-PID is shown in Fig. 1 and 2.

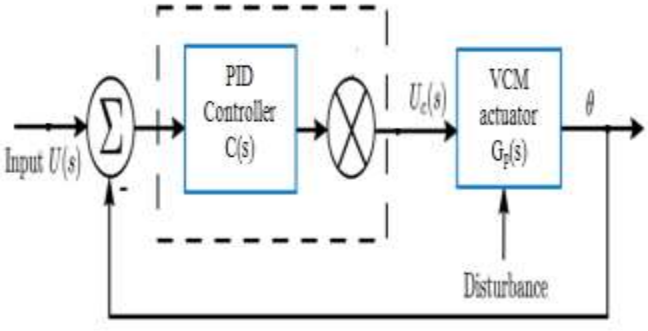


Fig. 1 *PID control HDD position servo system*

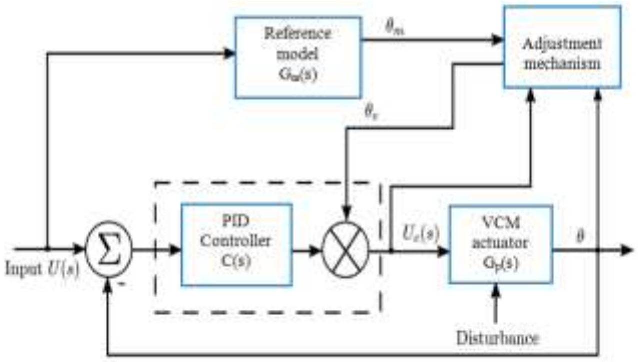


Fig. 2 *Proposed system architecture*

3.2 Mathematical Model of Voice Coil Motor of HDD

The voice coil motor (VCM) is a direct current (DC) motor, thus Fig. 3 shows the circuit arrangement of a DC motor in order to define the mathematical relationship between the rotary actuator torque and the coil current.

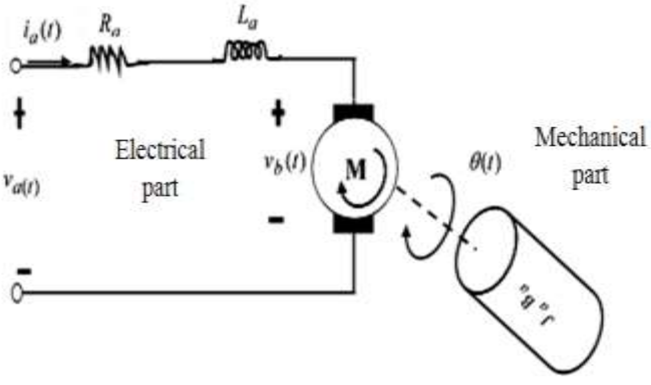


Fig. 3 *Circuit diagram of DC motor*

It can be seen from Fig. 3 that the DC motor circuit diagram is of two parts comprising the electrical and mechanical components [18]. Thus the equation that connects the rotary actuator torque and the coil current (which is the armature current of the DC motor) is given by:

$$\tau = K_m i_a \tag{1}$$

where K_m is the torque constant, and i_a is the VCM coil current (or armature current).

The motion of the rotary actuator torque is defined by:

$$\tau = J_a \frac{d^2\theta}{dt^2} + B_a \frac{d\theta}{dt} + K\theta \tag{2}$$

where J_a is the moment of inertia of the head assembly, B_a is the viscous damping coefficient of the bearing, K is the return spring constant, and θ is the angular displacement or position.

Combining (1) and (2) gives the mathematical model of HDD servo system given by the following differential equation:

$$J_a \frac{d^2\theta}{dt^2} + B_a \frac{d\theta}{dt} + K\theta = K_m i_a$$

(3)

Taking the Laplace transform of (3) assuming zero initial conditions, gives:

$$J s^2\theta(s) + B_a s\theta(s) + K\theta(s) = K_m I_a(s) \tag{4}$$

Rearranging Equation (3.4) as a transfer function expression of HDD head position servo system gives:

$$G_p(s) = \frac{\theta(s)}{I_a(s)} = \frac{K_m}{J_a s^2 + B_a s + K} \tag{5}$$

Substituting the values of the model parameters of HDD read/write head positioning servo system taken from Mbaocha et al. [6] as shown in Table 1, gives:

$$G_p(s) = \frac{9}{s^2 + 0.85s + 788} \tag{6}$$

Table 1: System parameters

Definition	Symbol	Value
Rotary actuator (motor)torque	τ	-
Coil current	i_a	-
Motor torque constant	K_m	9.0 Nmrad^{-1}
Moment of inertia of the head assembly	J_a	1.0 kgm^2
Viscous damping coefficient	B_a	0.85 $\text{Nmrad}^{-1}\text{s}^{-1}$
Spring constant	K	788 Nmrad^{-1}
Angular displacement	θ	-

3.3 Controller Design

Since the problem to be solved is that of the head-positioning servo system control, it means that accurate head positioning along centre of the track and the rapid movement of the head from track to track needs to be improved as shown in Fig. 4. Hence, a model reference adaptive controller

(MRAC) for HDD servo system is developed using modified MIT rule.

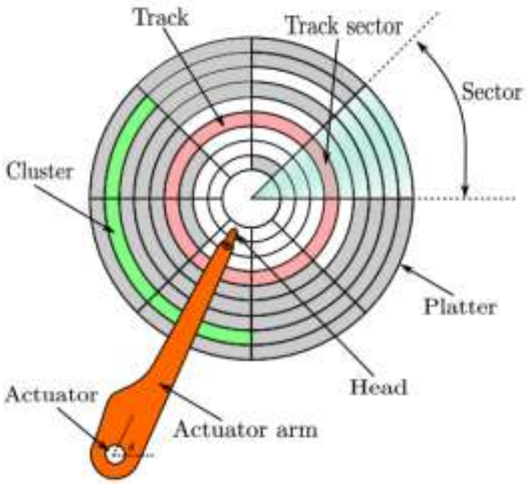


Fig. 4 *Illustration of HDD head position and movement [19]*

The control strategy of MRAC is such that the adaptive controller forces the plant or system (in this case the HDD R/W head) to follow or mimic a reference model. The performance of the system is described by the reference model. Thus, by adjusting the parameters of the controller, the output of the system tracks the reference model output. There are two loops that make up the MRAC: an inner loop and an outer loop. The inner loop has an ordinary controller, which in this work is a PID controller. The parameters of the controller are tuned by the outer controller, which is the adaptation mechanism as shown in the proposed scheme of Fig. 2.

3.3.1 Adjustment Mechanism

Let the difference between actual output θ_a of the process and the reference model θ_m output be defined as the error, e given by:

$$e = \theta_a - \theta_m$$

(7)

The cost function θ_c is expressed in terms of the error in (7) and is given by:

$$J(\theta_c) = \frac{1}{2} e^2 \qquad (8)$$

Minimizing the cost function such that the change in the parameter θ_c can be maintained in the direction of the negative gradient of J given by:

$$\frac{d\theta_c}{dt} = -\gamma \frac{\partial J}{\partial \theta_c} = -\gamma e \frac{\partial e}{\partial \theta_c} \qquad (9)$$

Equation (9) is an expression of the change in θ_c with respect to time in order to able to minimize the cost function to zero. The expression $\partial e / \partial \theta_c$ is called the sensitivity derivative, which depicts the change in error *e* with respect to the cost function θ_c. The quantity γ is a positive value that represents the gain of the adaptation mechanism of the controller.

Now the objective is to design a reference model defined characteristic performance that the dished antenna position system will automatically followed or tracked irrespective of the variations in system or environment parameters.

Let the transfer function of the dish antenna system be equal to $KG_p(s)$ where K is a parameter whose value is unknown. Thus the reference model is defined by:

$$G_m(s) = K_o G_p(s)$$

(10)

where K_o is a parameter whose value is defined, thus the error can be expressed by:

$$E(s) = KG_p(s)U(s) - K_o G_p(s) U_c(s)$$

(11)

where $KG_p(s)U(s) = \theta_a$ such that the control input to the plant is $U_c(s)$ and $K_o G_p(s) U(s) = \theta_m$ such that $U(s)$ is the control input to the reference model.

Therefore, control law is state as given by:

$$U(s) = \theta_c \times U_c(s)$$

(12)

Substituting (12) into (11) and taking the partial derivative gives:

$$\frac{\partial E(s)}{\partial \theta_c} = KG_p(s)U_c(s) = \frac{K}{K_o}\theta_m$$

(13)

Equating (9) and (13) gives:

$$\frac{d\theta_c}{dt} = -\gamma e \frac{K}{K_o}\theta_{model} = -\gamma^1 e \theta_m$$

(14)

where $\gamma^1 = \gamma K / K_o$ and the (14) is the law for parameter θ_c adjustment and represents the adjustment mechanism of the adaptive controller.

3.3.2 Reference Model

It is required that reference model $G_m(s)$ be designed approximately as a second order system since the HDD plant is a second order system as shown in (6).

The second order reference model is defined by:

$$G_m(s) = \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

(15)

where ω_n, ζ stands for the natural frequency and damping ratio. These quantities are determined as follows:

$$M_p = e^{-\pi\zeta / \sqrt{1-\zeta^2}}$$

(16)

where M_p is the maximum percentage overshoot of value 5%. Solving (16) given by:

$$\log_e\left(\frac{5}{100}\right) = -\frac{\pi\zeta}{\sqrt{1-\zeta^2}}\log_e^e$$

(17)

Results in $\zeta = 0.69$ and taking a settling time of $T_s = 1\text{s}$, the natural frequency of the system is computed using:

$$T_s = \frac{4}{\zeta\omega_n}$$

(18)

Thus $\omega_n = 5.77\text{rads}^{-1}$. Substituting these values into (15) gives:

$$G_m(s) = \frac{33.3}{s^2 + 7.96s + 33.3} \tag{19}$$

3.3.3 PID Controller

The PID controller is the common controller largely used in industrial control systems for three-term closed loop feedback mechanism and it is shown in Fig. 5.

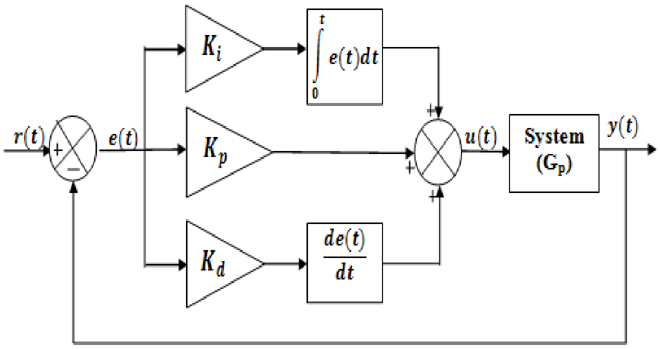


Fig. 5 *PID control system representation*

In its basic form, the control action can be expressed as [20]:

$$u(t) = k_p\left(e(t) + \frac{1}{T_i}\int_0^1 e(v)dv + T_d\frac{d}{dt}e(t)\right)$$

(20)

where $e(t) = r(t) - y(t)$ is the control error as shown in Fig. 5, k_p is the proportional gain, T_i is the integral time constant, and T_d is the derivative time constant. The corresponding transfer function is:

$$C(s) = \frac{U(s)}{E(s)} = k_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$

(21)

Actually, the transfers function in (21) representing a PID controller can be defined in simplified form as [21] given by:

$$C(s) = k_p + k_i\frac{1}{s} + k_d s \tag{22}$$

where k_p= 20.8, k_i= 100,k_d=10

The PID is developed in MATLAB using the MATLAB PID Tuner. The Simulink model of the proposed system is shown in Fig. 6.

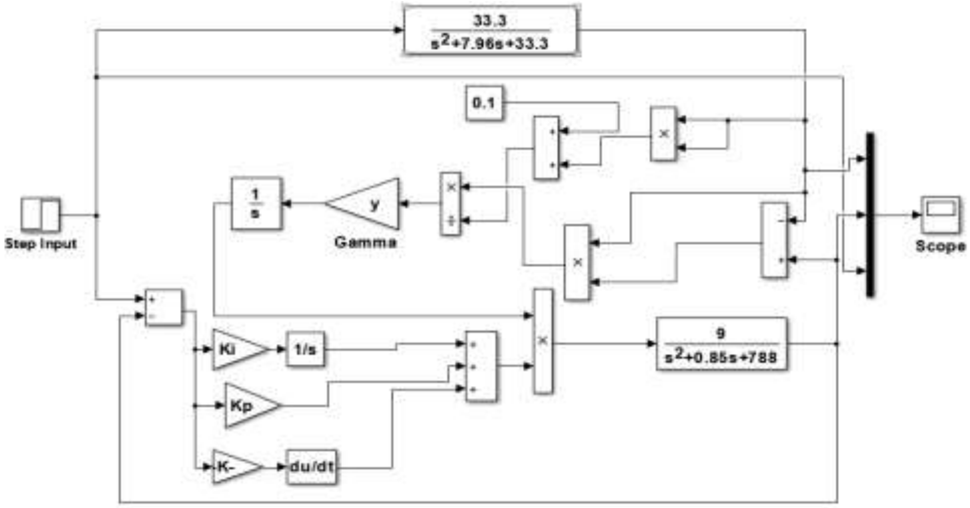


Fig. 6 *Simulink model of proposed system*

3.4 Optimal Performance Evaluation

The main objective of HDD position servo control system is to ensure that the R/W head is moved from the present track by the track seeking to a specified destination track in minimum time using a bounded control effort, while ensuring that positioning error is minimized. Hence, the positioning error is considered as the cost function to define the optimality of the system. In this work, the position of the R/W head θ is compared from the initial time t_0 to final time of t_f. This can be simulated to determine the performance of the PID controller and the proposed MRAC-PID on the HDD's R/W head position servo system in terms of positioning error, which includes the tracking performance, control effort (performance of the control input), and the error signal performance indices such as Integral Square Error (ISE), Integral Absolute Error (IAE) and Integral Time Absolute Error (ITAE). The expressions for the optimal performance indices are given by Eze et al. [22]

- Integral Square Error (ISE):

$$\mathrm{ISE} = \int_0^\infty e^2(t)dt$$

(23)

- Integral Absolute Error (IAE):

$$\mathrm{IAE} = \int_0^\infty |e(t)|\,dt$$

(24)

- Integral Time Absolute Error (ITAE):

$$\mathrm{ITAE} = \int_0^\infty t\,|e(t)|\,dt$$

(25)

4. RESULTS AND DISCUSSION

The time domain transient response characteristics performance of the HDD system assuming it is operating alone without a controller to compensate for error between the desired position and the actual position of the hard disk R/W head is shown in Fig. 7 and the numerical evaluation is shown in Table 2.

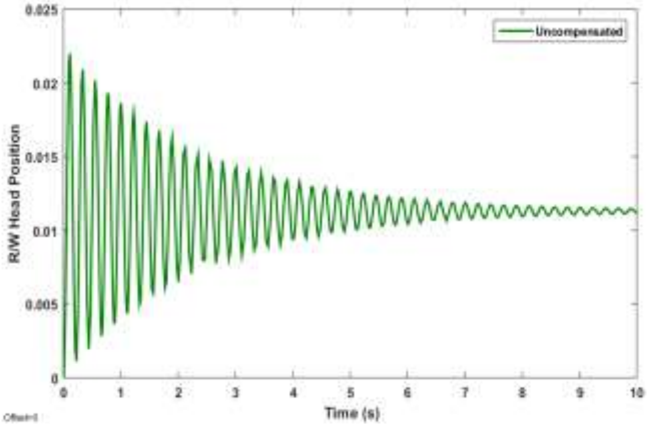


Fig. 7 Step response of HDD system (uncompensated)

Table 2 Numerical analysis of uncompensated system transient response

Parameter	Value
Rise time	0.0373 s
Overshoot	95.4%
Settling time	9.13 s
Final value	0.0113
Steady state error	0.9887

The step response of the uncompensated system shows significant cycling or oscillation of the R/W head of the HDD operation as can be seen in the 95.4% overshoot observed from the simulation plots analysis in Table 2. This cycling results in system instability and as such will lead to undesirable positioning of the R/W head of the HDD on appropriate track. This will largely affect the performance efficiency of the HDD positioning. Looking at Table 2, the final value of the system is 0.0113, which is far less than desired input (unit step input). Thus, the steady error of the system in this case is very high 0.9887.

The resulting simulation curves for the step response performance of the system considering different adaptive gains are shown in Fig. 8. The gains are tagged MRAC1 for adaptive gain gamma: $\gamma = 4$, MRAC2 for adaptive gain gamma: $\gamma = 5$, and MRAC3 for adaptive gain gamma: $\gamma = 6$. The numerical evaluation of each step response curve with respect to adaptive gain is shown in Table 3

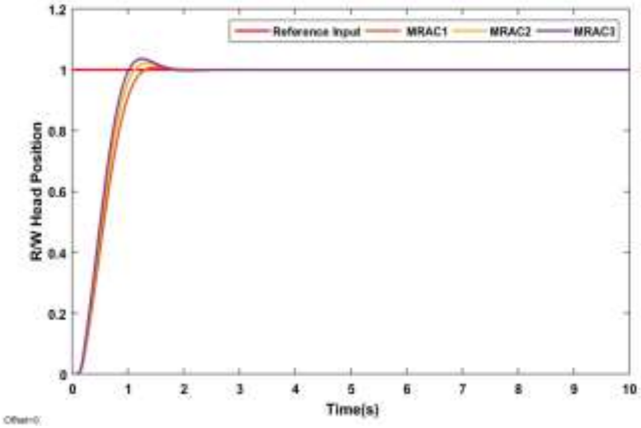


Fig. 8 Step response curves of HDD system (compensated)

Table 3 Numerical performance analysis of MRAC control R/W positioning system

Parameter	MRAC1	MRAC2	MRAC 3
Rise time	0.0894 s	0.0415 s	0.0066 s
Overshoot	0.85%	1.1%	1.15%
Settling time	1.45 s	1.45 s	1.45 s
Final value	1.0000	1.0000	1.0000
Steady-state error	0	0	0

As can be seen in Fig. 8, the simulation curves for the system step response in terms of the different adaptive gains implemented revealed that the reference (desire) unit step input was tracked by the controller for MRAC1, MRAC2 and MRAC3. Looking at Table 4.2, it can be seen that time domain transient response performance characteristic of the controller when any of the adaptive gain was implemented appeared almost the same or nearly equal. The only different performance metrics are the rise time and percentage overshoot. Though, with MRAC1, the system overshoot was 0.85% and this was followed by 1.1% with MRAC2 and later by 1.15% for MRAC3. However, with MRAC3, the system response to unit input measure in terms of rise time, revealed faster response of the time with adaptive gain equal to 6. Generally, with the adaptive gains simulated in this work the controller ensures that system is fast, stable, and able to keep the desired position of the R/W head at the appropriate track on the disk drive which in this case is considered to be the ability to follow and track a unit step input.

The simulation curves for the step response of the system for each adaptive in the presence of disturbance are shown in Fig. 9. The numerical evaluation of the effect of the disturbance is shown in Table 4.

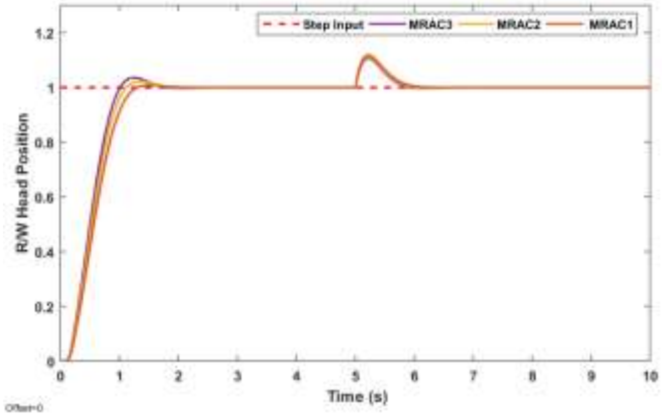


Fig. 9 *Step response in the presence of disturbance*

Table 4 Numerical performance analysis of MRAC with disturbance

Parameter	MRAC1	MRAC2	MRAC3
Rise time	0.0900 s	0.0511 s	0.0070 s
Overshoot	0.85%	1.1%	1.15%
Settling time	1.455 s	1.455 s	1.455 s
Peak Amplitude due to disturbance after 5s	1.117	1.112	1.106
Final value	1.0000	1.0000	1.0000
Steady state error	0	0	0

As shown in Fig. 9 and Table 4, the introduction of unit step disturbance after 5 s, causes the time domain transient response performance characteristic to be slightly offset from what was obtainable in the absence of disturbance as shown in Table 3. After 5 s as can be seen in Fig. 9, the introduction of disturbance caused the R/W position of the HDD to deviate from its desire position such that the amplitude of the position was 1.117, 1.112 and 1.106 with MRAC1, MRAC2 and MRAC3 respectively. However, this was quickly corrected by the controller after 0.75 s for each gain of the adaptive controller.

Simulation analysis regarding performance comparison of the proposed adaptive controller and conventional PID controller when implemented with R/W head positioning of the HDD system is shown in Fig. 10 in the absence of disturbance, whereas Fig. 11 shows the simulations in the presence of disturbance. Tables 5 and 6 show the numerical analysis of the comparison of both controllers regarding for Fig. 10 and 11 respectively.

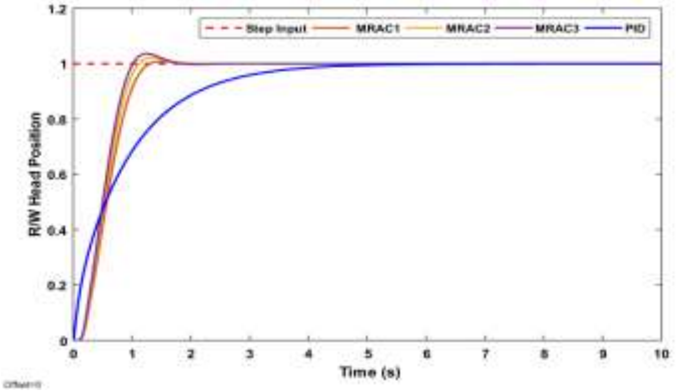


Fig. 10 *Step response performance comparison (no disturbance)*

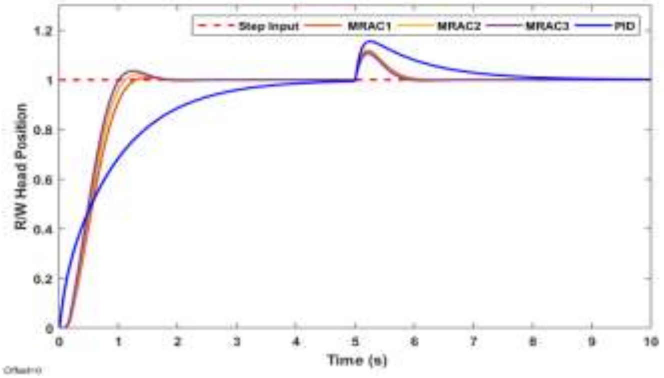


Fig. 11 *Step response performance comparison (no disturbance)*

Table 5 Numerical performance comparison of MRAC and PID

Parameter	MRAC1	MRAC2	MRAC3	PID
Rise time	0.0894 s	0.0415 s	0.0066 s	0.3169 s
Overshoot	0.85%	1.1%	1.15%	0 %
Settling time	1.45 s	1.45 s	1.45 s	2.51 s
Final value	1.0000	1.0000	1.0000	1.0000
Steady-state error	0	0	0	0

Table 6 Numerical performance analysis of MRAC and PID with disturbance

Parameter	MRAC 1	MRAC2	MRAC3	PID
Rise time	0.0900 s	0.0511 s	0.0070 s	0.3207s
Overshoot	0.85%	1.1%	1.15%	0%
Settling time	1.455 s	1.455 s	1.455 s	2.617 s
Peak Amplitude due	1.117	1.112	1.106	1.155

to disturbance after 5s				
Final value	1.0000	1.0000	1.0000	1.01
Steady state error	0	0	0	

Figure 10 is the step response performance evaluation of the proposed MRAC and conventional PID controller. Looking at the simulation curves in Fig. 10 and numerical analysis of the curves in Table 5, it can be seen that the proposed MRAC outperforms the PID in terms of all the time domain parameters except the percentage overshoot. However, this will not in any way limit the superiority of the MRAC over the PID controller since before the PID will even rise and settle, the MRAC must have completed the control action required by the R/W head positioning system of the HDD to achieve enhanced and favourable track keeping operation. This is because, with the MRAC, the R/W head function is achieved faster (in terms of rise time) and stability achieved even faster (in terms of settling time).

Figure 11 is the step response performance evaluation of the MRAC and PID controller when the system is subjected to parameter variation due to unit disturbance input that enters the system. The simulation curves revealed that with disturbance introduced into the system after 5 s, the stability of the MRAC and PID controlled R/W position of HDD was altered which resulted in the position of the R/W head being displaced above the desired value (unit input). The displaced values of the R/W head position from its expected position due to disturbance in the system as shown in Table 6 are 1.117 for MRAC1, 1.112 for MRAC2, 1.106 for MRAC3 and 1.155 for PID respectively. This represents 11.7%, 11.2%, 10.6% and 15.5% displacement from the expected or desired position for MRAC1, MRAC2, MRAC3 and PID control system. Also, while it took the MRAC 0.75 s to recover after the disturbance was introduced, it took 3.01 s for the PID controller to return and stabilize at the desired value as shown in Fig. 11. Thus, using the PID controller for R/W head positioning control of the HDD will make the system to suffer largely with prolonged negative effect when disturbance or parameter variation probably due to nonlinear effect of current amplifier or any distortion in component behaviour occurs.

In order to ascertain the MRAC gain that provided optimal performance in terms of the deviation of the actual output from the desired output (error), simulation results are presented in terms of the three adaptive gains (MRAC1, MRAC2 and MRAC3) including the PID controller. The analysis is conducted in terms error signal performance indices called integral square error (ISE), integral absolute error (IAE) and integral time absolute error (ITAE). The plots and the numerical evaluations of the system performance obtained from the MATLAB/Simulink simulations carried out are presented in Fig. 12 and Table 7.

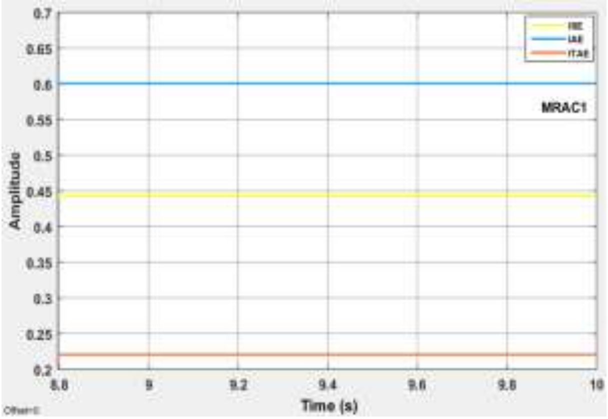


Fig. 12a Error performance indices for MRAC1

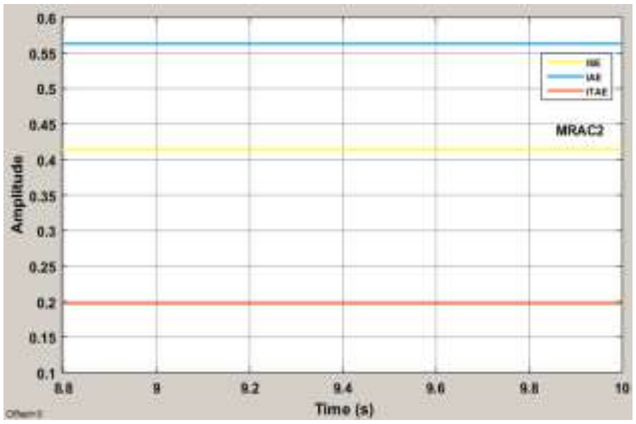
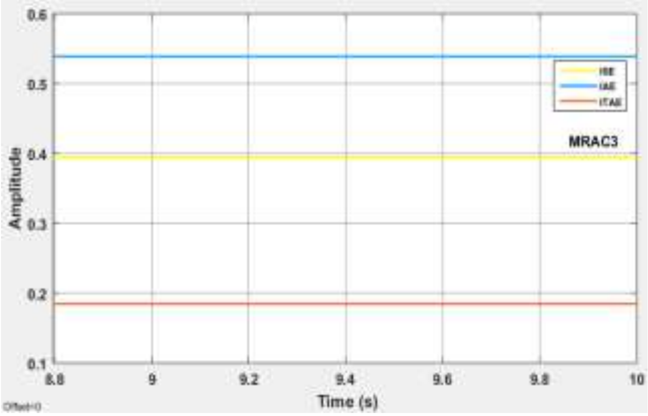


Fig. 12b Error performance indices for MRAC2



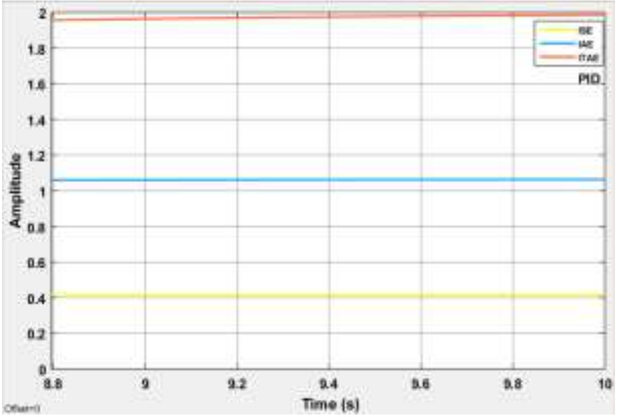


Fig. 12c Error performance indices for MRAC3

Fig. 12d Error performance indices for PID

Table 7 Numerical analysis of error performance indices

Control Scenario	ISE	IAE	ITAE
MRAC1	0.443	0.6005	0.2206
MRAC2	0.4146	0.563	0.1972
MRAC3	0.3942	0.5388	0.1847
PID	0.4189	1.064	1.987

Looking at Fig. 12 and Table 7, it can be seen that the proposed adaptive controller provided the least or minimum error performance when the adaptive gain was 6 (MRAC3). That is for positioning control action; the proposed controller will provide the optimal performance with adaptive gain of 6. However, for the three adaptive gains implemented, the proposed scheme outperforms the PID controller. As it can be seen, in Table 7 that the PID controller was the least error performance except for ISE where it outperformed MRAC1.

5. CONLUSION

In this paper the read/write (R/W) head position servo control system of hard disk drive using adaptive mechanism that is based on Model Reference Adaptive Control (MRAC) has been presented. The mathematical equation of hard disk drive servomechanism was respected as a transfer function to describe the dynamic behaviour of the R/W head position servo of hard drive in a computer system. An MRAC system was designed based on modified MIT rule to determine the adaptive gain of the controller. The MRAC was enhanced with the addition of PID control parameters. The proposed control scheme was model in MATLAB/Simulink environment for the purpose of analyzing its effectiveness. The evaluation of the performance of the HDD system was basically performed under three conditions that include open loop (or uncompensated system), closed loop control in the absence of disturbance or system parameter variation, and closed loop control in the presence of disturbance. The proposed adaptive controller was implemented with three gains of which from the simulation results, it was observed that any of the gain can be used to effectively improve the performance of the R/W head positioning of HDD. The proposed control scheme was further compared with the popular PID control technique, where it proved to be superior.

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