

# Assessment of Position Control of DC Servomotors with PID and Sliding Mode Control Approach

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**Abstract:** A position control of a discussion of DC servomotors is addressed in this article via a novel adaptive PID with sliding mode control approach. In this works to introduce the exact type of power control by sliding mode control for position and speed control of DC servo motor. The paper contributes union and examination of DC servo motor with sliding mode controller and a regular PID controller. This procedure has done through the demonstrating and reproductions are done and their performing is evaluated as in consistent and in addition in a transient state. Thusly, the DC servo motor position drive is dubious to parameter grouping and load disturbing effect, a liberal control approach in light of sliding mode. The proposed approach has the additionally favored standpoint that, for outside unsettling influence, it just requires a bound to exist, without having to know the extent of this bound. The proposed controller is connected to control a model of unverifiable acceptance servomotor subject to huge unsettling influences and a model of DC servomotor with obscure parameters and vulnerability in load condition. In this article, the helpfulness of the anticipated Procedure is approved by performing simulations utilizing MATLAB device. The reproduction comes about an exhibit that the part of the sliding mode-based course of action is supplementary strong than robust than fixed gain PID controller.

**Keywords:** DC Servomotors, Sliding Mode Control, PID Controller

## Introduction

Following is every now and again connected with servomechanism applications demanding high accuracy in rotor situating (Barambones and Etxebarria, 1999). Automation plays a very vital role in our everyday life, it can be established in practically any robotic manipulator and electronic appliance we use in day-to-day life, starting from air conditioning systems, automatic doors and automotive battery-operated vehicle control systems to additional innovative machinery system such as robotic arms and thousands of industrial, scientific and research applications (He *et al.*, 2018.). Presented This paper underwrites modeling and investigation of governing of DC servo motor with PID controller and SMC (Choudhary *et al.*, 2018). DC servo motors are one of the main modules of automatic control systems used in nowadays (Hung *et al.*, 1993). The position control of the DC servo motor necessary to study because DC servo motors are broadly used in servomechanism (Mondal and Mahanta, 2013). DC servo motor has shortcomings of undefined and nonlinear characteristics which slow down the working of controllers. On the other

side based on these observations, Sliding Mode Control (SMC) is one of the widespread control methodologies to a pact with the nonlinear uncertain system (Kassem and Yousef, 2009). The main reason behind using a servo is that it provides angular precision, i.e., it will just pivot as much we need and after that stop and sit tight for next flag to make additionally move (Ghany and Bensenouci, 2004). This is dissimilar to an ordinary electrical motor which begins pivoting as and when control is connected to it and the revolution proceeds to the point when we turn off the power. These characteristics of the sliding-mode control might be occupied with controlling of a DC servo motor. There are two fundamental strides in the outline of SMC, right off the bat to choose a sliding surface that models the required closed loop execution and furthermore to outline a control law with the end goal that the stage plane directions of the system are constrained towards the sliding surface. The sliding-mode manage can provide many proper properties, which includes right overall performance against unmodeled dynamics (Qureshi *et al.*, 2018), insensitivity to parameter versions, outside disturbance rejection and rapid dynamic response. The unexpected instability can arise due to unwanted

chattering effect because it excites unmolded high-frequency plant dynamics (Ghany and Bensenouci, 2004).

In this article presents a position and speed control of a DC servo motor drive system with sliding mode control approach techniques. The purpose of the designed controller is to force the motor speed and position to follow the desired tracks without excessive overshoots undershoots and zero steady state error. The system responses compared with a fixed gain PID controller (Lyshevski, 2012). The PID controller is chosen on the grounds that the performance cost of the PID controller is modest and it is utilized as a part of ventures on an extensive scale. A MATLAB based simulation is done to demonstrate the acceptability of the proposed controller.

### Description of DC Servo Motor Modelling

The transfer function of the DC servomotor can be imitative consuming Kirchoff's voltage law and Laplace transform as resulting: This segment demonstrates the plan of a controller to control the position and speed of the DC servo motor. The block diagram of the DC servo motor is shown in Fig. 1. The dynamic equations below describe the behavior of the motor (Yousef, 2012). A DC motor drive is an actuator that converts the electrical form to mechanical revolution utilizing the standards of electromagnetism. Three conditions of movement are crucial to the determination of the exchange work. Connections amongst torque and current, voltage and angular displacement and torque and system inertias are utilized.

The differential equation governing the electrical part of the model can be written:

$$V = IR + L \frac{di}{dt} + E \tag{1}$$

We can say that Back-electromotive force (emf)  $E_b$  can be found by.

Using the equation shown below:

$$E_b = K_a \frac{d\theta}{dt} = K_a \omega_r \tag{2}$$

where,  $E_b$  is the induced voltage,  $K_a$  is the motor torque Constant and  $\omega_r$  is the angular rotating speed. It can be seen that  $\omega_r$  can be calculated by the equation shown below:

$$\omega_r = \dot{\theta}_r \tag{3}$$

Using the Laplace Transform:

$$\omega_s = s\theta_s \tag{4}$$

Our motto in this phase is to control the angular rotating Speed by controlling the input voltage  $V_a$ . Where:

- $J$  = Rotor moment of inertia
- $B_m$  = Damping ratio
- $T_L$  = Motor Load Torque
- $i_a$  = Armature Current
- $E_b$  = Back emf
- $\theta_r$  = Angular position of rothe tor
- $K_a$  = Electromotive force constant
- $\omega_r$  = Measured angular Speed
- $R_a$  = Motor Armature Resistance
- $L_a$  = Inductance
- $V_a$  = Armature Voltage

The resulting transfer function:

$$\frac{\omega_r}{V_a} = \frac{K_a}{(J_s + B_m)(L_a s + R_a) + K_a^2} \tag{5}$$

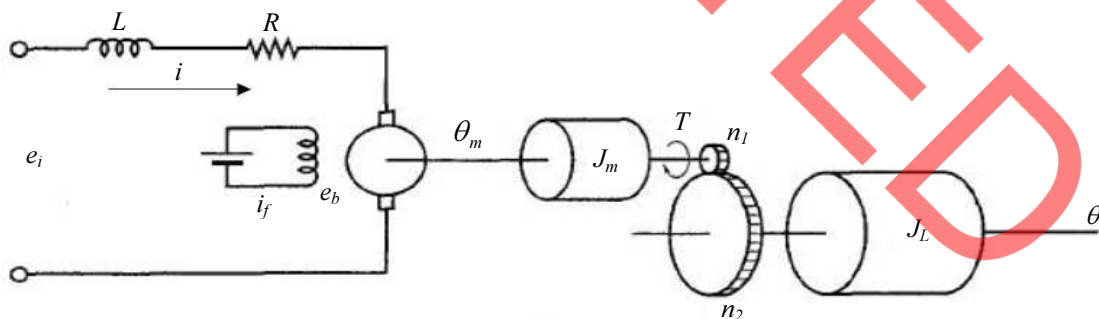


Fig. 1: DC servo motor

**Table I:** Parameters of Dc servo motor

Parameters	Values
Armature resistance $R_a$	2.7Ω
Armature inductance $L_a$	0.004H
Motor inertia $J_m$	0.0001
Viscous friction constant $B_m$	0.00008
Back emf constant $K_e$	0.11 V-sec/rad
Torque constant $K_t$	0.11N-m/A
Gear constant $K_{gear}$	0.1
$T_i$	0.0001
D	±1
$K_p$ (proportional constant)	0.5
$K_i$ (integral constant)	0.034
$K_d$ (derivative constant)	31

Our real concern in this exploration is the correct control of the angular speed of the motor; since angular speed is the part that experiences most the non-linearity. Figure 1 demonstrates the Block graph which expresses to the servomotor system utilizing MATLAB SIMULINK. Table 1. Given the parameters of DC servo motor.

Permanent magnet DC motor actuated servo system with all its modeling is represented by the following differential equations. The power converter dynamics is represented by the differential equation and the applied armature voltage to the motor is controlled by varying the amplifier duty ratio'. The following differential equations are taken to mock-up the transient behavior of DC servo motor:

$$\frac{dv_a}{dt} = \frac{1}{T_i} V_a + \frac{K_i}{T_i} d \quad (6)$$

$$\frac{di_a}{dt} = \frac{1}{L_a} V_a - \frac{R_a}{L_a} i_a - \frac{K_a}{L_a} \omega_r \quad (7)$$

$$\frac{d\omega_r}{dt} = \frac{K_a}{J} i_a - \frac{B_m}{J} \omega_r - \frac{1}{J} T_L \quad (8)$$

$$\frac{d\theta_r}{dt} = \omega_r \quad (9)$$

From the exceeding equation, we can write as according to space-state model:

$$X(t) = Ax + Bu \quad (10)$$

$$\begin{bmatrix} \frac{dV_a}{dt} \\ \frac{di_a}{dt} \\ \frac{d\omega_r}{dt} \\ \frac{d\theta_r}{dt} \end{bmatrix} = \begin{bmatrix} -\frac{1}{T_i} & 0 & 0 & 0 \\ \frac{1}{L_a} & -\frac{R_a}{L_a} & -\frac{K_a}{L_a} & 0 \\ 0 & \frac{K_a}{J} & -\frac{B_m}{J} & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} V_a \\ i_a \\ \omega_r \\ \theta_r \end{bmatrix} + \begin{bmatrix} \frac{K_i}{T_i} \\ 0 \\ 0 \\ 0 \end{bmatrix} d + \begin{bmatrix} 0 \\ 0 \\ -\frac{1}{J} \\ 0 \end{bmatrix} T_L \quad (11)$$

## PID Controller

The PID controller is very widely used in the industries. A PID controller is the simple three-term controller. The letter P, I and D stand for P- Proportional, I- Integral, D- Derivative. The main function of the PID controller is to make the plant less sensitive to changes that take place in surroundings. The basic PID controller composes of three terms proportional (P), derivative (D) and integral (I) to stabilize the response of the system. In this paper, conventional PID-ZN (Ziegler–Nicholas) closed loop tuning process has been commonly used (Utkin *et al.*, 1993):

$$Y(t) = e(t)K_p + K_i \int_0^t e(t)dt + K_d d_{e(t)} \quad (12)$$

Equation (xii) shows the output of the PID controller:

Where:

$e$  = Error signal

$K_p$  = Proportional Constant

$K_i$  = Integral Constant

$K_d$  = Derivative Constant

## Sliding Mode Controller

The sliding mode controller has been produced by consolidating the idea pole placement technique and power rate achieving law (Hung *et al.*, 1993). Given that the system described by Equation 10 and 11, Controllability is a vital property of a control system and the controllability property assumes an urgent part in numerous control issues, for example, stabilization of unstable systems by feedback, or ideal control.

Controllability of the system saw by traditional strategy:

$$X(t) = Ax + Bu \quad (13)$$

By testing the rank of the controllability matrix  $Q_c$ , where:

$$Q_c = [B \quad AB \quad A^2B \dots A^{(n-1)}B] \quad (14)$$

For the given system, in this calculation, we have to find the Rank = 4. Subsequently the rank of the  $Q_c = 4$ .

Therefore, the system is fully controllable. Every sliding mode controller design needs two main things, firstly the designing of the sliding surface and secondly the synthesizing of control law.

Utilizing the idea of variable structure framework, the plan of the sliding mode controller is performed. The non-linear sliding surface is (Hsu *et al.*, 2005):

$$X = P_1V_1 + P_2i_a + P_3\omega_r + P_4\theta_r + P_5E_a \quad (15)$$

So that:

$$\ddot{X} < 0$$

The basis of Lyapunov stability theory which the control law is derived:

$$V = Sgn(P_1v_1 + P_2i_a + P_3\omega_r + P_4\theta_r + P_5E_a) \quad (16)$$

$$-1 \leq V \leq 1$$

With the use of Pole placement technique and power rate reaching law (Hung *et al.*, 1993; Mondal and Mahanta, 2013; Kassem and Yousef, 2009; Ghany and

Bensenouci, 2004; Lyshevski, 2012; Yousef, 2012; Utkin *et al.*, 1993; Hsu *et al.*, 2005; Lin and Hsu, 2004).

### Result Analysis

The result shown in Fig. 2 The position of the servo system with a PID controller. Following graphs show that simulation results of a DC servo motor running in at No load and at ON load all situation controlled with PID controller and Sliding Mode Control Approach.

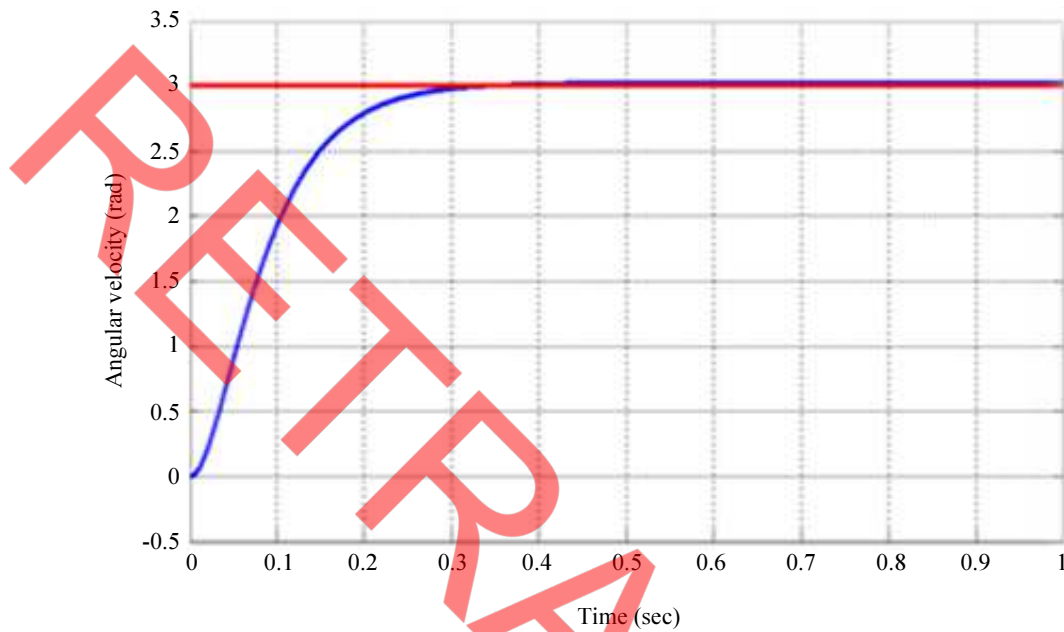


Fig. 2: The position of the servo system with a PID controller

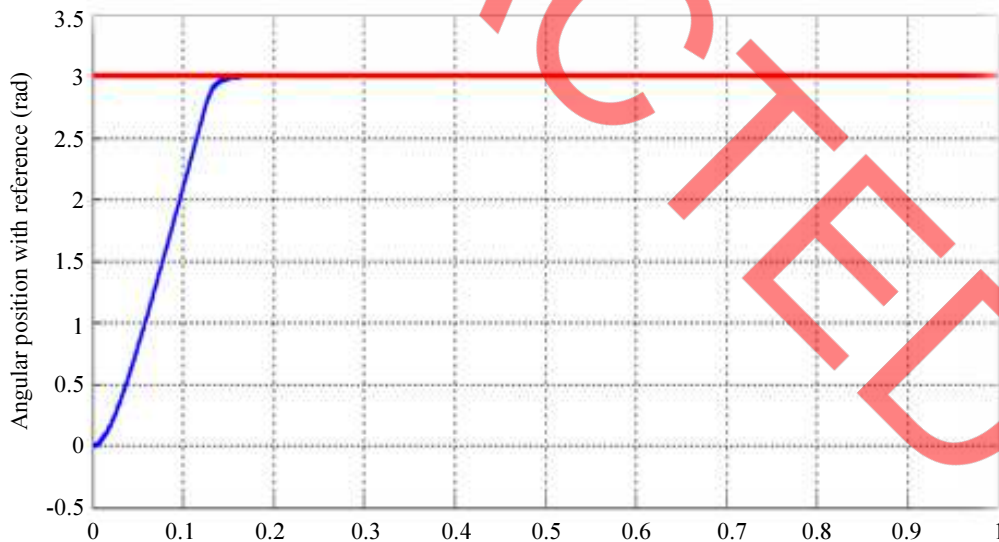
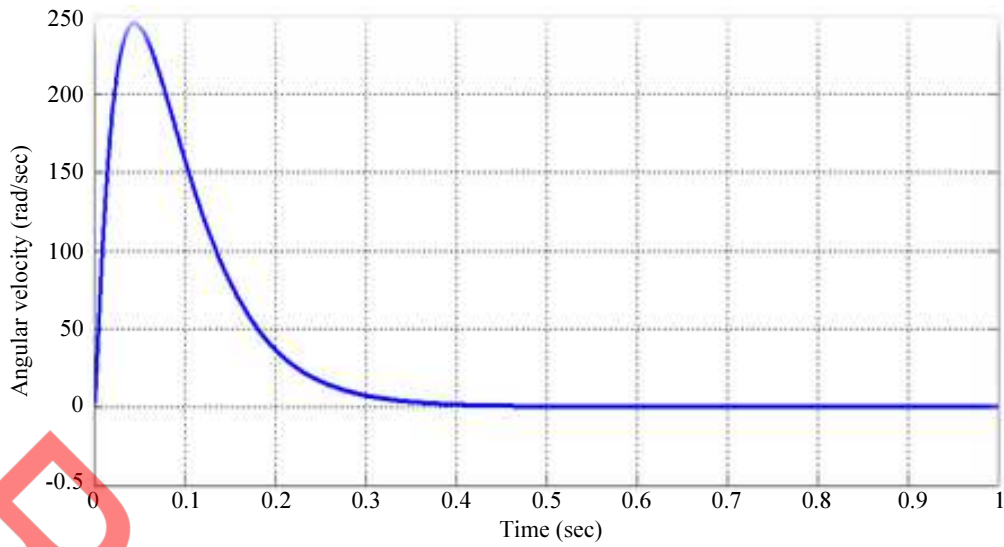
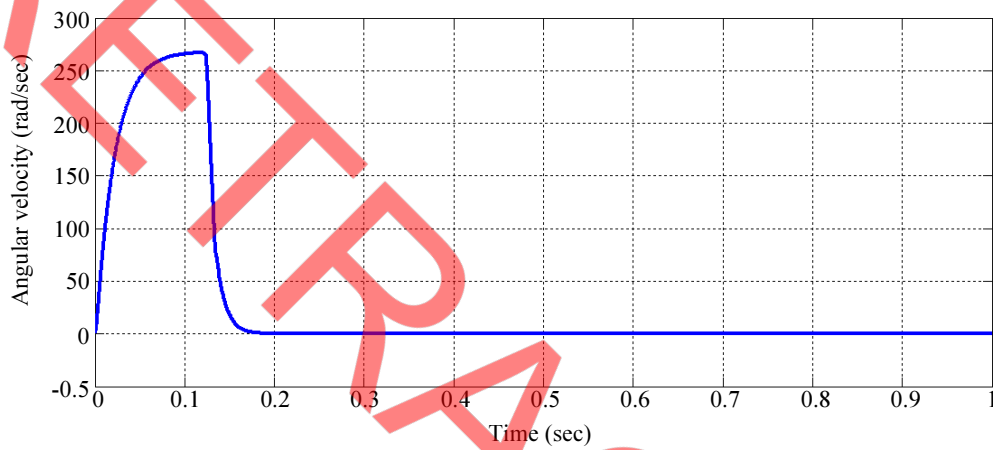


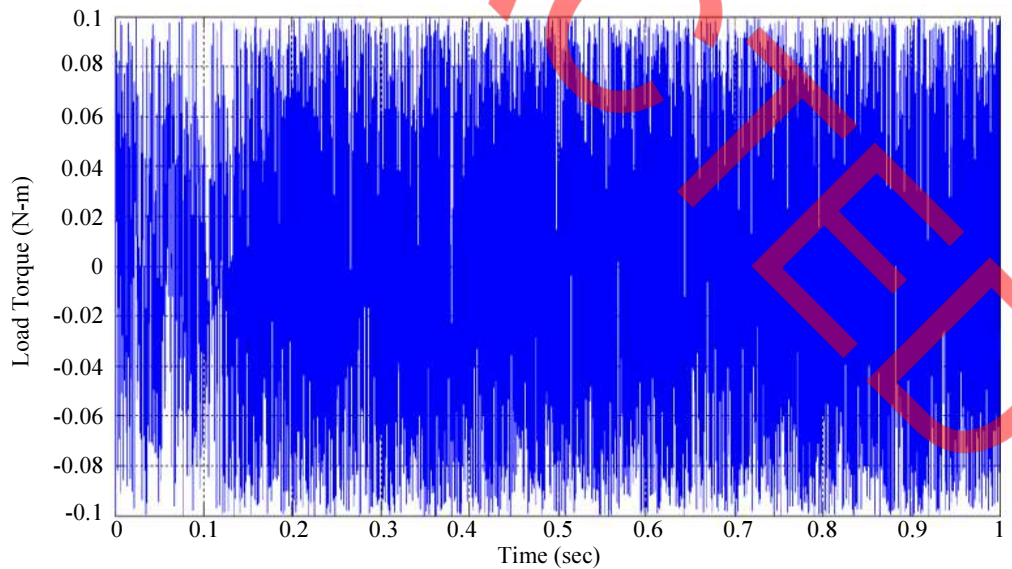
Fig. 3: The position of the servo system with SMC at no load



**Fig. 4:** Angular velocity of servo system with PID controller at no load

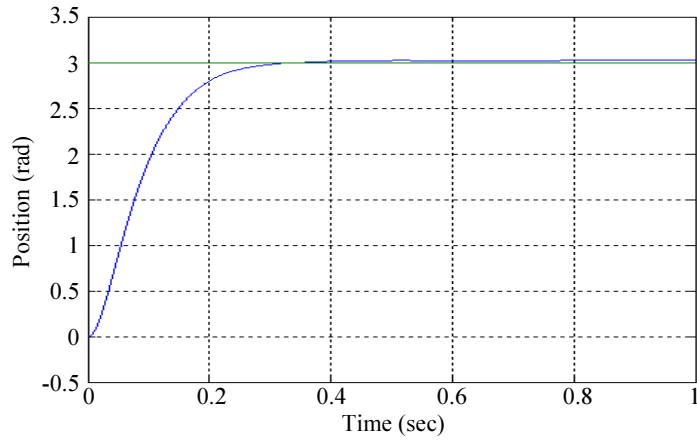


**Fig. 5:** Angular velocity of servo system with SMC

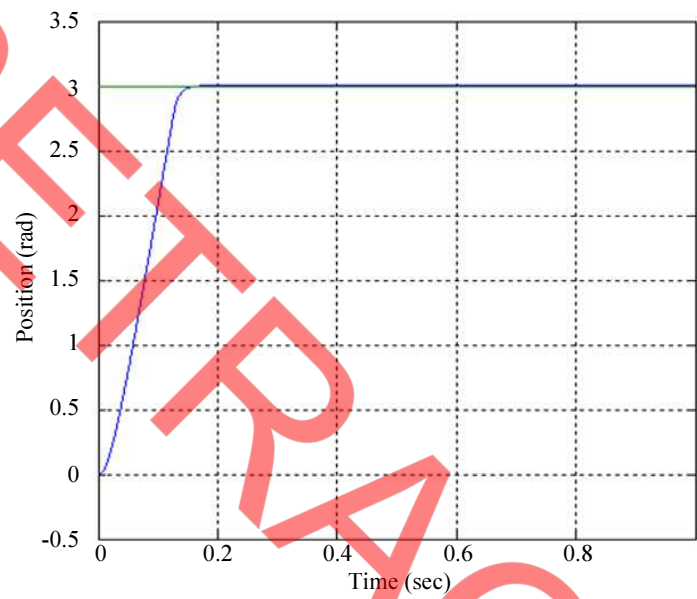


**Fig. 6:** Load Torque as a disturbance

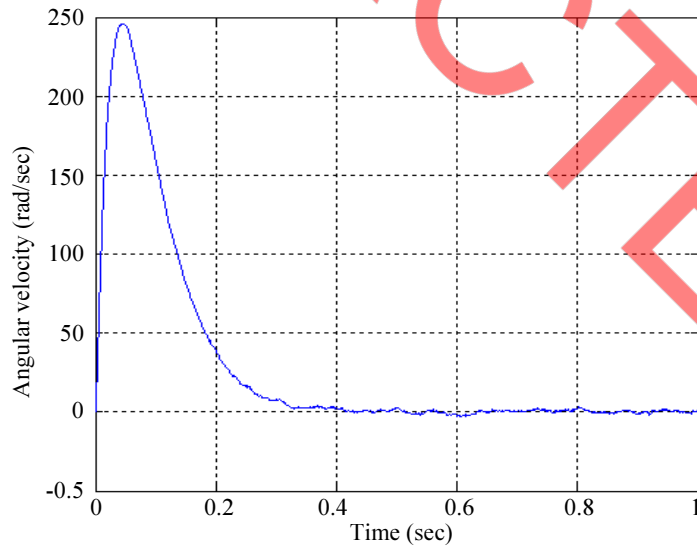




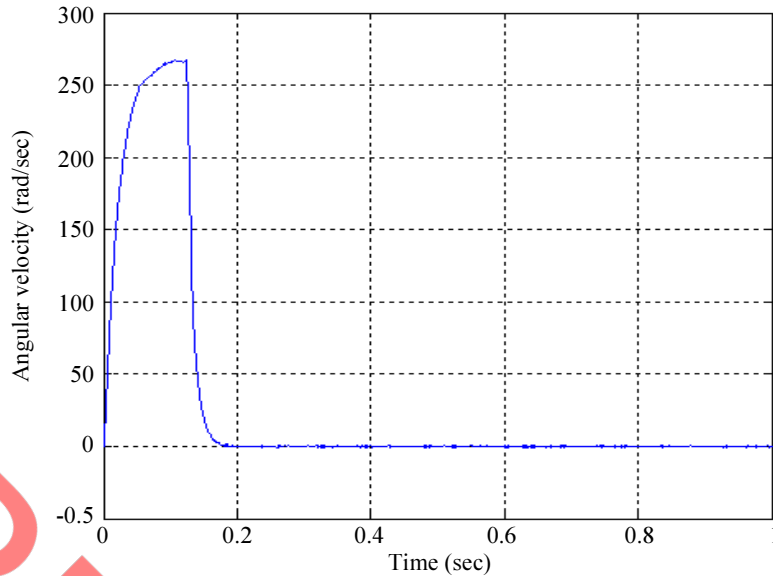
**Fig. 7:** The position of the Servo system with PID at load



**Fig. 8:** The position of the Servo system with SMC at load



**Fig. 9:** The angular velocity of the servo system with PID at load



**Fig. 10:** Angular velocity of servo system with SMC at load

**Table 2:** System time response specifications

Control variable	Time response specifications	PID	SMC
Position of Servo system	Settling time (sec)	>13sec	0.146 sec
Angular velocity of servo system	Settling time (sec)	>3.05rad	No overshoot

Figures 3 and 4 show the angular position and angular velocity Response characteristics in that order due to the step change in the reference angular position angle using PID Controller and SM control Approach at no load circumstance. The PID controller has been tuned which brings about appropriate following method, aftereffects of the controller that SMC the settling time is 0.146 sec and in PID it is .13sec, Given Table 2. System time response specifications of the system by controllers. It is observed through the all Figs. 5-10 and discussion that SM control provides important advantages over the traditional PID controller.

## Conclusion

In this study, we have been discussed the dynamic modeling and two methodologies for stabilizing and tracking of DC Servo Motor, DC servomotor has been considered as a plant. A dynamic model of the complete plant was derived. PID control endows with the stabilization; equally, SMC yields the robustness to the parametric uncertainty and exhibits disturbance rejection capabilities. Both stabilizing and tracking control of DC Servo Motor has been scrutinized using.

PID and SMC according to Time response domain analysis. A close to that investigation of the fixed gain PID controller and Sliding Mode Controller have been improved the situation controlling the position and the

speed of DC motor in servo drive system which outcome that the aftereffect of sliding mode controller is vastly improved than traditional PID controller, the robustness of the proposed controller is confirmed through no load and on load circumstance as an inconvenience. In this work are intended to compare the two Controllers namely, PID controller and Sliding Mode Control (SMC) Approach for the position control and Angular Velocity of Servo system. It is observed that SM control provides important advantages over the traditional PID controller like limiting the overshoot in position, thus the starting position overshoot can be reduced.

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## Author's Contributions

**Santosh Kumar Suman:** Designed the research plan and organized the study. Heimplemented thiswork. He contributed to part of the literature collection and drafted the manuscript.

**Awadhesh Kumar:** He devised the main conceptual ideas and supervised this work. He contributed to figure out the whole work as a research paper. Also provided critical feedback and helped to outline the exploration and manuscript.

## Ethics

This article is an original research paper. There are no ethical issues that may arise after the publication of this manuscript.

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