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# Experimental Object Identification and Control for Servo Motor

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**Abstract** **Original Research Article**

Control of speed and position of servo motors is an important and highly concerned problem in robot manipulator control. To effectively and precisely control industrial robot manipulators, a reliable model is needed from which to synthesize a controller for the system. In this paper, the authors apply the transient response-based identification method to determine the mathematical model of a servo motor using a real object from Tecquipment. A suitable design method is applied to calculate and design the PID controller for the actual object. The quality of the controller will be tested on the real system in cases of setpoint changes and disturbances.

**Keywords:** System Identification, Speed Control, PID Controller, Servo Motor, Position Control.

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## 1. INTRODUCTION

Servo motor drive systems have become an indispensable component in many modern industrial sectors, especially in high-precision automation applications such as CNC machine tools, automated production lines, and particularly complex robotic manipulators, (Zainab et al., 2025). Characterized by closed-loop control capabilities, these systems receive feedback signals of rotational speed and angular position from the motor shaft, allowing them to maintain stable and precise performance in varying operational environments. The outstanding advantages of servo drives include a wide speed range with high torque, fast dynamics, high-precision positioning, short acceleration times, compact design, and reduced weight. The integration of speed and position sensors directly onto the motor shaft also contributes to space saving and reduced production costs. (Arnob et al., 2018, Bac et al., 2018, Bac et al., 2022). Thanks to these superior features, servo motor drive systems not only help improve production efficiency but also enhance product quality and ensure operational safety, playing a pivotal role in the robotized industry.

In the field of controlling servo motor drive systems, problems related to motor shaft speed and position control are always at the forefront of research and development. These are technical challenges that demand high accuracy, fast response capabilities, and robust stability against disturbances and load changes. Many research works have been conducted and published on methods and techniques for designing controllers for motor position and speed loops (Khoshnam et al., 2013, Chauhan et al., 2014, Zhiwen et al., 2024, Rolf et al., 2011). However, these studies still have some significant limitations. Some proposed methodsinvolve controllers with complex structures, making them difficult to implement and optimize their control coefficients. Furthermore, although many advanced control algorithms have been developed in simulation environments, they often lack comprehensive validation on real systems. This leads to a gap between theory and practice, affecting the reliability and operational effectiveness of the controllers when facing nonlinear characteristics, noise, and model errors in real environments.

To overcome these limitations and contribute to the development of practical servo control systems, this paper focuses on researching and conducting experimental identification of the mathematical model of a servo motor drive system. Identifying an accurate model from the real object is a crucial basis for synthesizing a suitable controller, as theoretical models often cannot fully reflect the complex and nonlinear dynamics of a physical system. After the model is determined, the paper will propose and apply an appropriate design method to calculate the coefficients for the PID controller. Although modern control methods are increasingly diverse, the PID controller remains a popular choice due to its simplicity, ease of implementation, and superior effectiveness in many industrial applications when optimally tuned. Finally, the quality of the designed controllers will be rigorously verified on the real experimental system from Tecquipment, through scenarios involving setpoint changes and disturbance impacts, to evaluate its tracking capability, stability, and robustness under actual operating conditions.

## 2. DETERMINING THE MATHEMATICAL MODEL OF A SERVO MOTOR

### 2.1. Identification Methods

In system identification, there are many methods, divided into two main approaches: theoretical methods and experimental methods. Theoretical methods include: least squares method, recursive least squares method... Theoretical methods require knowledge of the internal interaction rules of the object and the relationship between the object and the external environment. In cases where understanding of the object is limited, it will cause many difficulties in building a model. In such cases, it is necessary to combine with experimental identification methods, such as the two-point reference method, the identification method based on transient characteristics, .. (Rolf et al., 2011, Phuoc et al., 2005). In this paper, the authors use the identification method based on transient characteristics due to its suitability for the object, simple operation, and fast response time.

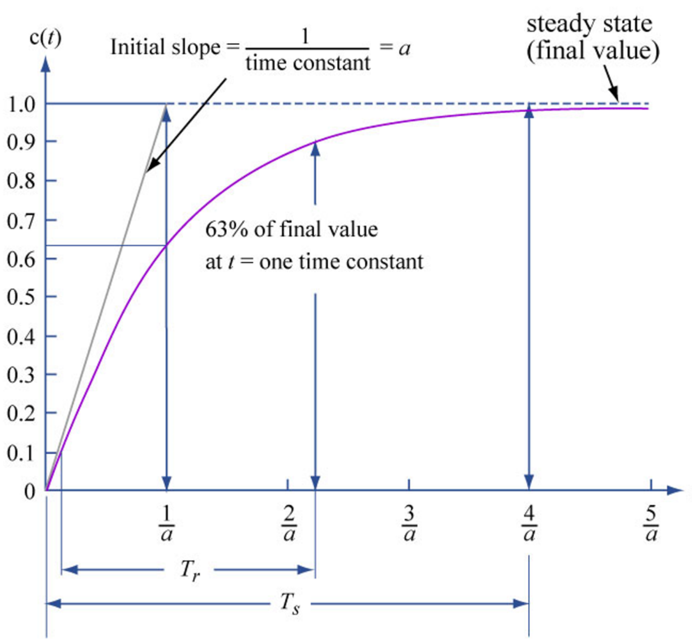


*Figure 1: Transient function of a first-order inertial element*

Assuming the object has a transient function represented as Figure 1, the mathematical model of the object is a first-order inertial element (Phuoc et al., 2005):

$$G(s) = \frac{K}{1+Ts} \quad (1)$$

Where $K$ is the gain coefficient, $T$ is the time constant.

To determine the model parameters in formula (1) anh Figure 2, the following steps are performed:

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- Draw a tangent line to *y(t)* at $t \rightarrow \infty$, to get $y(\infty)$, then infer $k$.
- Determine the point whose ordinate is 0.632 of.
- The abscissa of the just determined point is the parameter $T$ to be found.

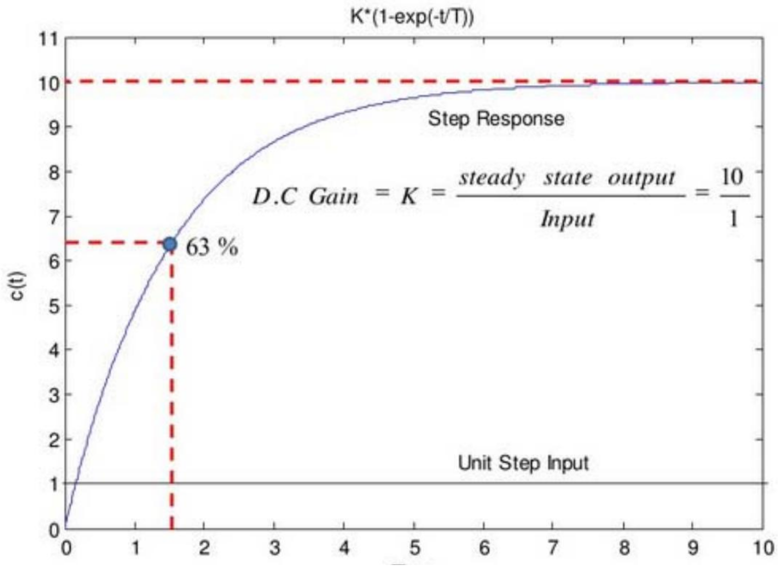


*Figure 2: Approximate determination of parameter T*

## 2.2. IDENTIFICATION ON THE ACTUAL MODEL FROM TECQUIPMENT

The experimental system used in the paper is the servo drive system from Tecquipment. The model has an open-loop schematic diagram as shown in Figure 3.

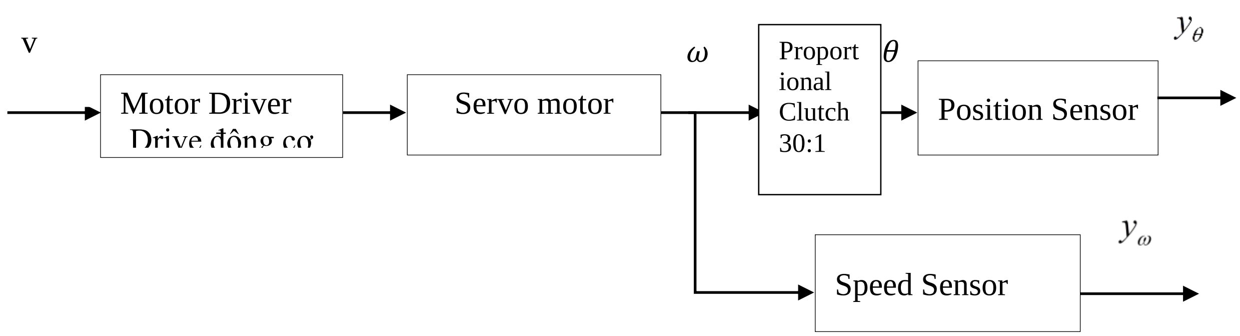


*Figure 3: Open-loop schematic diagram of Servo drive system*

Where $v$ is the voltage applied to the motor, $\omega$ is the motor shaft speed, $\theta$ is the motor shaft position, and $y_\omega$ and $y_\theta$ are the output signals of the speed and position sensors, respectively.

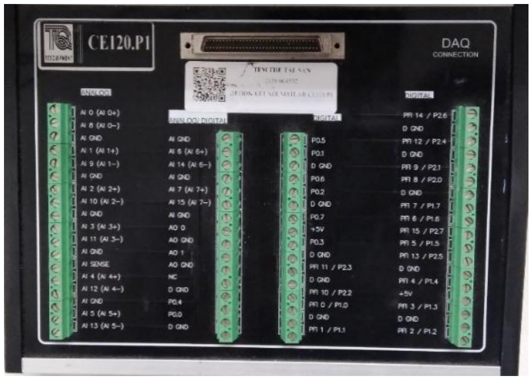

*Figure 4: Card PCIe-6321 by NI Module DAQ*

To design the motor shaft speed and position controllers, it is necessary to determine two transfer functions speed $G_{\omega}(s)$ and position $G_{\theta}(s)$. The model from Tecquipment is connected to a computer via a PCIe-6321 card Figure 4. The collected system signals are implemented according to the structure in Matlab/Simulink software as shown in Figure 5, with a sampling period of $Ts$ = 10ms. The gain block in Matlab/Simulink is a proportional block, responsible for calculating speed based on the measured voltage from the speed sensor (1V corresponds to 200 revolutions/ minute) (Minh et al., 2021).

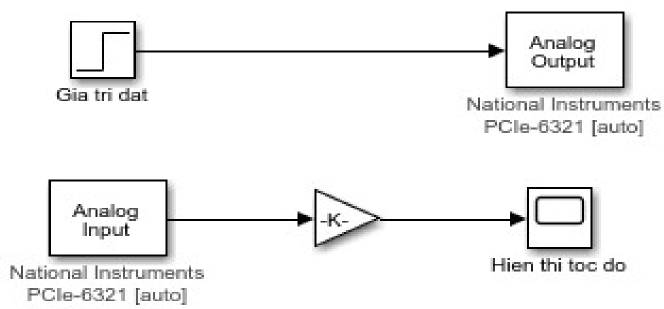

*Figure 5: Structure of motor speed acquisition system via PCIe-6321 card with Matlab software*

## DETERMINING THE SPEED TRANSFER FUNCTION

Typically, the speed transient response of a servo motor can be modeled as a first-order inertial element because it starts from the origin and stabilizes after a period of time (Minh et al., 2021). In this case, a complex process can be approximated by a simple first-order model as in formula (1).

Given the setpoint $v$ = 5V, connecting the system as shown in Figure 5 via the PCIe-6321 card and Matlab/Simulink software, the output signal shown in Figure 6 is obtained.

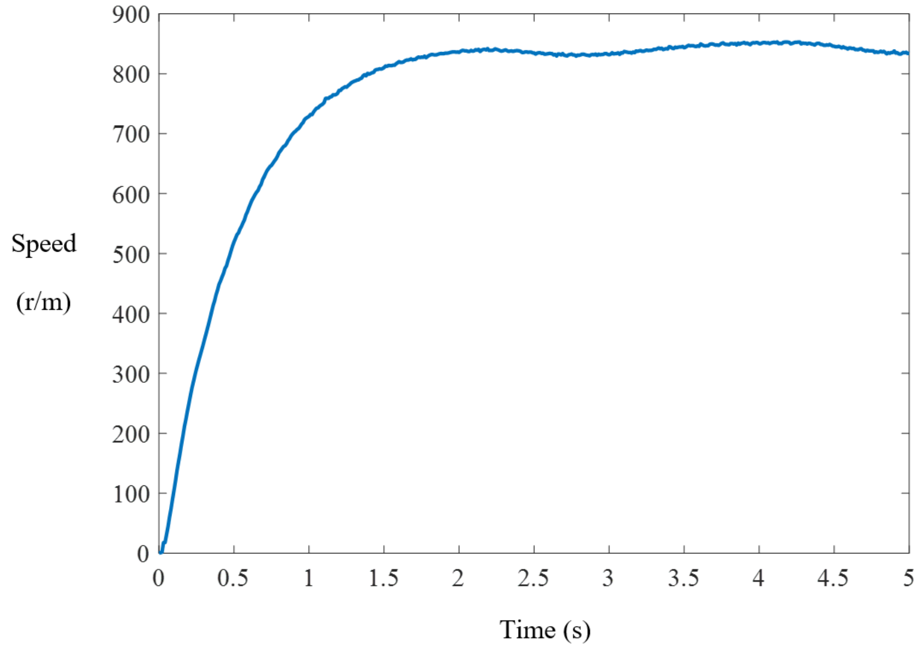


*Figure 6: Motor speed transient characteristic on the experimental system with setpoint v = 5V*

From the experimental graph in Figure 6, applying the method based on transient characteristics (Phuoc et al., 2005, Minh et al., 2021), the following parameters are determined:
$K$ = (820/5) : 200 = 0.82
$T$ = 0.52 s

The speed transfer function $G_\omega(s)$ is the following first-order inertial element:

$$G_\omega(s) = \frac{K_\omega}{1+Ts} = \frac{0,82}{1+0,52s} \qquad (2)$$

The transfer function in equation (2) has a good response, closely tracking the actual speed characteristics ((Minh et al., 2021).

## DETERMINING THE POSITION TRANSFER FUNCTION

When controlling position, the speed control loop is nested within the position control loop. Therefore, if the speed loop is represented by the transfer function $G_\omega(s)$, the open-loop position control system structure is as Figure 7 follows:

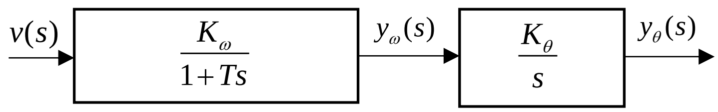

*Figure 7: Open-loop structure diagram for servo system*

From Figure 6, the position transfer function is determined (Ladaci et al., 2021):

$$G_\theta(s) = \frac{K_\theta}{s}.G_\omega(s) \qquad (3)$$

with $K_\theta = \dfrac{k_\theta}{30k_\omega}$ (4)

The angular position sensor constant $k_\theta$ and the speed sensor constant $k_\omega$ have the values (TecQuipmetn et al.,2013):

$k_\theta = 20$ , $k_\omega = 0.3$

According to formula (4), the coefficient $K_\theta$:

$$K_\theta = \frac{k_\theta}{30k_\omega} = \frac{20}{30.0,3} = 2,22 \qquad (5)$$

Thus, the position transfer function $G_\theta(s)$ is an integral-inertial element:

$$G_\theta(s) = \frac{K_\theta}{s}.G_\omega(s) = \frac{2,22}{s}.\frac{0,82}{1+0,52s} \qquad (6)$$

## 3. CONTROLLER DESIGN ON THE ACTUAL MODEL

### 3.1. Speed Controller Design

The PID controller is a classic controller in the field of automatic control. PID controllers are widely used in control systems from simple to complex such as temperature, pressure, speed, position control, etc. PID controllers have many advantages such as: simple and easy to implement, effective operation, stable, easy to tune. There are many methods to design PID controller coefficients (Almeida et al., 2019, Khaliq et al., 2019). Among them, Kuln's sum T method provides good quality and simple calculation (Chauhan et al., 2014). Therefore, this paper uses Kuln's sum T method to design the controller for the actual experimental drive system. The result after applying Kuln's sum T method is the following PI controller:

$$PI_\omega(s) = 1,2\left(1+\frac{1}{2,6s}\right) \qquad (7)$$

The schematic diagram of the control system built on Matlab-Simulink software is shown in Figure 8:

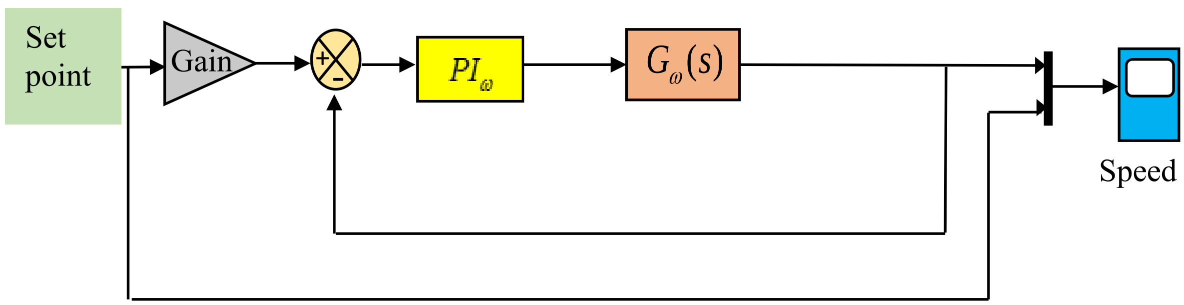


*Figure 8: Structure diagram of a speed control loop*

### 3.2. Position Controller Design

Position control in servo motor drive systems is of great interest and widely applied in robot manipulator control systems and CNC machine tools. There are several methods to design a position controller, and in this paper, the authors use the symmetric optimum method to calculate the PID coefficients (Yaregal et al., 2025, Chen et al., 2015, Anisa et al., 2022). The advantages of this method are its suitability for the system's mathematical model, simplicity in calculation, and coefficient tuning.

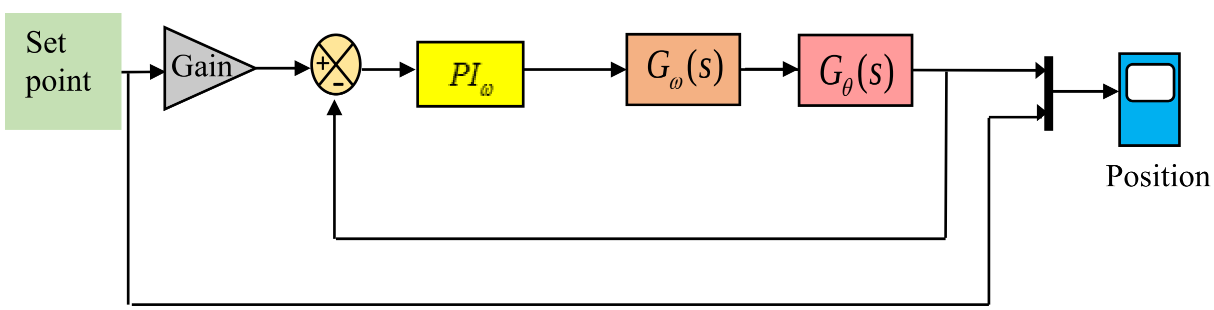


*Figure 9: Structure diagram of the position control loop of the actual system*

Designing a controller to control the position for the system in Figure 9, where speed control is not considered. By the symmetric optimum method, the proportional-integral controller is designed based on the identified object model (6):

$$PI_\theta(s) = 12\left(1+\frac{1}{0,04s}\right) \qquad (8)$$

## 4. EXPERIMENTAL SYSTEM AND RESULTS

### 4.1. Introduction to the Experimental System

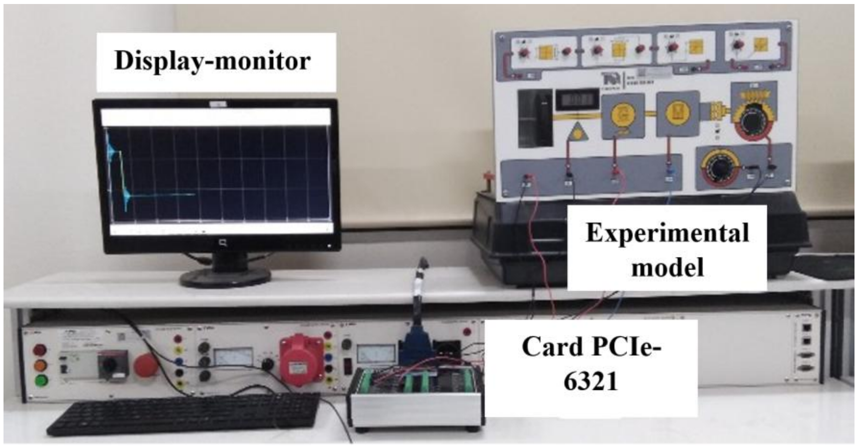


*Figure 11: System identification and control of the actual model*

The experimental system consists of a servo motor M66CE-24, HEDS 9100 sensor, and M0710 2211 clutch. The connection of the system in Figure 11 with the signal input and output structure is presented in Figure 4.

### 4.2. Experimental Results

In this section, for the aforementioned cases, the authors conduct experiments on the actual model from Tecquipment to verify the controllers in real-time. The experimental process is conducted with the following options:

### Speed Control Verification

Figure 12 shows the speed response corresponding to the controller (C_\omega(s)) with a setpoint of 1000 rev/min. The results show that after 1.57s, the speed response reaches the setpoint, with an overshoot of 1%. At times 15.5s; 23s; 34.3s, load disturbance occurs. The speed response then oscillates with a maximum overshoot of 17% in 2s, then quickly stabilizes with an error of 1%.

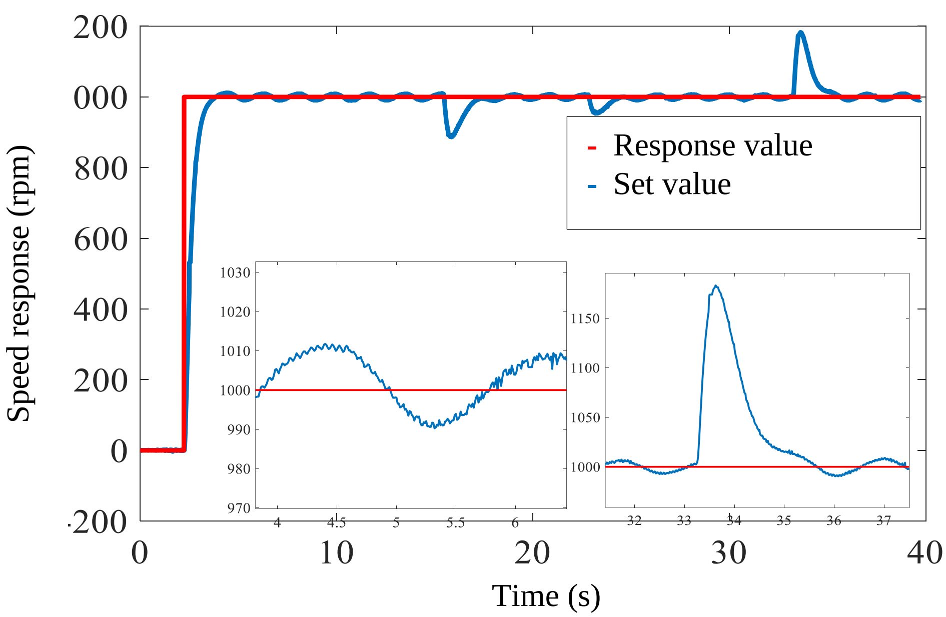


*Figure 12: Motor shaft speed response when load changes at ω = 1000 rev/min*

## POSITION CONTROL VERIFICATION

In Figure 13, the position response corresponding to the controller $PI_{\theta}$ with a setpoint of $\theta$ = 0.72 rad is shown. The results show that after 2.4(s), the position response reaches the setpoint, the overshoot is still large, and the error compared to the setpoint is 0.5%.

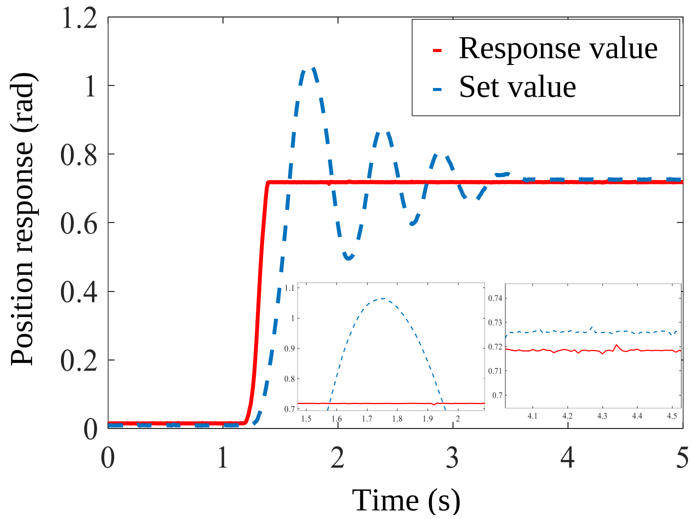


*Figure 13: Motor shaft position response when setpoint value is $\theta$ = 0.72 rad*

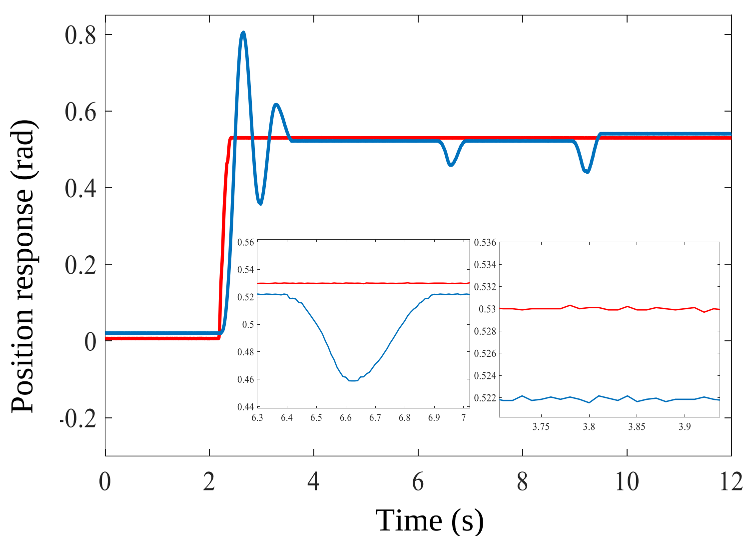


*Figure 14: Motor shaft position response when disturbance changes at $\theta$ = 0.53 rad*

Continued disturbance is applied to the system. To apply disturbance, a small rubber hammer is gently tapped on the motor shaft end. The results are shown in Figure 14. At times 6.4(s); 9.2(s), disturbance is applied when the system has stabilized with the setpoint $\theta$ = *0.53 rad*. When disturbance is applied, the position response is quite good, with a maximum overshoot of 7%, returning to the stable state with an error of 0.8% within 0.5(s).

Figure 15 shows the system speed response when the controller (C_\theta(s)) is present with the setpoint (θ_{setpoint}) and disturbance applied. At the times of disturbance, the maximum speed overshoot when disturbance is applied is 12%, and after 0.5s, the system stabilizes again. From the above conclusions, it is shown that the position control system tracks the setpoint, but still has limitations in terms of overshoot.

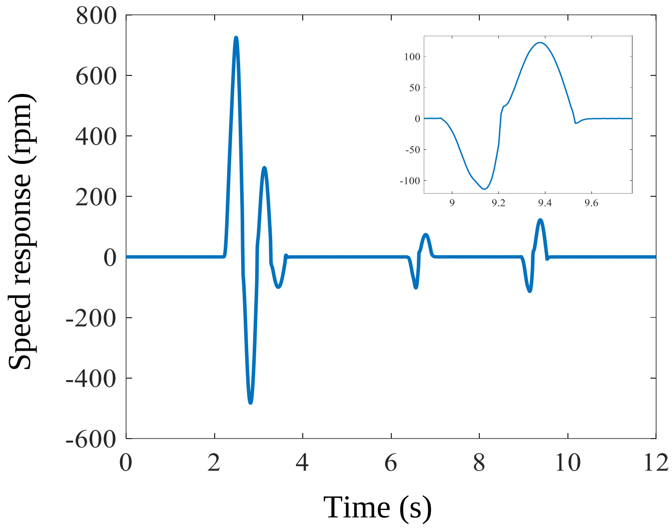


*Figure 15: Motor shaft speed response when disturbance changes at θ = 0.53 rad*

## 5. CONCLUSION RECOMMENDATIONS

In this paper, the authors present an experimental method for identifying the object when applied to the servo motor control problem on the CE105 model. The identification results based on transient characteristics yield a first-order inertial element suitable for the actual object, from which the controller was synthesized to control motor speed and position in the case of load disturbances. The real-time verification of the servo motor control system has shown the effectiveness of the proposed controller, providing a robust solution for maintaining consistent performance under varying load conditions.

For future work, it is recommended to extend this identification methodology to higher-order systems or more complex motor configurations. Furthermore, exploring adaptive or robust control strategies would enhance the system's resilience against unmodeled disturbances and parameter variations. Finally, testing and implementing this solution on larger-scale industrial control systems represents a promising direction for practical deployment.

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