MCT-241: Modelling & Stimulation

Modeling, Simulation, and Control of a Four-Bar Mechanism with a Brushless Servo Motor

Submitted By:

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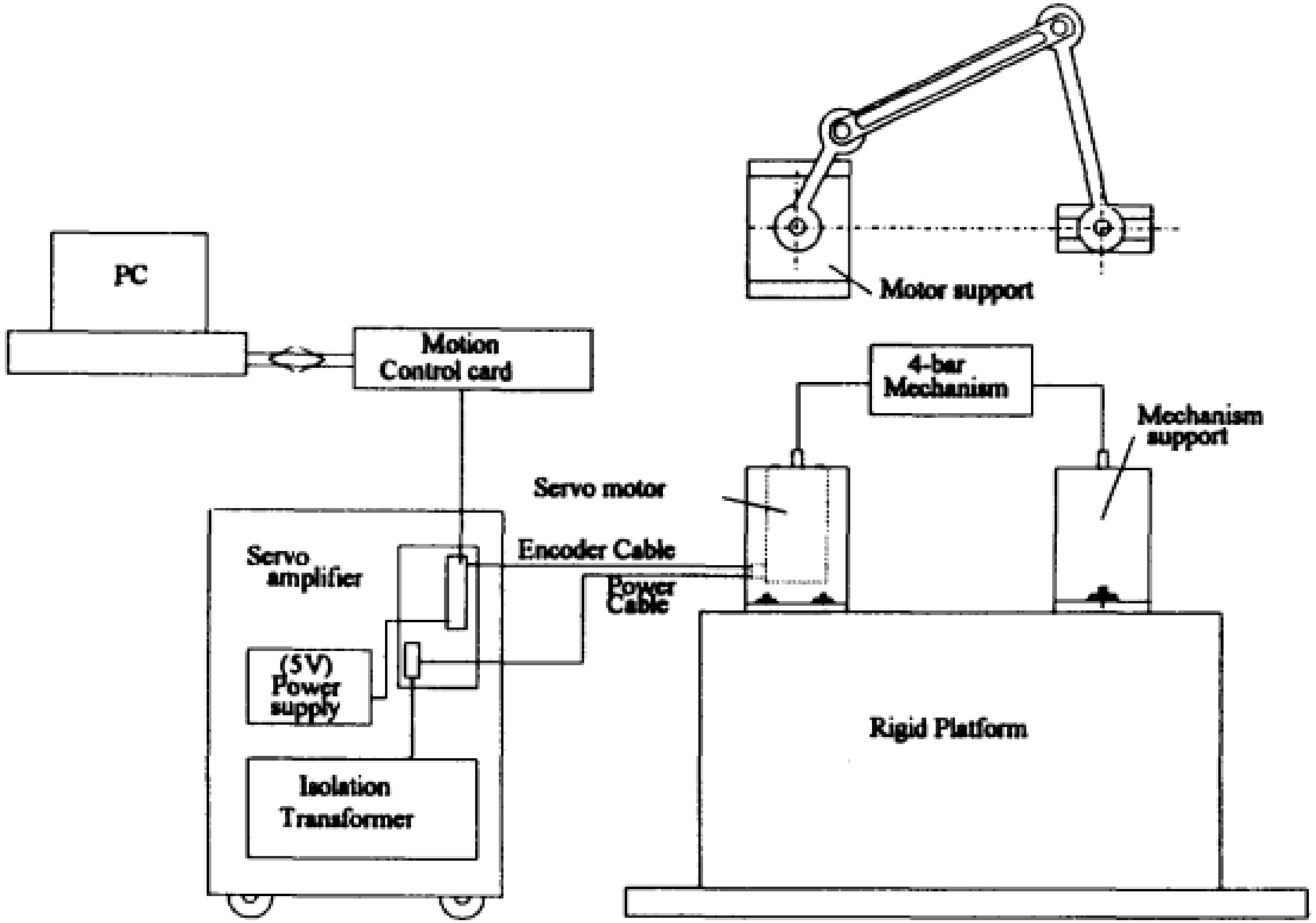
Objectives

- To obtain the mathematical model of the four-bar mechanism and motor system.
- To study the variation of system parameters and analyze their effects.
- To model and simulate the system using MATLAB/Simulink.
- To design a control strategy to achieve precise motion control.
- To evaluate the system's response under different conditions and optimize performance.

Introduction

Imagine a mechanical arm connected to a motor that allows it to move in a controlled manner. This arm setup, known as a four-bar mechanism, is common in machines that need to transfer rotational motion into a specific type of movement, like robotic arms or vehicle suspension systems. By modeling and simulating this setup on a computer, we can understand how the system behaves under different conditions and tweak the motor's performance to ensure it moves just right.

Block Diagram



Mathematical Model of Entire System

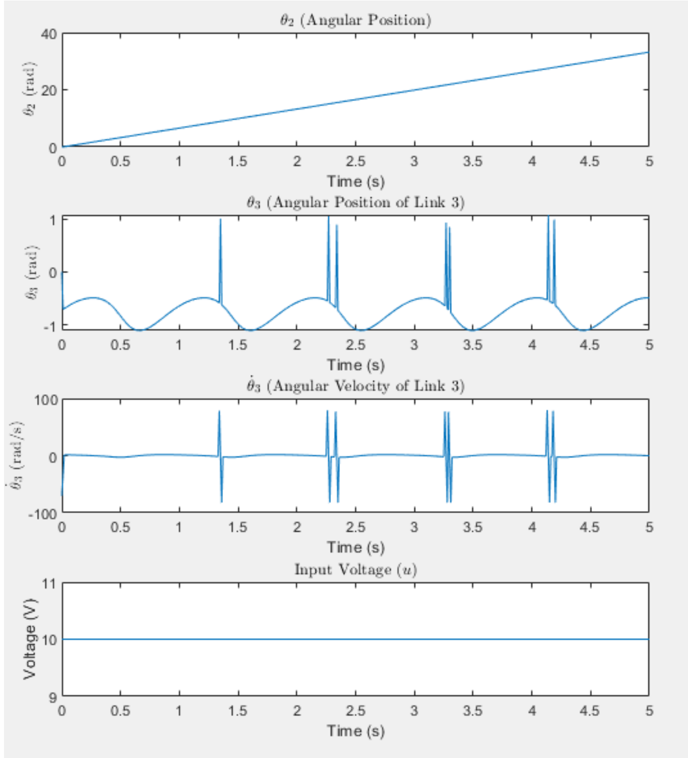
$$
\begin{aligned}
&\ddot{\theta}_2\Bigg[J_m + m_2 r_2^2 + J_2 + m_3 a_2^2 + 2m_3 a_2\left(\frac{\partial\theta_3}{\partial\theta_2}\right)(p\cos(\theta_2-\theta_3)+q\sin(\theta_2-\theta_3)) \\
&\quad + \left(\frac{\partial\theta_3}{\partial\theta_2}\right)^2(m_3(p^2+q^2)+J_3) + \left(\frac{\partial\theta_4}{\partial\theta_2}\right)^2(m_4 r_4^2 + J_4)\Bigg] \\
&\quad + \dot{\theta}_2^2\Bigg[\left(\frac{\partial^2\theta_3}{\partial\theta_2^2}\right)\left(\frac{\partial\theta_3}{\partial\theta_2}\right)(m_3(p^2+q^2)+J_3) + \left(\frac{\partial^2\theta_3}{\partial\theta_2^2}\right)m_3 a_2(p\cos(\theta_2-\theta_3) \\
&\quad + q\sin(\theta_2-\theta_3)) + \left(\frac{\partial^2\theta_4}{\partial\theta_2^2}\right)\left(\frac{\partial\theta_4}{\partial\theta_2}\right)(m_4 r_4^2 + J_4) \\
&\quad + \left(\frac{\partial\theta_3}{\partial\theta_2}\right)m_3 a_2\left(q\cos(\theta_2-\theta_3)\left(1-\frac{\partial\theta_3}{\partial\theta_2}\right) - p\sin(\theta_2-\theta_3)\left(1-\frac{\partial\theta_3}{\partial\theta_2}\right)\right)\Bigg] = K_t I, \qquad (2)
\end{aligned}
$$

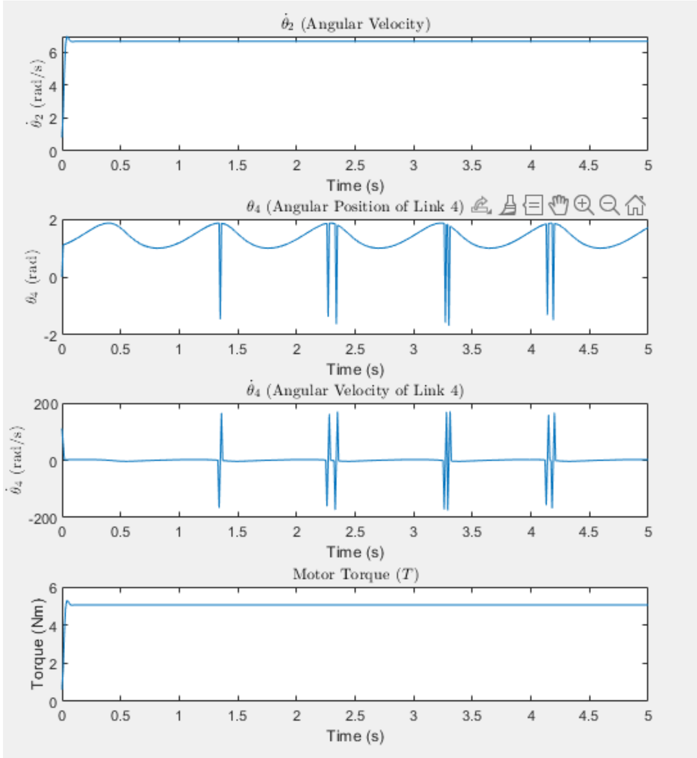
State-Space Representation

$$\dot{\mathbf{x}} = A\mathbf{x} + B\mathbf{u}$$

$$A = \begin{bmatrix} 0 & 1 & 0 \\ 0 & -\frac{\partial C}{\partial \dot{\theta}_2} / J_{\text{eff}} & K_t / J_{\text{eff}} \\ 0 & -K_e / L & -R / L \end{bmatrix}, \quad B = \begin{bmatrix} 0 \\ 0 \\ 1/L \end{bmatrix}$$

Stimulated Graphs





Conclusion

This project modeled and analyzed a servo motor coupled to a four-bar mechanism using linear and nonlinear approaches. While the linear model provided simplicity and efficiency for steady-state analysis, the nonlinear model captured intricate dynamics and offered high-fidelity results. Graphical outputs revealed the significant impact of nonlinear effects on performance, highlighting their necessity for realistic simulations. This work provides a foundation for advanced control strategies and system optimization.