Lab 3. Simulation components of dynamic systems

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Specialization: Automation

Variant	U	Ψ	R	L	J_M	J_L	b	k
94	24	0.229183	0.35	0.00035	0.001501	0.004502	0.06	1700

1. Simscape model of DC-motor.

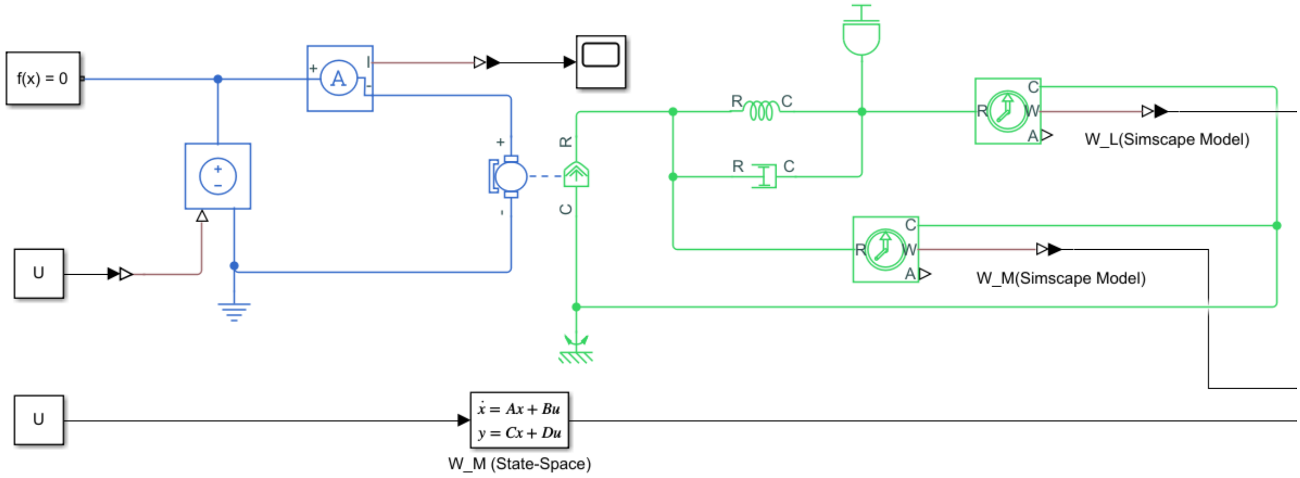


Figure 1. Equivalent circuit.

2. Block diagram model of DC-motor.

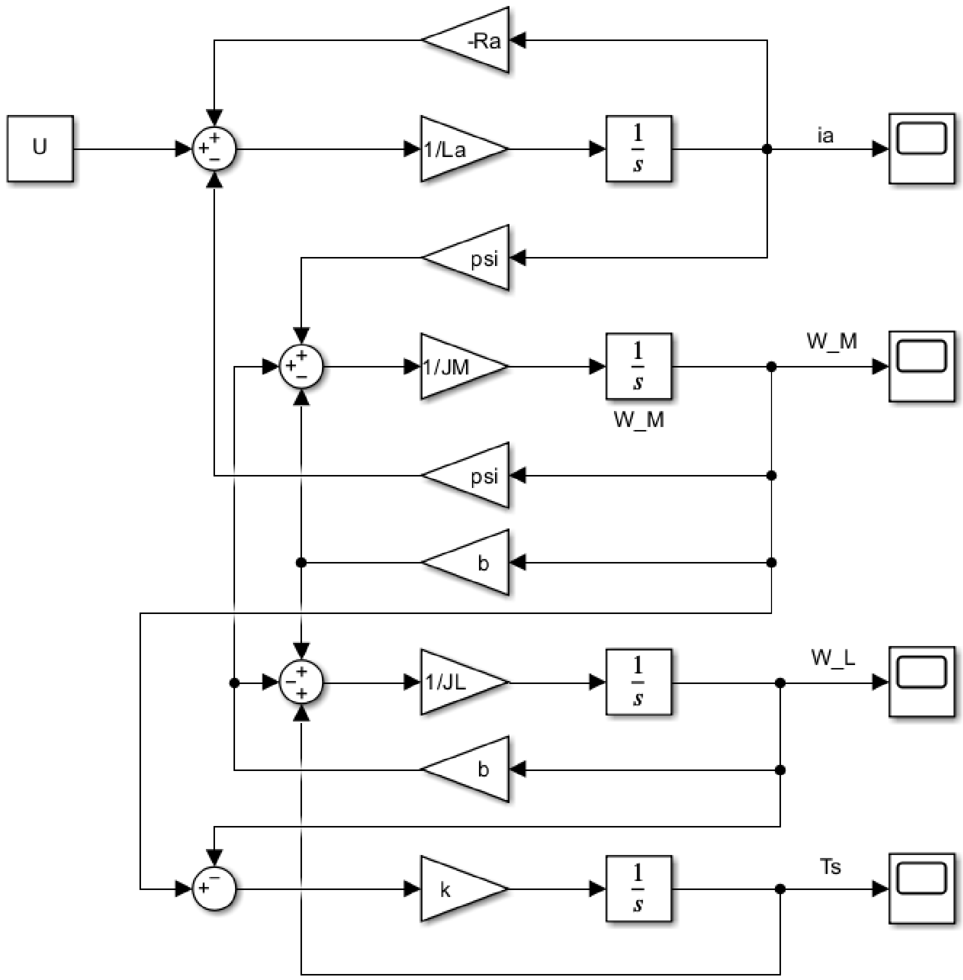


Figure 2. Simulation circuit.

2. Transfer functions of DC-motor.

$$W_1 = \frac{\omega_M}{U} = \frac{\psi(J_L \cdot s^2 + b \cdot s + k)}{J_L J_M L_a \cdot s^4 + (J_L J_M R_a + J_L L_a b + J_M L_a b) \cdot s^3 + (J_L \psi^2 + J_L R_a b + J_M R_a b + J_L L_a k + J_M L_a k) \cdot s^2 + (\psi^2 b + J_L R_a k + J_M R_a k) \cdot s + \psi^2 k}$$

$$W_2 = \frac{\omega_L}{U} = \frac{\psi b \cdot s + \psi k}{J_L J_M L_a \cdot s^4 + (J_L J_M R_a + J_L L_a b + J_M L_a b) \cdot s^3 + (J_L \psi^2 + J_L R_a b + J_M R_a b + J_L L_a k + J_M L_a k) \cdot s^2 + (\psi^2 b + J_L R_a k + J_M R_a k) \cdot s + \psi^2 k}$$

3. State-space model.

$$L_a \cdot \frac{di_a}{dt} = U - R_a \cdot i_a - \Psi \cdot \omega_M$$

$$J_M \cdot \frac{d\omega_M}{dt} = \Psi \cdot i_a - T_S - b(\omega_M - \omega_L)$$

$$J_L \cdot \frac{d\omega_L}{dt} = T_S + b(\omega_M - \omega_L)$$

$$\frac{dT_S}{dt} = k(\omega_M - \omega_L)$$

$$A = \begin{bmatrix} -\frac{R_a}{L_a} & -\frac{\psi}{L_a} & 0 & 0 \\ \frac{\psi}{J_M} & -\frac{b}{J_M} & \frac{b}{J_M} & -\frac{1}{J_M} \\ 0 & \frac{b}{J_L} & -\frac{b}{J_L} & \frac{1}{J_L} \\ 0 & k & -k & 0 \end{bmatrix} \quad B = \begin{bmatrix} \frac{1}{L_a} \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad C = \begin{bmatrix} 0 & 1 & 0 & 0 \end{bmatrix} \quad D = 0$$

5. Simulation results for 2 cases

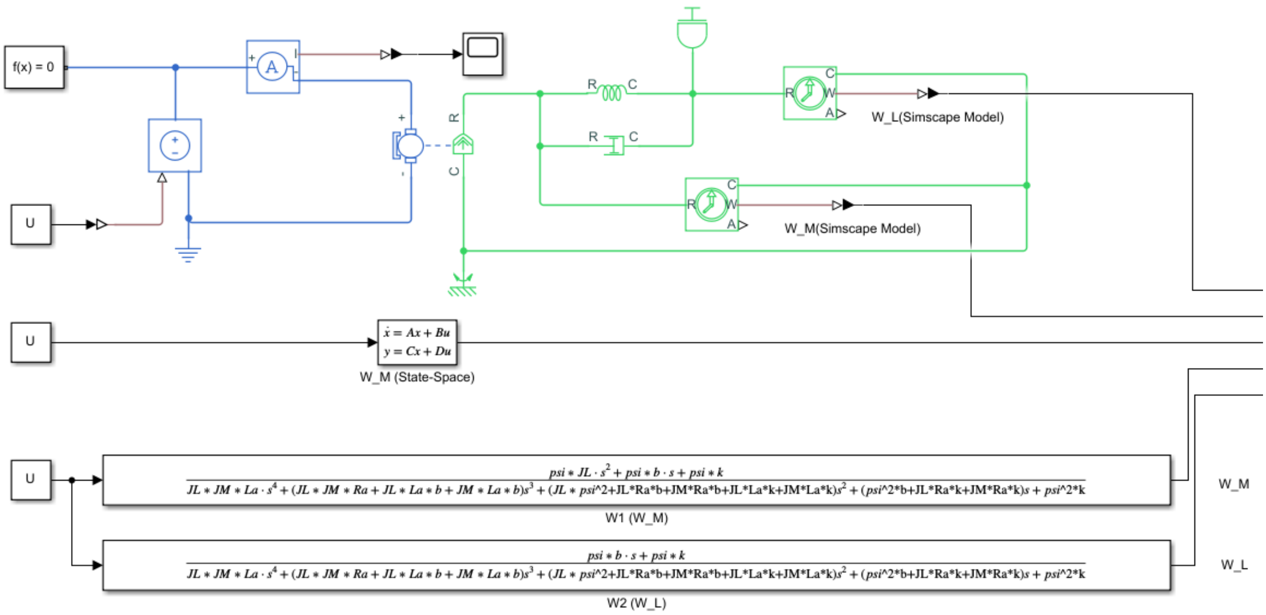


Figure 3. Three models

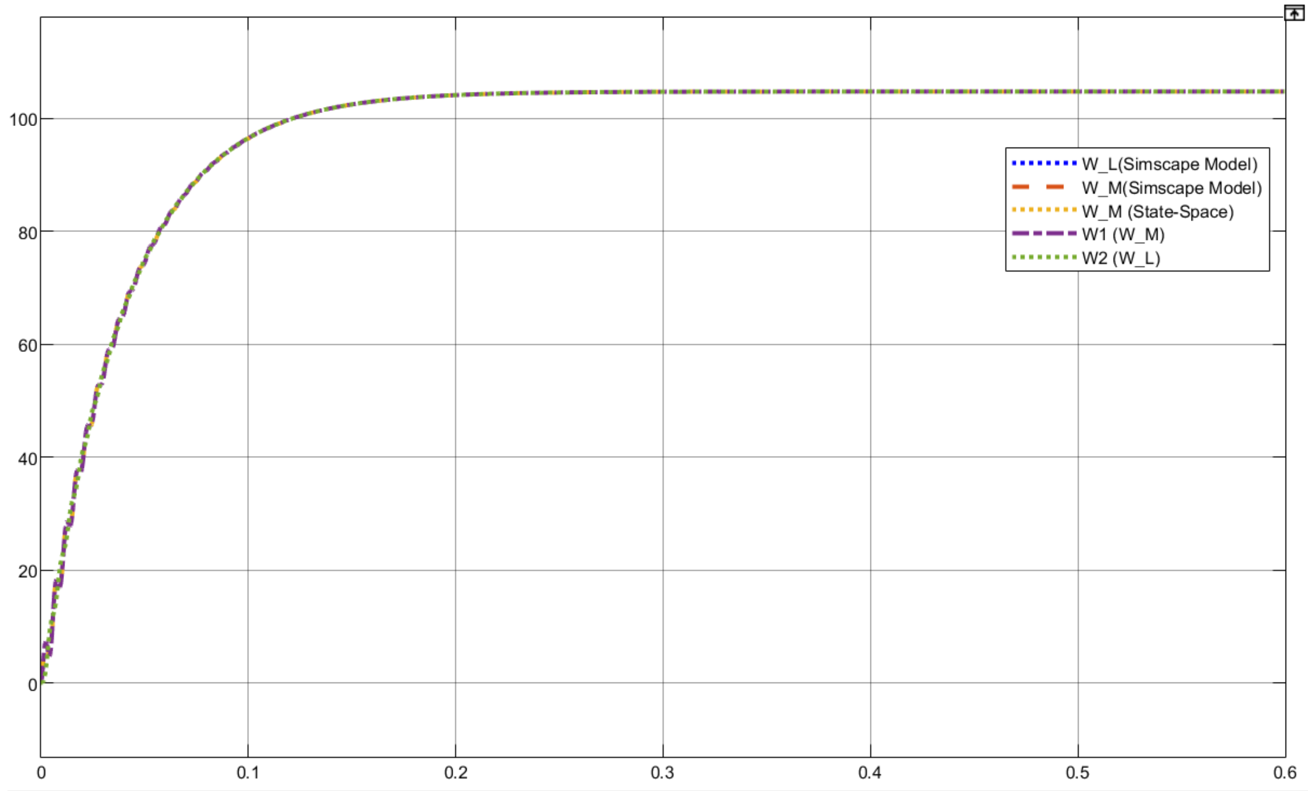
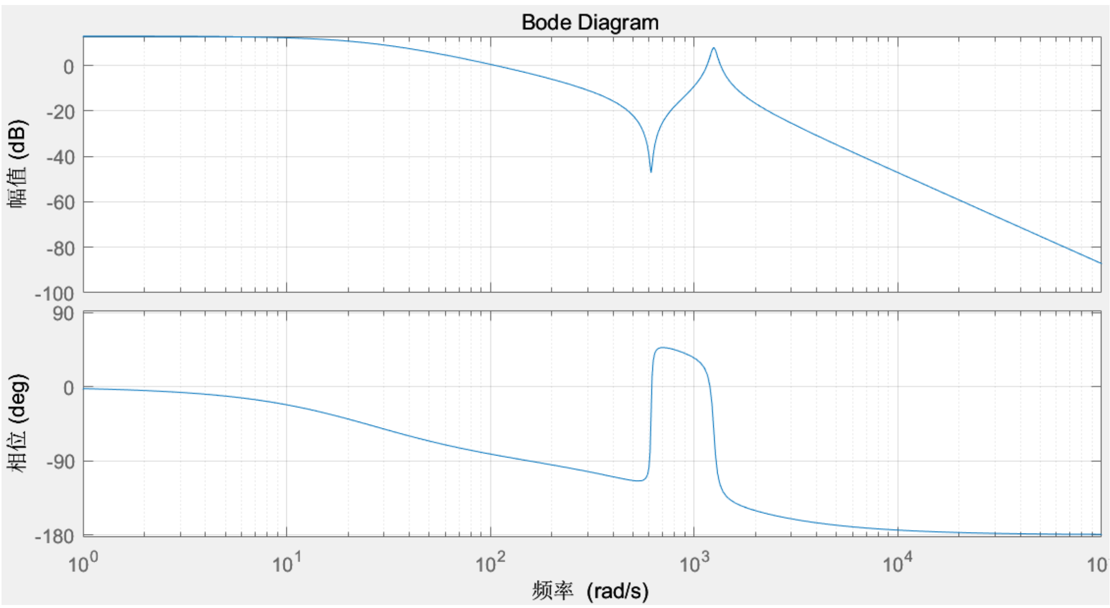


Figure 4. Simulation results of different models.

6. Calculation of transient response.



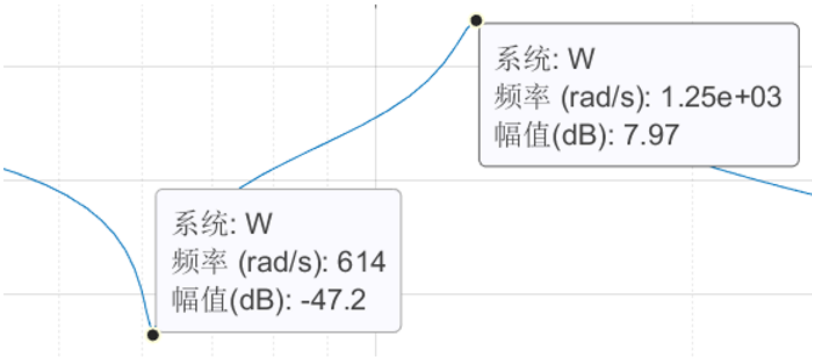


Figure 5. Bode plots of W1

Resonant frequency of the mechanical subsystem: **614 (rad/s), 1250 (rad/s)**

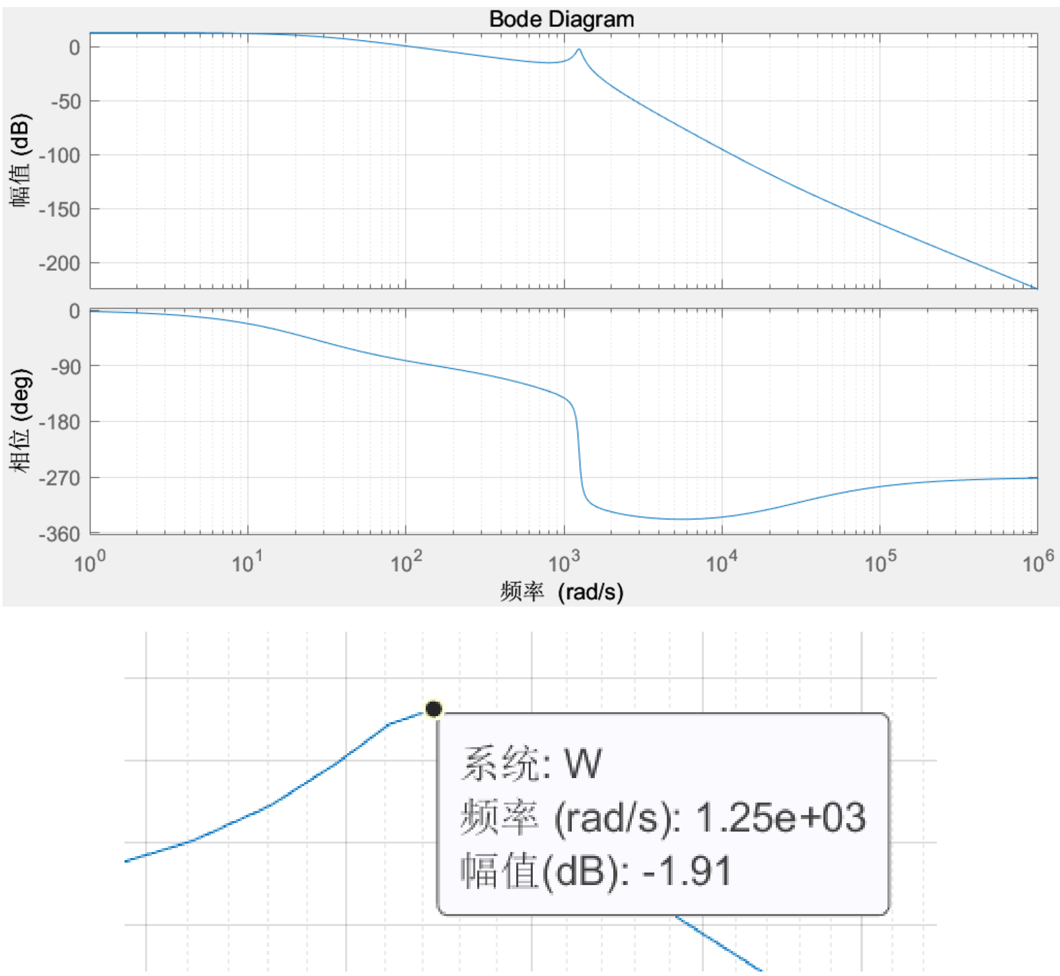


Figure 6. Bode plots of W2

Resonant frequency of the mechanical subsystem: **1250 (rad/s)**

7. Multi-harmonic input signal.

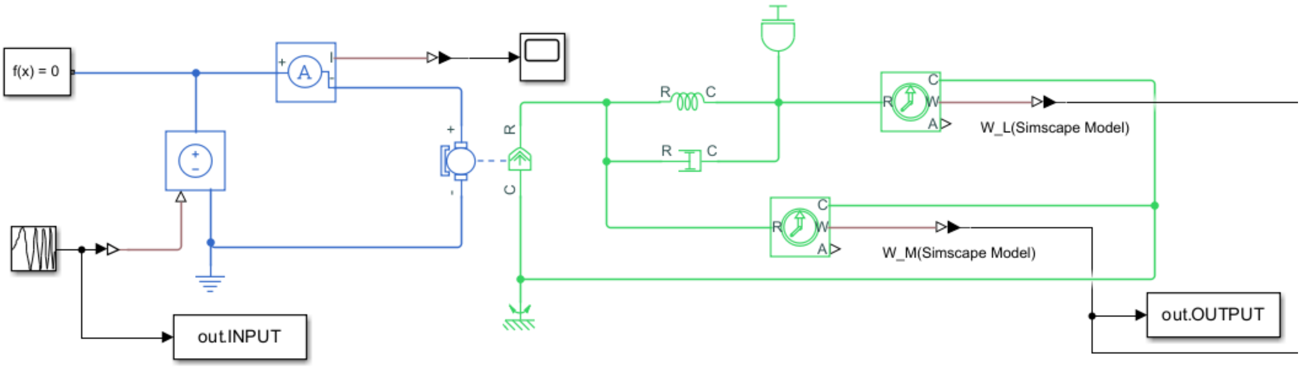


Figure 7. Equivalent circuit.

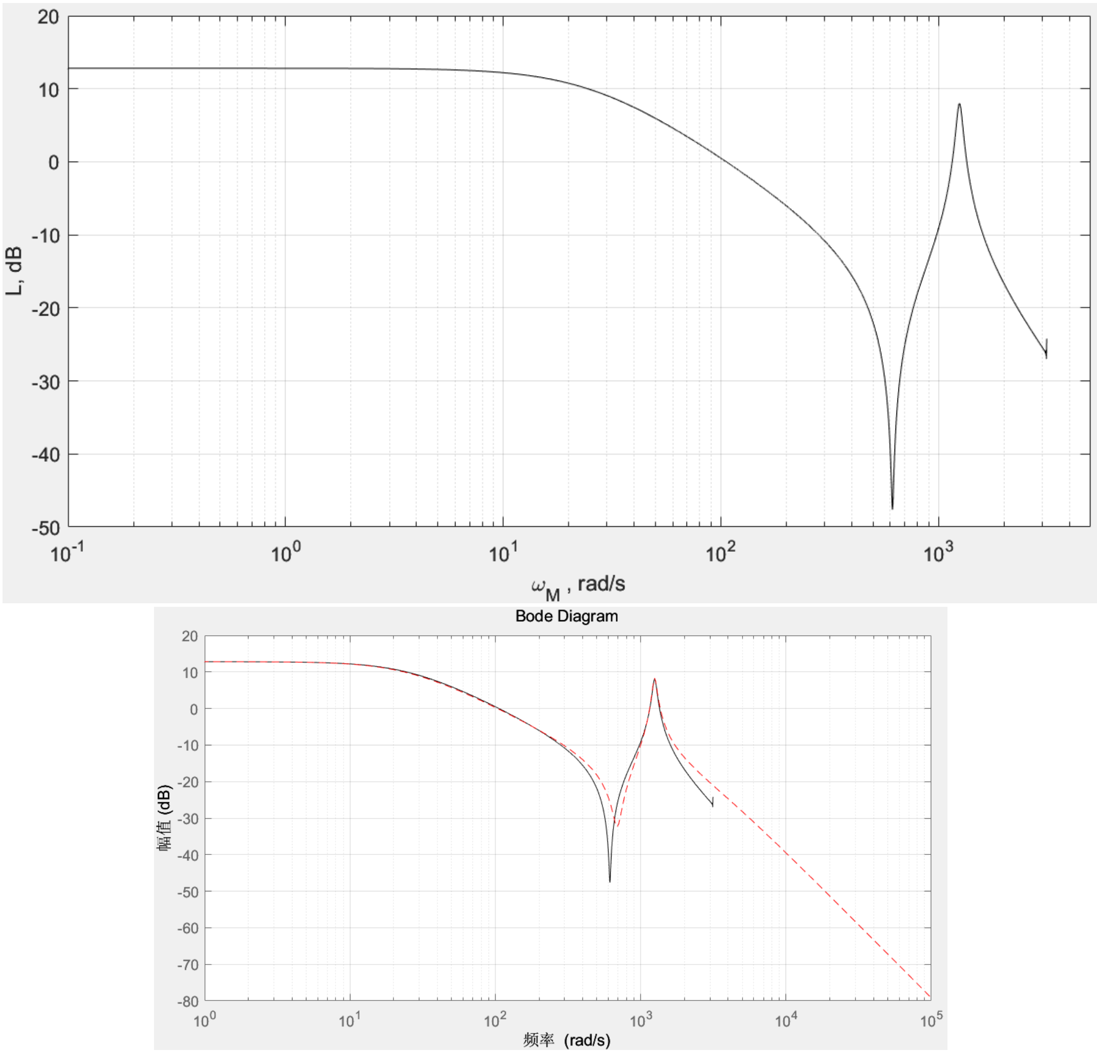


Figure 8. Frequency response.

It seems to have a little shift for the first Resonant frequency compared to the original one. Maybe there is some problem in recognization in matlab.

Conclusions:

1. Dynamic Models: The DC motor with a two-mass load and elastic joints was successfully modeled using Simscape, block diagrams, transfer functions, and state-space representations. Each model provided unique insights into the system's behavior.
2. Bode Plots & Resonant Frequencies: Bode plots were constructed, revealing resonant frequencies at 614 rad/s and 1250 rad/s, critical for stability analysis. The frequency response showed good agreement between models.
3. Simulation Results: Simulations validated the models, showing consistent results across Simscape, block diagrams, and state-space representations. Transient responses highlighted underdamped and overdamped behaviors.
4. Experimental Validation: The experimentally estimated frequency response and transfer function matched well with the original model, confirming the accuracy of the experimental approach.
5. Model Comparison: All models (Simscape, block diagram, transfer function, state-space) produced consistent results, reinforcing their reliability. The experimental transfer function slightly deviated but overall aligned with the original.