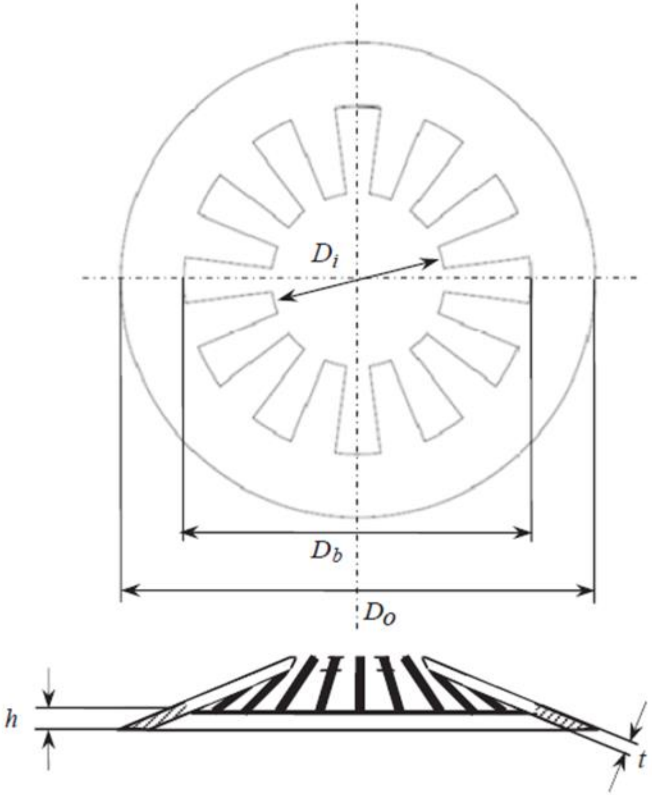
Development of AMT control system

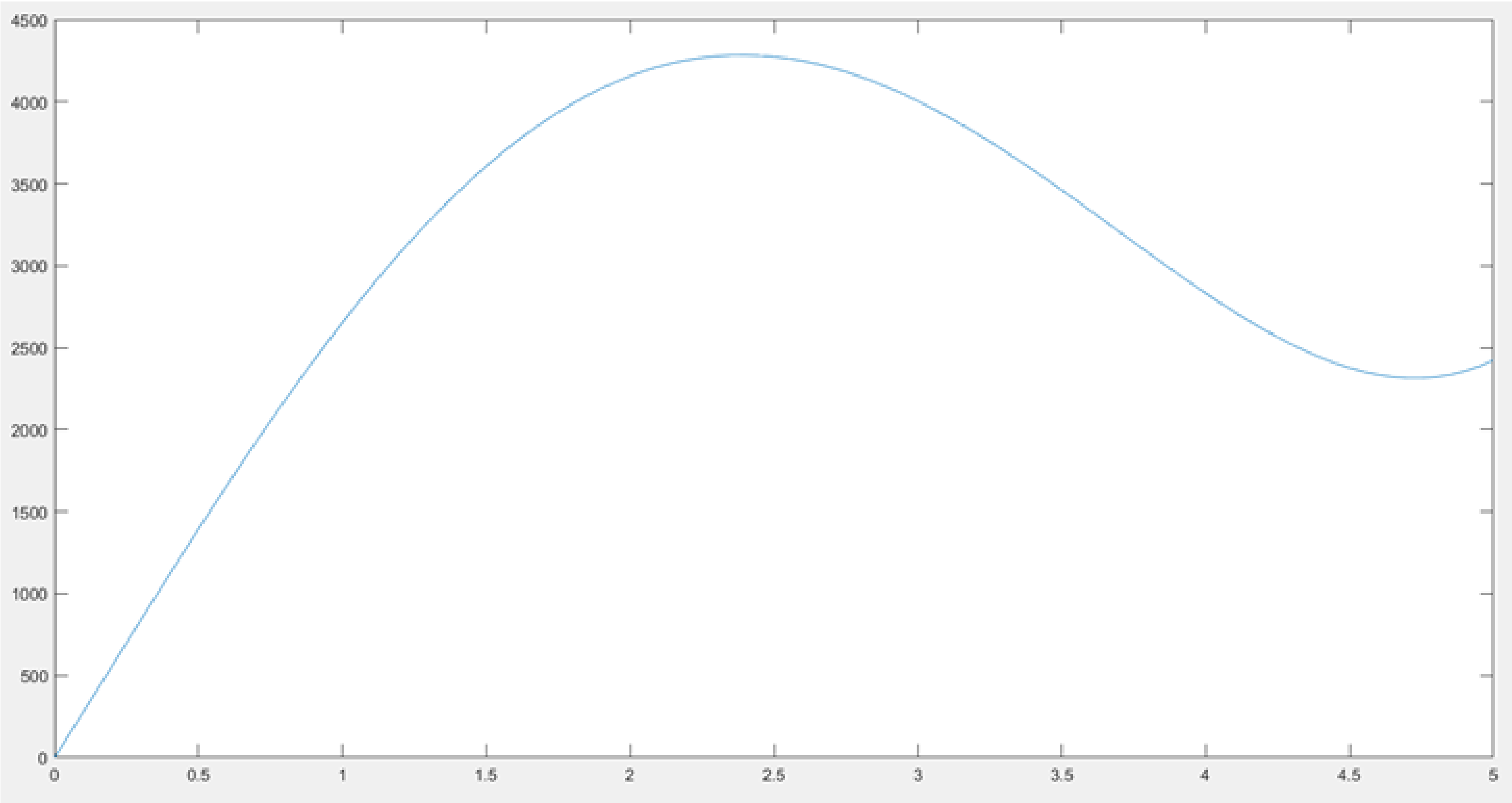
Test-Rig Simulation

1. Induction Motor shaft

- $J_m \ddot{\theta}_m = T_{em} - T_f - T_{air-clutch}$
- $T_{em} = \frac{m}{\omega_s} \frac{V_s^2}{\left(R_s + \frac{R_r}{s}\right)^2 + (X_s + X_R)^2} \frac{R_r}{s}$
- $T_f = \frac{D+d}{2} \mu_{clutch} F_{clutch}$
- $\mu_{clutch} = \left[\mu_k + (\mu_s - \mu_k) e^{-\beta |\dot{\theta}_m - \dot{\theta}_f|}\right] \tanh\left(\sigma \times \left(\dot{\theta}_m - \dot{\theta}_f\right)\right)$

2.Clutch model





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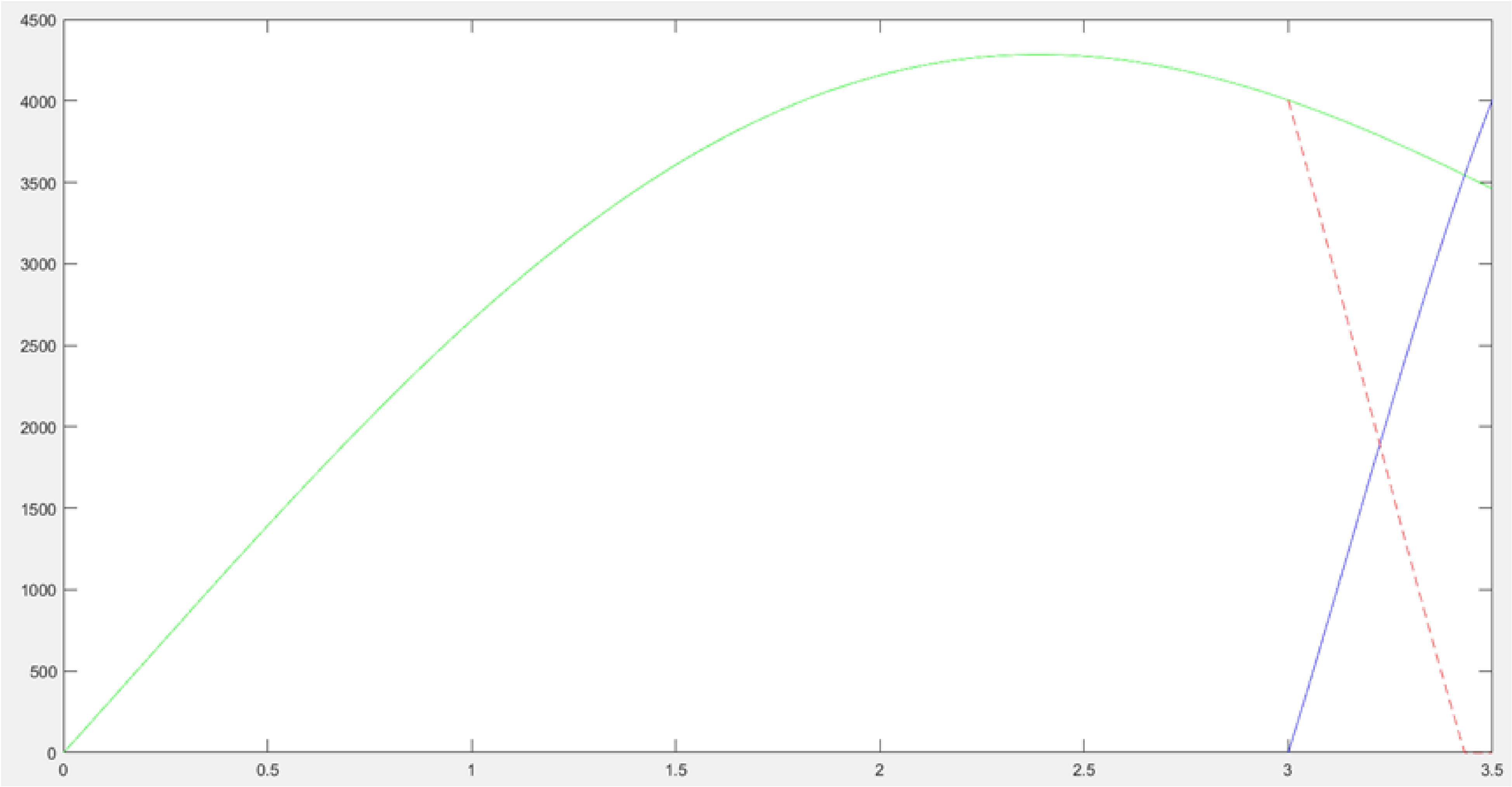


3. clutch friction disc

- $J_f \ddot{\theta}_f + b(\dot{\theta}_f - \dot{\theta}_{in}) + k(\theta_f - \theta_{in}) = T_f$

4. 1st case: 3-body configuration

- $J_{eq} = J_{in} + J_c \left(\frac{N_i}{N_c}\right)^2 + J_o \left(\frac{N_{kc}}{N_{ko}} \frac{N_i}{N_c}\right)^2$
- $J_{eq} \ddot{\theta}_{in} + b(\dot{\theta}_{in} - \dot{\theta}_f) + k(\theta_{in} - \theta_f) = -T_{air-flywheel} \left|\frac{N_{kc}}{N_{ko}} \frac{N_i}{N_c}\right|$

5. 2nd case: 4-body configuration

- $J_{in-eqv} = J_c \frac{1}{\left(\frac{N_c}{N_i}\right)^2} + J_{in}$
- $J_{in-eqv}\ddot{\theta}_{in} = b\left(\dot{\theta}_f - \dot{\theta}_{in}\right) + k\left(\theta_f - \theta_{in}\right) + \mu_{cone}Fr_c/sin\alpha \times \left(\frac{N_{kc}}{N_{ko}}\frac{N_i}{N_c}\right)$
- $J_o\ddot{\theta}_0 = -\mu_{cone}Fr_c/sin\alpha - T_{air-flywheel}$

6. DC model for Actuators

- $\frac{dI}{dt} = \frac{1}{L}[V - IR - K_e\omega]$
- $\frac{d\omega}{dt} = \frac{1}{J}[K_e I - B\omega - T_{Load}]$
- $T_{rising} = \frac{d_m}{2}\left[\frac{\mu+\cos(\theta)\tan(\alpha)}{\cos(\theta)-\mu\tan(\alpha)}\right] F$ [*]
- $T_{lowering} = \frac{d_m}{2}\left[\frac{\mu-\cos(\theta)\tan(\alpha)}{\cos(\theta)+\mu\tan(\alpha)}\right] F$ [*]

- [*]: ignoring collar friction

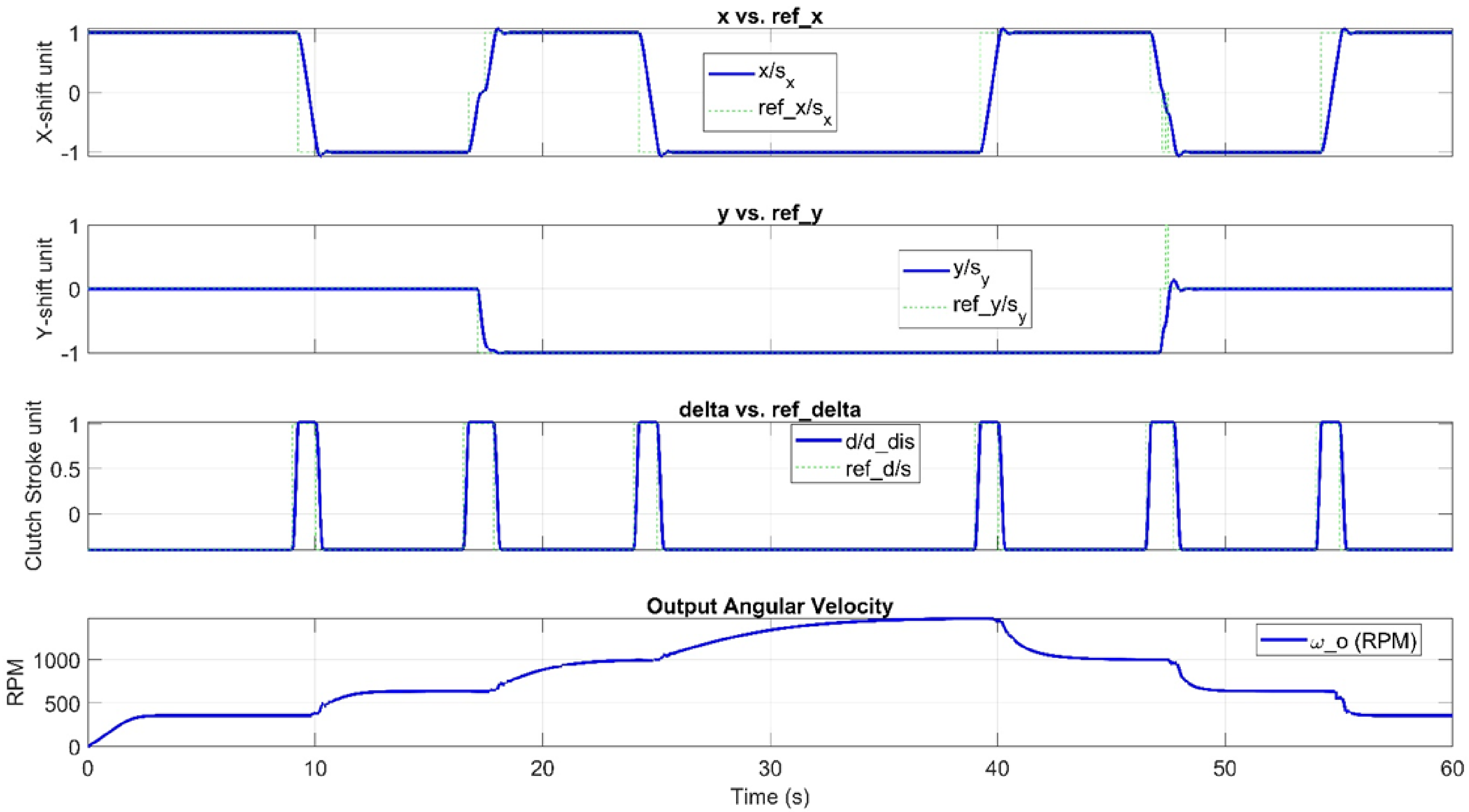
7. Code structure

Simulation Loop:

1. Configure Current position.
2. Decision of the shift (final references for shift).
3. Routing logic to implement decision (temporary references for shift actuators and clutch actuator till reaching final references).
4. PID control signals for actuators (control signal).
5. Plant (system) numerical D.Es output.

8. scenario

- Results of pushing the pedal for max in 30 seconds and back for the other 30 seconds:



Model Predictive Control (MPC)

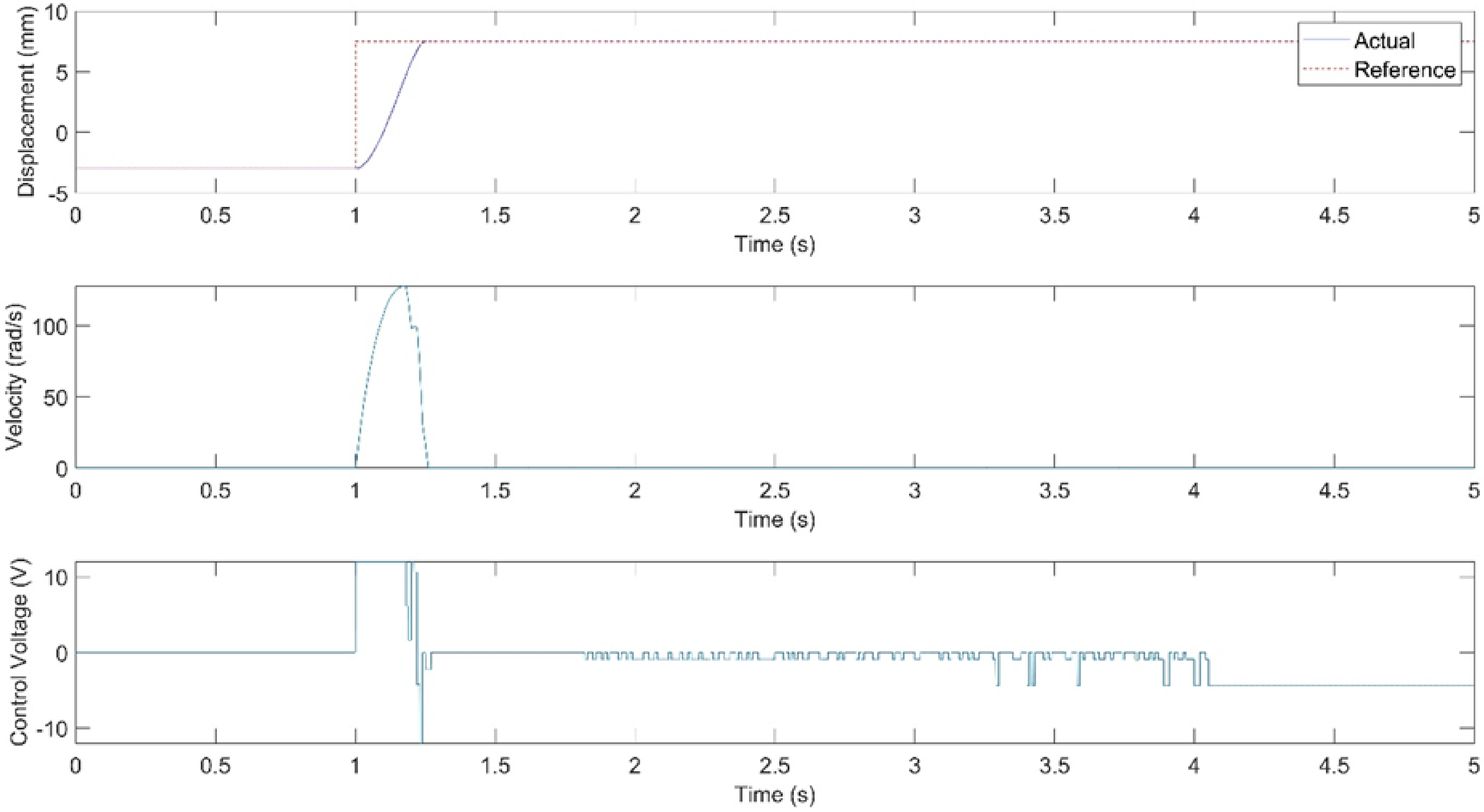
Clutch actuator discrete MPC

- non-linear MPC that our State model is non-linear ODEs
- constraints to the voltage that its magnitude not pass 12 volts

$$
\begin{aligned}
x_m(k+1) &= A_m x_m(k) + B_m u(k), \\
y(k) &= C_m x_m(k),
\end{aligned}
$$

$$x_m(k+1) - x_m(k) = A_m(x_m(k) - x_m(k-1)) + B_m(u(k) - u(k-1)).$$

[Valid for time invariant matrices A, B, C]



[*] Ignoring induction in the model