



Position Control of a Linear Motor

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Fig. 1: The linear motor

1 Position Control System

Fig. 1 shows the linear motor. Two movers (coils) are wound around one cylindrical stator (permanent magnet). The motor is controlled by passing electric current through the mover. The position x of the motor is measured utilizing an encoder (resolution $1\mu\text{m}$). Fig. 2 shows a block diagram of the position control system using a linear motor. The control system consists of a controller and a control target (Plant), where DOB stands for disturbance observer and shall be given by the structure shown in Fig. 3. $x, \dot{x}, \hat{x}, x^{ref}, \dot{x}^{ref}, s, k_t, k_{tn}, m, m_n, d, f^{coul}, f^{ext}$, and $\hat{f}^{dis}$ are the motor position, motor speed, estimated motor velocity, motor position reference, motor current reference, Laplace operator, thrust constant, nominal value of k_t , motor inertia, nominal value of m , viscous friction coefficient, Coulomb friction force of the motor, external force applied to the motor, and estimated disturbance force applied to the motor, respectively. k_1 and k_2 represent the controller gains. g_1 and g_2 denote the cutoff angular frequency of the low-pass filters (LPFs), that are determined by the encoder resolution and control period (update period of $\dot{x}^{ref}$ and measurement period of x^{res}) t_c . For this time, the integrator $1/s$ is implemented as the pulse transfer function $t_c/(1 - z^{-1})$. Let S denote the saturation function and define its output signal f^m as

$$f^m := \begin{cases} -a & (k_t \dot{x}^{ref} < -a) \\ k_t \dot{x}^{ref} & (k_t \dot{x}^{ref} \geq -a \wedge k_t \dot{x}^{ref} \leq a) \\ a & (k_t \dot{x}^{ref} > a) \end{cases} \quad (1)$$

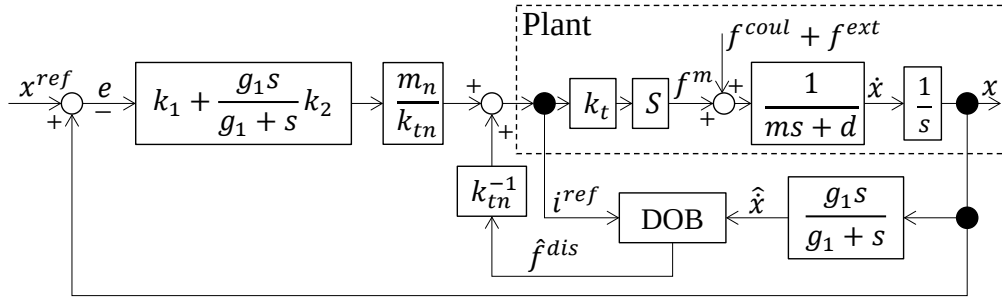


Fig. 2: Block diagram of the position control system

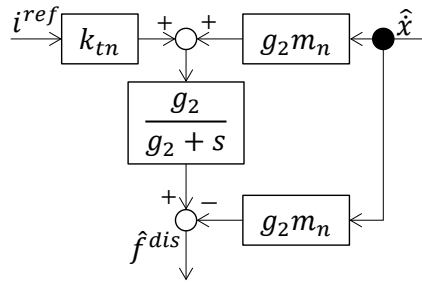


Fig. 3: Block diagram of the disturbance observer

Here, a means the upper limit of the motor driving force. The values of the physical variables of the experimental setup are shown in Table 1. g_2 is 0 or 300 [rad/s].

Table 1: Physical variables

Motor inertia	m [kg]	0.54
Viscous friction coefficient	d [N/(m/s)]	10.0
Thrust constant	k_t [N/A]	33.0
Control period	t_c [s]	0.0002
LPF cutoff angular frequency	g_1 [rad/s]	300.0
LPF cutoff angular frequency	g_2 [rad/s]	0.0 or 300.0
External force applied to the motor	f^{ext} [N]	0.0

2 Simulation using Matlab

Assume $S = 1$, $m = m_n$, $k_t = k_{tn}$, $f^{coul} = -1$ N, the initial value at time 0 s of x^{ref} is 0 mm and the target value is 20 mm.

1. Illustrate the step responses of x , $k_{tn}i^{ref}$, and $\hat{f}^{dis}$ from time 0 s to 1 s, and determine the rise time t_s , overshoot a_{max} with a reference of 20 mm, and position deviation e at time 1 s.
2. Derive the transfer function from x^{ref} to e and the transfer function from f^{coul} to e .
3. Find the steady state value of e from these transfer functions using the final value theorem and compare it with e obtained from Matlab.

3 Simulation using C language

Let $a = 33$ or 1000, $m = m_n$, $k_t = k_{tn}$, $f^{coul} = -1$ N, the initial value of x^{ref} at time 0 s is 0 mm and the target value is 20 mm.

1. Illustrate the step response of x , $k_{tn}i^{ref}$, and $\hat{f}^{dis}$ from time 0 s to 1 s when using the same k_1 and k_2 as in Section 2.