MF2007 - Workshop A

Adam Lang 861110-3956
Gabriel Andersson Santiago 910706-4538
Andreas Fröderberg 880730-7577

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Parameter identification

This section covers the methods behind finding the parameters to enter into the model to get the biggest similarity to the physical plant.

Level 1

To identify the parameters of the DC motor, firstly an idealized model is studied theoretically to understand which physical parameters that affect the performance of the motor. In the Laplace frequency domain, a model of the motor without inductance can be expressed as

$$X = \frac{k(1+\frac{1}{Rd})}{s\frac{J_t}{\frac{k^2}{R}+d}+1}U, \tag{1}$$

where X is the rotational speed, U is the input voltage, k, R and d are the electric motor constant, internal resistance and the viscous friction. The variable J_t represents the total inertia of the motor and the load. With the load inertia after a gear with gear ratio n, the total inertia is

$$J_t = J + \frac{J_{load}}{n^2}. \tag{2}$$

Here, the load inertia and the inertia of the motor are separated and the motor inertia from the datasheet is presumed to be correct, leaving only the load inertia as an unknown. Now the relations between the motor parameters and the time performance can be seen. The time constant is given by the term

$$\frac{J_t}{\frac{k^2}{R}+d} \tag{3}$$

and as such contains all the parameters of the motor. According to the final value theorem, the steady state value from a step input is given by setting $s = 0$ and therefore the steady state gain is given by

$$k(1+\frac{1}{Rd}). \tag{4}$$

This contatiains only one unknown parameter. Therefore, to estimate the viscous friction parameter d, it is suitable to examine and match the steady state rotational speed of the real system and the model. Since this model contains no static friction which is probably present in the real system, the test is conducted at maximum permissable input voltage to minimize the disturbances in the test data. Since the desired value does not depend on frequency, only a square wave input is used to simulate steps in both directions.

Now that the friction parameter is presumed to be correct and fixed, the time constant in Equation (3) only has one unknown, the load inertia. This is estimated from taking the time constant from step inputs, simulated by a square wave signal. Again, to minimize model disturbances caused by the static friction present in the real system, the square wave is run at a full 24 V.

Level 2

As could be seen in the earlier friction model, it did not incorporate the effects of static friction which led to inaccuracy in the model when varying the rotational speed. A model which captures the real behaviour of the system is used here, called the Karnop friction model. In addition to the linear friction, the static friction is taken into account by adding a stick-slip zone where the friction tourque is equal to the applied torque. The model is given by the equation

$$M_f = d\dot{\phi} + F_c sgn(\dot{\phi}), \tag{5}$$

with the friction torque M_f and the static friction F_c. This friction is the maximum static friction torque that can be applied in the stick slip zone. There is now one more design parameter that needs to be tuned, F_c.

The linear friction is still most prominent when at high velocities and the static friction is the strongest when at low velocities. The inertia is decided solely from the rise time and should not differ much from the previous model. Firstly, the step response to a 5 V square wave is examined to determine the static friction. When the static friction is set, the response to a square wave at 24 V is examined and d is adjusted to fit the static friction. A sine of low amplitude is then run to test the behaviour around the turning points.