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Dc Motor Speed Control by PID Controller

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Abstract

Principle of control of a DC motor. Characteristics of DC Motor: The DC motor has a relatively small mechanical inertia. Easy to change speed over a fairly wide range. The complex structure due to the brush on the semicircular rim leads to low engine life, periodic maintenance, easy to generate sparks, so it does not work in places with underground gas and explosion-proof. The capacity of a DC motor is usually low because of its complicated structure. If the capacity is high, it will be cumbersome and expensive. The efficiency is not high compared to other types of electric motors. However, due to the advantage of DC motors that there are many methods to change the speed and easily change the speed and direction of rotation, small-capacity DC motors are still commonly used today.

Keywords: *dc motor, dc motor speed, PID controller*

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I. INTRODUCTION

A DC motor is an electric motor that works with direct current. DC motors are widely used in civil and industrial applications

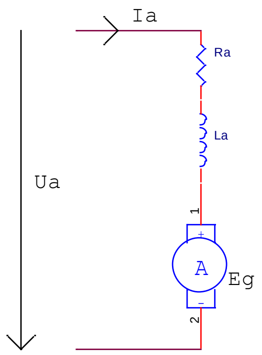
The structure of the motor consists of two parts: the stator is stationary and the rotor rotates relative to the stator. The inductor (the excitation part - usually placed on the stator) generates a magnetic field that travels in the magnetic circuit, through the armature windings (usually located on the rotor). When current flows in the armature circuit, the armature guides are acted upon by electromagnetic forces in the direction tangential to the rotor cylinder, causing the rotor to rotate.

Depending on how the rotor and stator windings are connected, the following types of motors are available:

- Independent excitation motor: field winding (stator winding) and armature winding (roto) are connected separately, can be powered separately.
- Series excitation motor: Field winding in series with armature winding:

For the independent excitation motor, one can replace the field coil by a permanent magnet, then we have a DC motor that uses permanent magnets. This is the type of engine used in this project.

II. MODELING DC MOTOR



$$u_a = R_a i_a + L_a \frac{di_a}{dt} + e_g \qquad (1.1)$$

$$e_g = k_v \Phi n$$

where Φ is the magnetic flux caused by the permanent magnet. n is the motor speed.
Electromagnetic torque:

$$T_d = K_t \Phi i_a$$

Equation of the engine:

$$T_d = J\frac{d\omega}{dt} + B\omega + T_L$$

B: coefficient of friction
T: monen load.
In setup mode:

$$u_a = R_a i_a + e_g$$

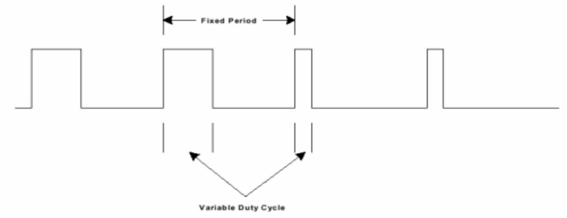
$$T_d = 2\pi nB + T_L = K_t \Phi i_a$$

We get the motor speed at steady state:

$$n = \frac{U_a - I_a R_a}{K_v \Phi}$$

III. MOTOR SPEED CONTROL METHOD

For the type of independently excited motor using permanent magnets, to change the speed, we change the voltage supplied to the rotor. It is often difficult to apply variable DC voltage, so the pulse modulation method (PWM) is used:



The pulse modulation method will keep the frequency constant, change the duty cycle to change the average voltage applied to the motor.
Average voltage:

$$V_{dk} = \frac{T_{on}}{T} V_{in}$$

Due to the inductive nature of the motor, the current through the motor is a continuous

IV. INVESTIGATE THE TRANSFER FUNCTION

Laplace transform we get

$U_a(p) = R_a I_a(p) + pL_a I_a(p) + E_g(a)$

Approximate transfer function found experimentally:
To find the transfer function experimentally we find the impulse response of the motor.
We apply the voltage equal to the rated voltage to the motor and plot the velocity versus time graph. Because of the small velocity sampling time, we do not see the inflection points of the graph, so here we approximate the motor drive function as the first order of inertia, which has the following form.

$$G = \frac{k}{Tp + 1}$$

Impulse response of the motor:

$$n(p) = \frac{kU}{(Tp + 1)p}$$

Inverse Laplace transform we get

$$E_g(p) = k_v \Phi n(p)$$

$$T_d(p) = K_t \Phi I_a(p)$$

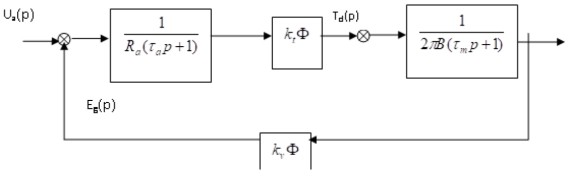
$T_d(p) = 2\pi pJn(p) + 2\pi Bn(p) + T_L(p)$

$$n(p) = \frac{T_d(p) - T_L(p)}{2\pi B(p\tau_m + 1)}$$

$$I_a(p) = \frac{U_a(p) - E_a(p)}{R_a(\tau_a p + 1)}$$

Where $\tau_a = L_a/R_a$ Time constant of the armature circuit

τ_m =J/B Mechanical time constant.



When the load torque is zero, we have:

$$n(p) = U_a(p)\frac{1}{\frac{2\pi BR_a}{K_t\Phi}(\tau_a p + 1)(\tau_m p + 1) + K_v\Phi}$$

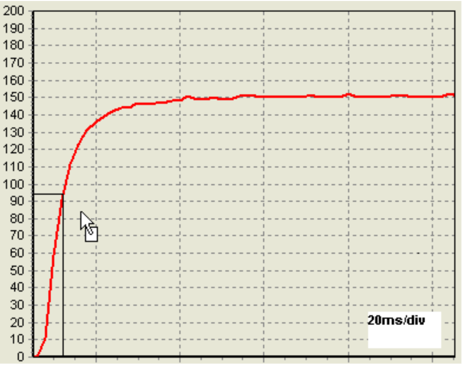
So the transfer function of the motor now has the form of an oscillating link

$$n = kU(1 - e^{-t/T})$$

$t = T$, $n = kU(1-e^{-1}) = 0.63kU = 0.63n_{max}$

So on the graph we determine the point at which n=0.63nmax then find T

Based on the graph found by experiment, we can find the parameters kU and T



kU = 150

T = 30ms=0.03s

So the transfer function is approximate

$$G = \frac{k}{Tp + 1} = \frac{150/24}{0.03p + 1} = \frac{37.5}{0.03p + 1}$$

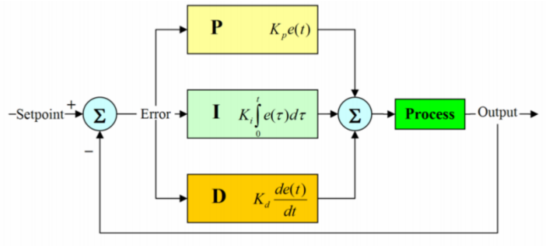
V. METHOD OF STABILIZING MOTOR SPEED USING PID

PID algorithm

$$G = K_p + K_i\int e(\tau)d\tau + K_d\frac{de(\tau)}{d\tau}$$

In there:

- Kp: Ratio stitching factor (amplification step)
- Ki: Integral coefficient
- Kd: differential coefficient



Ziegler-Nichols PID parameter calibration method:

Usually the selection of parameters P, I, D is determined experimentally based on the impulse response of the system. Ziegler - Nichols proposed a method to choose PID parameters for the first-order inertia model with hysteresis. Here we approximate the transfer function of the motor to use this method, although not completely accurate, but can give a relatively good response.

This method requires to calculate the limit value of the proportional link Kgh and the limit period of the closed system Tgh. Then find other parameters according to the following table:

	K_P	T_I	T_D
P	$0.5 \cdot K_{gh}$	-	-
PI	$0.45 \cdot K_{gh}$	$0.83 \cdot T_{gh}$	-
PID	$0.6 \cdot K_{gh}$	$0.5 \cdot T_{gh}$	$0.125 \cdot T_{gh}$

To find Kgh and Tgh, we initially set Ki, Kd to zero and then slowly increase Kp so that the system is at the border stable (oscillations with constant amplitude and period), here we can determine Kgh. and Tgh¬ then calculate other parameters depending on the controller as shown in the table above.

Ki = Kp/Ti

Kd = KxTd

For convenience in the process of adjusting and observing the response of the motor, in this project we have built a program written in VB on the computer to communicate with the control circuit.

VI. CONCLUSION

we see that the rate law (P) has the characteristics of fast acting but cannot eliminate the bias, and at the same time overshoot the increasing system. The integral step allows for the suppression of bias but is slow to act. The differential stage responds to the rate of variation of the error. We need to determine the parameters Kp, Ki, Kd to get the system with the desired quality.

ACKNOWLEDGEMENT

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