

Novel Robust Control Algorithm of DC Motors

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Abstract - In this paper, a novel speed control algorithm of dc motors is presented. The key contribution here is a robust controller of motor speed created based on the reference velocity of system. This velocity reference is adjusted before the controller to improve the control performance of the motor speed. Therefore, our proposed velocity control algorithm for dc motors works with only a PWM signal. The current control loop can be neglected while the performance of the system is maintained. Moreover, after this method is applied, a simpler controller as well as a less complex turning method of DC motor's velocity could be achieved. Those eliminations make the design process of DC motor control convenient, and less complex. This proposed control method is investigated by both mathematic analysis and experimental results.

Keywords - DC motor control, feedback control algorithm of DC motors, reduced control scheme of dc motor, robust control of DC motor.

1. Introduction

Direct current (DC) motors are widely used in industrial applications including mechatronics, automobile, robotics, and aerospace systems [1, 2]. In those systems velocity control is one of the most typical topics of dc motor control. For example the velocity control of mobile robots, CD-ROM, electrical screw driver, computer hard-disk, and so on.

In general, an accurate velocity control scheme requires two closed-loops, an inner current control loop [1,3] and an outer velocity control loop. In this paper, a novel robust control method of dc motors is presented. Our proposed velocity control algorithms for dc motors need only a simple PWM signal. The current control loop can be removed while the performance of the system is maintained. Moreover, after this method is developed, a simpler controller as well as a less complex turning method is possible.

2. General velocity control method of dc motors

2.1 DC motor modeling

The electrical diagram of the permanent magnet DC motor is shown as Fig. 1. According to the Kirchhoff law, the electrical equation of DC motors can be expressed as Equation (1).

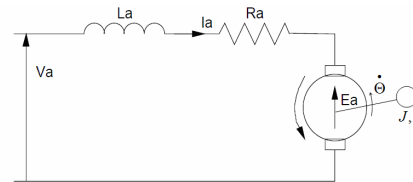


Fig. 1. Electrical diagram of permanent magnet DC motors

By applying the Newton's law and Kirchoff's law to the dc motor system, we have mathematic equations (1) and (2) of DC motors.

$$V = L \frac{di}{dt} + Ri + Ea \quad (1)$$

$$J \ddot{\Theta} + b \dot{\Theta} = \tau_m \quad (2)$$

Where V is the supply voltage, i the armature current, Ea is the back-emf (electromotive force). L and R are the electric inductance, and electric resistance respectively. J is the moment of inertia of the rotor, b is the damping ratio of the mechanical part. The motor torque, τ_m , is related to the armature current, i , by a constant factor k_t (In SI units, k_t (armature/torque constant) is equal to k_e (motor/speed constant)). The back emf, e , is related to the rotational velocity by the equation (3).

$$\tau_m = k_t i \quad (3)$$

2.2 Typical velocity control structure for dc motors

Fig 2 illustrated a typical velocity control structure of dc motor. The control scheme consists of an inner current control loop. And an outer velocity control loop. The output signal of velocity controller is the input of the current controller. Those two controllers can be designed independently because the mechanical dynamics of the system is usually much slower than the dynamics of the armature circuit.

Reference velocity $\dot{\Theta}_{ref}$ is the desired velocity which the motor should be achieved after designed time. The controller found in typical industrial systems is PID control algorithm. It also can be include fuzzy, neural network, or adaptive controllers. The current sensor and

encoder are usually used as feedback devices in the system.

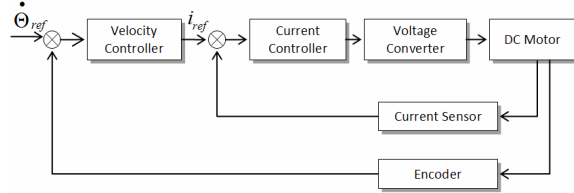


Fig. 2. A typical velocity control structure for dc motor

3. Novel robust velocity control algorithms

3.1 Overview of proposed velocity control algorithms

To simplify the velocity control of DC motors, we have proposed a new control scheme shown in Fig. 3. The novel concept here is the original reference velocity is multiply with a gain m . The modified reference now becomes the reference input of the controller. With this modification, the current control loop can be removed in this control scheme while steady-state error can be converged to zero. The detail analysis of steady-state error and the method to find the exact value of m are presented in session 3.2.

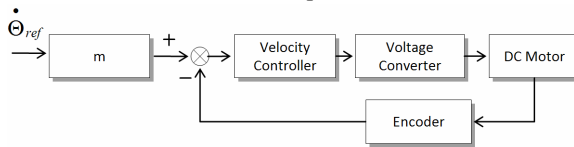


Fig. 3. Proposed scheme for motor velocity control

3.2 Mathematical analysis of the proposed algorithm

Let consider a P controller for velocity control loop in typical control scheme in Fig. 2. The closed loop system can be described as:

$$\dot{\Theta} = \frac{K_p G(s)}{1 + K_p G(s)} \dot{\Theta}^d$$

where $G(s) = \frac{K_{obj}}{s + T_{obj}}$ is the transfer function of the DC motor

K_{obj} and T_{obj} are constant which relate to motor parameters. The error is given by:

$$E(s) = \dot{\Theta}^d - \dot{\Theta} = \frac{1}{1 + K_p G(s)} \dot{\Theta}^d$$

For a step reference input: $\dot{\Theta}^d(s) = \frac{\Omega^d}{s}$

$$\text{We have, } E(s) = \frac{s + T_{obj}}{s + K_p K_{obj} + T_{obj}} \cdot \frac{\Omega^d}{s}$$

Therefore, the steady state error e_{ss} satisfies:

$$e_{ss} = \lim_{t \rightarrow \infty} e(t) = \lim_{s \rightarrow 0} sE(s) = \frac{T_{obj}}{K_p K_{obj} + T_{obj}} \cdot \Omega^d > 0$$

The steady-state error can be calculated as followings:

$$\Omega^d - \Omega = e_{ss} = \frac{T_{obj}}{K_p K_{obj} + T_{obj}} \cdot \Omega^d$$

$$\frac{\Omega^d}{\Omega} = \frac{1}{1 - \frac{T_{obj}}{K_p K_{obj} + T_{obj}}} = m$$

It means we can get the steady state velocity equals to Ω^d if the reference input equals to $m \cdot \Omega^d$. Therefore, the

novel control scheme shown in Fig. 3 is able to provide zero steady-state error.

4. Experiment and result

4.1 Experimental setup

The experiment was set as Fig. 4. A DC maxon motor was used. The encoder had 4096 pulse/revolution. An PCI board (NI PCI 7356) was used to connect the DC motor with an user interface developed in LabVIEW invernment.

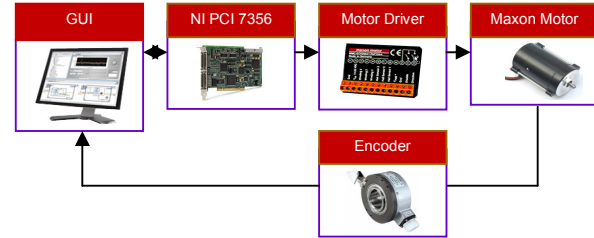


Fig. 4. Proposed scheme for motor velocity control

4.2 Experimental result

Fig. 5 shows experimental result of proposed method. Measured velocity follows reference velocity with error 7%, and setting time is 2 ms.

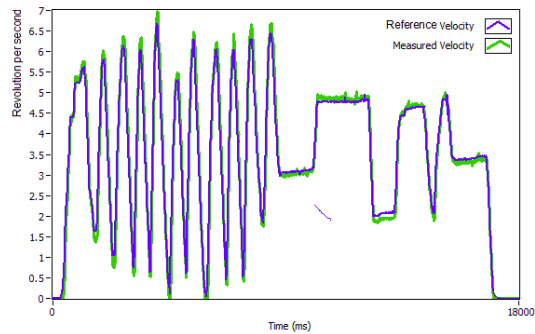


Fig. 5. Experimental result of proposed control method

5. Conclusion

A novel and simple control scheme of motor velocity was proposed. The steady-state error is proved to be converged to zero. Its feasibility was demonstrated with experimental result.

References

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