Research on Development of a Wide Range Velocity Control Method of Small Size DC Motor for Portable Drug Delivery System

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=Abstract=

Small size DC motor control method for portable drug delivery system has been developed to be used for the actuator of insuline pump. The control method gives the controllabilities both in high speed(40-50 revolution per second(rps)) DC motor drive and also in low speed(0.5-1rps). In low speed mode DC motor is controlled to act like stepping motor and in high speed to optimize power consumption. To control both mode modified bang bang control is suggested. Using this method small size DC motor(spec.) speed is controlled from 0.2 rps to 50 rps.

Experimental setup is developed using micro-processor(PIC16C73, Micro Chips co., USA), motor turns checking circuitry, small size DC motor for pager(SM1012, Samhong co., Korea) and gear box. Results from experiment meet need for vailable load condition which is require for portable drug delivery system.

Introduction

In some chronic disease, therapy is injecting proper rate of chemicals to patients.[1,2,3] Most of portable drug delivery system such as infusion pump have been used stepping motor as an actuator to inject drug because of its control conveniency in spite of its large size and poor power consumption efficiency. But need for smaller, lighter, more efficient actuator is increased for its portability and comportablility of using.

As one of the alternatives, electromagnetic solenoid actuator is suggested and used as commercial device[4]. But this type of actuator seem to have mechanical unreliability due to fatigue of large amount of solenoid contact. This paper suggests the actuation method using small size geared DC motor imitating stepping motor operation.

In this paper, we investigated the feasibility of small size geared DC motor as an actuator of portable drug delivery system by using both small inertial effect of DC motor and large inertia effect of multiple gear under the variable operational conditions. We found possibility of this application through measuring the accuracy of motor turns of high and low speed operation.

The following sections include description of DC motor control method, our experimental setup, result of experiment and discussion.

Materials And Methods

DC Motor Control Method

Compare to stepping motor, DC motor is known to be hard to control. In general, DC servo system is using conventional proportional integral derivative (PID) control as a control criterion and pulse width modulation(PWM) as a driving method. As shown in fig. 1, PWM method is applied for motor control under the linear approximation of motor system. To satisfy this assumption PWM frequency is below one by ten of time constant of motor. Conventional PID control criterion is well operated under the PWM linearization of motor current. Small size DC motor used in this research has relatively short time constant(below 0.1ms) compared to other DC motor used in any kind of portable system. Because of difficulty of generating PWM pulse with frequency of above 100 kHz, nonlinear PWM control is suggested. As shown in fig. 2, motor is nonlinear system and modeled to be R-L series pair. In this system motor current cannot be controlled by PWM

duty cycle, but like bang-bang control motor is operated on its current saturation region. In this application multiple gear box is assemble to motor axis and this reduce the motor turns totally to 1 over 3000. Short time constant means motor has small inertia and fast current saturation time and Multiple gear box has large inertia compared to that of motor. As shown in fig. 3, when motor is on(powered), motor current is saturated fast (*motor property*), and motor velocity increases more gradually than motor current (*multiple gear box property*) and this transient is change the equilibrium of motor power and inertive load of gear box. If motor is off in transient, current is decayed fast (*motor property*) but velocity is maintained in a while due to large inertia (*multiple gear box property*). By this mechanism velocity of nonlinear motor system is controlled to be very slow (0.5 to 1 rps.). And this low velocity controllability can make the high speed position control optimal compared to conventional PWM drive, because when the system need is high speed but accurate injection of relatively large amount of drug, we can power on the motor and stop it using mechanism mentioned above, by operating relative nonlinear PWM method at proper safe position before aimed position.

Experimental Setup

As shown in Fig. 4, the total system consists of controller and driver (PIC16C73, Micro Chips co., USA), motor turns checking circuitry(using counter of 68HC11, Motorola co., USA), small size DC motor(SM1012, Samhong co., Korea) with diameter of 8mm and length of 12mm, gear box of handicraft. Using binary coded decimal(BCD) switch turns that motor is command to turn is input to controller and another switch indicates to controller whether motor turns in high speed or low speed. And motor turns checking circuitry count motor turns and display it on LCD.

Results

Fig. 5 presents the low speed controllability of this system. Nonlinear PWM frequency is available for 600 Hz to 2kHz, and duty is about 7% for no additional load condition. Table 1 presents the result of experiments which measure accuracy of turns varying command to turn at 1kHz nonlinear PWM frequency. Even in operation high speed and large amount of turns accuracy of this system doesn't change.

Discussion

Although other actuation methods such as solenoid or shape memory alloy and are also available for driving portable drug delivery system and motor is the most conventional and easy to actuation wide range of drug delivery amount. DC motor is more efficient choice in size and power consumption than stepping motor.

Experimental results provide availability of DC motor in wide range control of actuation rate. Using this property to other industrial need, small size and accurate position control will be available. But DC motor actuator device originally has problem of mechanical reliability of contact brush and electrical reliability of drive overload so, in the near future more reliable and smart device such as micro actuator using semiconductor will take place of electrical motor system

Reference

(1) Patritia B, Grant F, Richard G, Geralmine C, "Ambulatory Antibiotic infusion Devices: Extending the

Spectrum Outpatient Therapies", The American Journal of Medicine, vol. 91 pp. 455-461. Nov. 1991

〔2〕 Williams D, Gibson J, Bosch D, "Home intravenous antibiotic therapy using a programmable infusion pump", Arch Intern Med, vol. 149, pp. 1157-60, 1989

〔3〕 Keefe D, Herlihy C, Gross Y, Kelly J, "Patient-controlled analgesia using miniature electrochemically driven infusion pump", British journal of Anaesthesia, vol. 73, pp. 843-846, 1994

〔4〕 MiniMed[R] Technologies , "The MiniMed[R] Infusion Pump", Instruction Manual, 1987, CA, USA

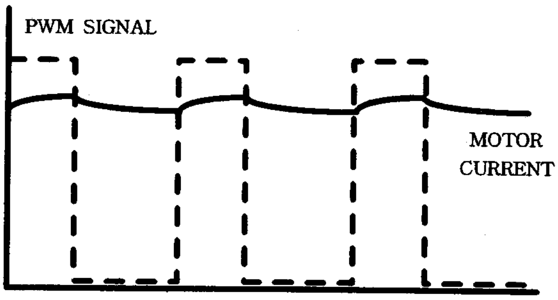

Fig. 1 Approximately Linear Characteristic of Motor Current. When PWM Frequency is below 1/10 of Time Constant of Motor.

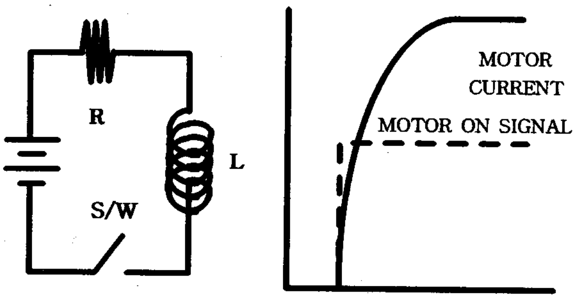

Fig. 2 Nonlinear Model and Characteristics of DC Motor

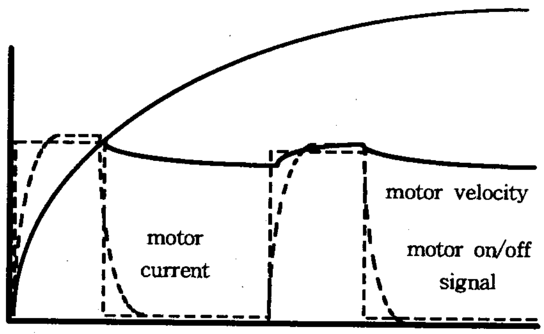

Fig. 3 Principles of Nonlinear PWM Control for Low

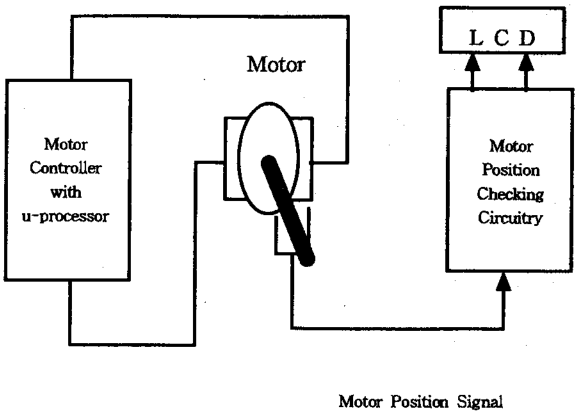

Fig. 4 Schematic Diagram of Experimental Setup

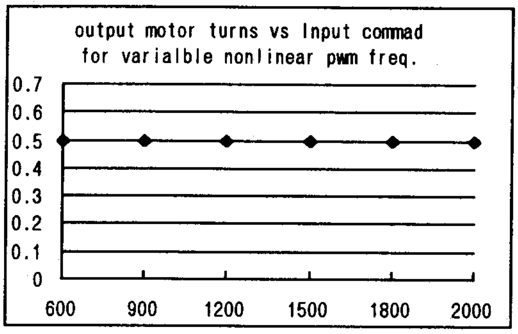

Fig. 5 Resulting motor turns for input command with varying linear PWM frequency

command	1 turns	10 turns	100 turns	1000 turns	2000 turns	3000 turns
result	1 turn	10 turn	100 turns	1000 turns	2000 turns	3000 turns
operation	low velocity			high velocity		

Table 1 Response of Experimental Setup for Varying Command Input at 1 kHz of Nonlinear PWM Frequency