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Digital Position Control Strategy of Traveling-wave Ultrasonic Motors

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Since a conventional controller is continuous one, control period is normally set for a long time. When applying that controller for a travelling-wave ultrasonic motor whose parameters and performance are time-varying as a result of increasing temperature and operating condition, it is consequently resulted in degradation of the control performance. In this paper, a digital control algorithm is proposed for position control of the motors to shorten the long control period to maintain the stability of the motor performance. The proposed controller is digitally implemented by a SH7125 microcomputer utilizing a high-performance embedded workshop. The state quantities such as acceleration, speed and position, which are necessary for digital implementation, are provided by a rotary encoder. However, the optical encoder causes quantization errors in the speed information. To overcome the problem, a digital Variable Structure System (VSS) observer is also included to estimate the state quantities. The control input will be calculated after comparing the measured values and the estimated values given by the VSS observer. In short, a small, low cost and fast responsive digital controller is designed, based on a digital VSS observer, by using the SH7125 microcomputer. Effectiveness and reliability of the proposed digital controller are experimentally verified.

Key words: Ultrasonic Motor, Microcomputer, Embedded System, Digital Controller, VSS Observer

Strategija upravljanja pozicijom ultrazvučnog motora s putujućim valom.
S obzirom da je standardni regulator najčešće kontinuirani, period upravljanja obično je postavljen na duži period. Koristeći takav regulator pri upravljanju ultrazvučnim motorom s putujućim valom, čiji su parametri i svojstva vremenski promjenjivi zbog povećanja temperature i promjena uvjeta rada, rezultat su smanjena upravljačka svojstva. U ovome radu predložen je digitalni upravljački algoritam za upravljanje pozicijom motora u svrhu smanjenja dugačkog perioda upravljanja za održavanje stabilnosti svojstava motora. Regulator je implementiran koristeći SH7125 mikroračunalo uz HEW (engl. *high-performance embedded workshop*) okruženje. Iznosi veličina kao što su akceleracija, brzina i pozicija, nužnih za digitalnu implementaciju, dobiveni su iz rotirajućeg enkodera. Međutim, optički enkoder dovodi do greške kvantizacije kod proračuna brzine. U svrhu smanjenja tog problema, u proces proračuna iznosa varijabli uključen je VSS (engl. *Variable Structure System*) estimator. Upravljački ulaz računa se nakon usporedbe mjerenih i estimiranih vrijednosti dobivenih korištenjem VSS-a. Dizajniran je digitalni regulator malih dimenzija, jeftine cijene i brzog odziva, temeljen na digitalnom VSS estimatoru koristeći SH7125 mikroračunalo. Eksperimentalno je provjerena efikasnost i pouzdanost digitalnog regulatora.

Ključne riječi: ultrazvučni motor, mikroračunalo, ugradbeni sustav, digitalni regulator, VSS estimator

1 INTRODUCTION

In recent years, ultrasonic motor (USM) has been gaining much attention as owning excellent characteristics and operating performances: high torque at low speed, high torque to weight ratio, fast and accurate speed response, holding torque without power supply, good start-stop dynamics, simple mechanical design, small in size and no electromagnetic noise. The USM is therefore much expecting to be applied to robot actuators, high precision positioning devices and medical equipments [1].

Although, many different types of USMs have been proposed up to date [1]-[4], travelling-wave ultrasonic motor (TWUSM) is still the most commonly used type of the USM category [4]. This study is therefore limited to the TWUSM.

The driving principle of the TWUSM is based on high-frequency mechanical vibrations and frictional force. Hence, mathematical model of the motor is quite difficult

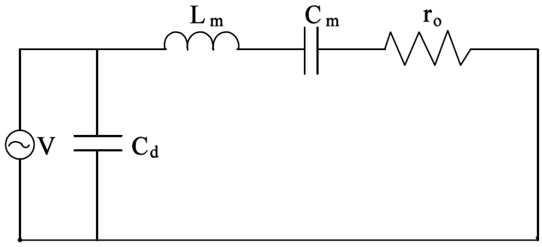


Fig. 1. Single Phase Equivalent Circuit of TWUSM

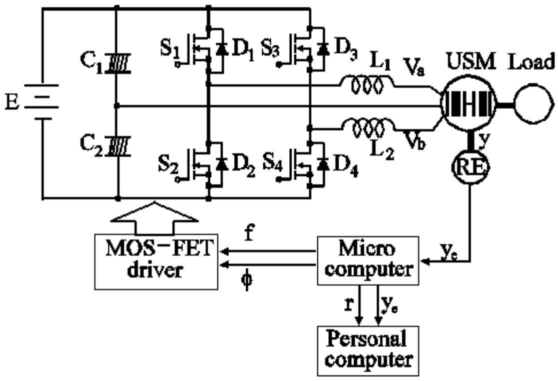


Fig. 2. Drive System of USM

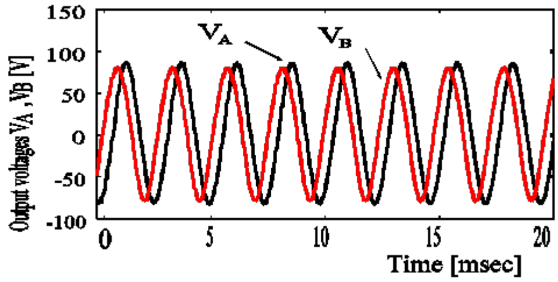


Fig. 3. Output Voltage of Two-phase Inverter

Table 1. Design Specification of USM

Drive frequency	40 kHz
Drive voltage	100 V_{rms}
Rated current	53 mA/phase
Rated torque	0.314 Nm
Rated output power	3 W
Rated speed	9.0 rad/s
Mass	0.240 kg

to derive [5]-[8]. The operating principle of the TWUSM also has complicated characteristics compared to a conventional electromagnetic motor and highly nonlinear [8]. Moreover, the motor parameters are time-varying due to increases in temperature and changes in the motor drive operating conditions [8]. Thus, it is very difficult to effectively control the motor due to those drawbacks.

Basically, speed and position of the TWUSM can be manipulated by controlling the driving frequency, phase difference and voltage amplitude of the input two-phase voltages [9]. Driving frequency control method is preferred as giving wide control area than the other methods [9]-[10]. Therefore, TWUSM is usually controlled by driving frequency method. Alternative methods can be hybrid or dual control methods with multiple control inputs [11]. Many control schemes have been reportedly applied to the position control of TWUSM in recent years such as model based, proportional-integral (PI), direct pulse width modulation (PWM), sliding mode, nonlinear adaptive, robust adaptive, fuzzy, adaptive fuzzy, neural network, and fuzzy neural network. Digital signal processors, computers, microcomputers, special microcontroller have been used to achieve that drives and controls [9].

PI control algorithm is simple and can be adapted easily to the TWUSM control system. Robust adaptive control algorithms can be considered as a complicated control applications of the TWUSM [12]. An optimum efficiency control strategy with varying step length based on fuzzy reasoning is proposed in [13] to increase the operational efficiency of the ultrasonic motor system. Single chip microcomputer device can be used to achieve control applications of the USM successfully [14].

However, most of the above control schemes are designed to work in continuous-time system. Thus, those controllers are continuous ones; control period is normally set for a long time. When applying them for the TWUSM whose parameters and performance are time-varying as a result of increasing temperature and changes of the motor working condition, it is consequently resulted in degradation of the motor performance.

In this paper, a digital position control is proposed to shorten the control period in order to maintain the stability of the motor performance. To apply the digital control for position control of the TWUSM, state variables such as acceleration, speed and position of the motor are required. A rotary encoder is therefore employed to provide these feedbacks. However, speed information detected by a rotary encoder has quantization errors, especially in low speed region [15]. For that reason, a digital VSS observer [16] with the possibility of decreasing quantization errors is also presented to estimate accurately the actual rotor speed as well as other state variables.

Usage of a microcomputer in embedded system has many advantages such as discretizing process, being stable and small size circuit in comparison to analog circuit, constructing control system at low cost, upgrading response and making the system design easier [17]-[18]. Therefore, in the experimental work, a microcomputer named SH7125 of SH/Tiny series of Renesas Electronics Corporation utilizing a High-performance Embedded Workshop (HEW) tool is used to implement the proposed control scheme. The digital implementation is to prove that the VSS observer really increases the control performance and a precise control method is successfully archived. The proposed controller is expected to be experimentally found satisfactory.

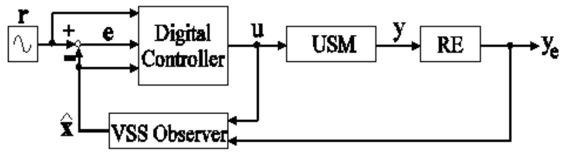


Fig. 4. System Configuration

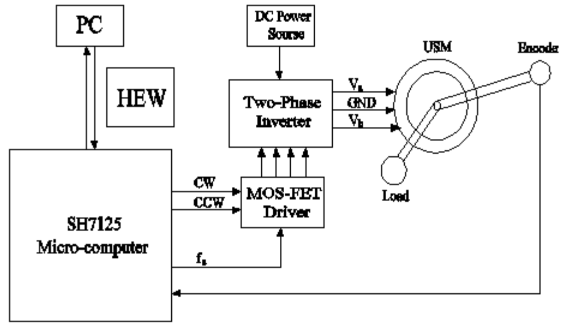


Fig. 5. Microcomputer-based Controller of USM

2 SYSTEM CONFIGURATION

2.1 Model of Ultrasonic Motor

In this study, a TWUSM called USR-60 of Shinsei Corporation is worked on. Specifications of the motor are shown in Table 1. The motor is driven by two-phase sinusoidal high frequency voltages with 90 degree phase difference. The speed of the TWUSM is controlled by amplitude, frequency and phase difference of the input two-phase voltages. The energy conversion of piezoelectric system is based on the piezoelectric element and mechanical vibration system. The electromechanical behavior of a piezoelectric ceramic used in the stator of the TWUSM can be modeled by means of equivalent circuit as shown in fig. 1. In fig. 1, L_m, r_0 and Cm are equivalent inductance, equivalent resistance and equivalent capacitance, respectively. V is applied voltage, Cd is damping capacitance. To obtain high efficiency in the drive system, the TWUSM should be driven at the near the frequency that creates resonance between Lm and Cm in the equivalent circuit. The detailed theoretical information and equations of the equivalent circuit and travelling wave can be found in [19].

2.2 Driving System of the TWUSM

For a practical operation of the TWUSM, a specific and individual power supply and high quality semiconductor devices are required. It is difficult to drive the piezoelectric ceramic because of its high damping capacitance. To drive piezoelectric ceramic smoothly, resonant frequency approach is commonly used. For this reason, a serial or parallel inductance is connected with each phase of the TWUSM to provide the resonant frequency. Fig. 2 shows drive system of two-phase high frequency voltage fed serial-resonant inverter of the TWUSM. The inverter includes PWM, pulse frequency modulation (PFM), and hybrid (PWM and PFM) control techniques. L_1 and L_2 inductances are connected in series with each phase to become resonant with the damping capacitance (C_d) of the TWUSM. The inverter produces rectangular waveforms with those PWM signals. However, it can be turned into sinusoidal waveform voltages by making resonance using the equivalent circuit of the TWUSM in Fig. 1. The inverter outputs are two-phase high frequency AC voltages with 90 degree phase difference as shown in Fig. 3. A traveling-wave is formed on the stator surface, when the voltage is applied to the stator, the rotor moves, and the TWUSM turns to the opposite direction of the traveling wave. The rotating direction is controlled by letting V_a or V_b lead. Clockwise (CW) and counter clockwise (CCW) inputs provide direction control signals. In practical work, the driving frequency is set to a higher value than the resonant frequency of the mechanical vibration system due to the basic operating characteristics of the TWUSM [20].

Speed and position control of the TWUSM were achieved by adjusting the driving frequency and the applied voltage phase difference. In this study, the applied voltage phase difference control method is used due to its higher performance [21]-[23]. The driving frequency, f, is constantly fixed at 41 kHz. The value of input is determined by the SH7125 microcomputer which embedded a digital controller and a digital VSS observer. The produced signal was applied to the switches through a metal oxide semiconductor-field effect transistor (MOSFET) driver.

The switching frequency, f_s, is adjusted by changing the level of reference DC voltage, and hence, the TWUSM is controlled. This circuit converts the PWM signal to the reference DC voltage according to the duty cycle of PWM. When the duty cycle of PWM signal is changed, the value of produced reference DC level also changes. Therefore, the switching frequency is adjusted. As a result, the outputs of the motor are varied to demanded value. The block diagram of digital controller for high effective control of the TWUSM is represented in Fig. 4. First, the output, y, of the TWUSM is measured and converted to the digital signal, y_e, b_y a rotary encoder (RE). Then it is used to calculate the estimated value. The input value is given after comparing the error value, e, i.e.; the difference between the reference value and the estimated value, and the estimated value itself. Reference position, r, and measured position, y_e, of the TWUSM are recorded. According to ye value and the reference value, r, the proposed controller generates the necessary frequency value to the motor. The symbols which appear in Fig. 4 are defined as:

r : reference value;
y : actual value;
ye : measured error;
e : error (r-$\widehat{\mathrm{x}}$);
u : control input;
$\widehat{\mathrm{x}}$: estimated value.

The block diagram of the SH7125 microcomputer-based TWUSM drive system is given in fig. 5. The control scheme is digitalized with 10 ms sampling time because of a low speed of the motor. The SH7125 microcomputer is set at PWM mode, timer interrupt, and phase number count mode of MTU2 to control the motor. An electromagnetic brake is used to apply the load torque when voltage is applied. The brake and the rotary encoder are coupled. The rotary encoder is used for detecting the produced pulse in proportion to angle of the rotation of the motor shaft. The quadrature encoder pulse circuit of event manager was used for encoder signals. The encoder used in this paper (RP-442Z of ONO SOKKI company with 10,000 pulse/rev) generates a two-phase square waveform signal. The microcomputer calculates the rotor position directly from pulse number detected by the rotary encoder. In order to drive the TWUSM drive system, a software program was written in C language and then transferred to the microcomputer via the HEW that is, build-in system, provides a GUI-based integrated development environment for the development and debugging of embedded application for the microcomputer. The HEW, a tool suite, features an industry standard user interface and is designed using a modular approach seamlessly incorporating device family-specify C compilers. The flow chart of the control algorithm is shown in fig. 6, and the steps are given as following:

step1: initialize micro computer
step2: display opening message
step3: wait for timer interrupt
step4: determine the setting time
step5: decide the control input
step6: estimate the state values.
step7: display the measured value.

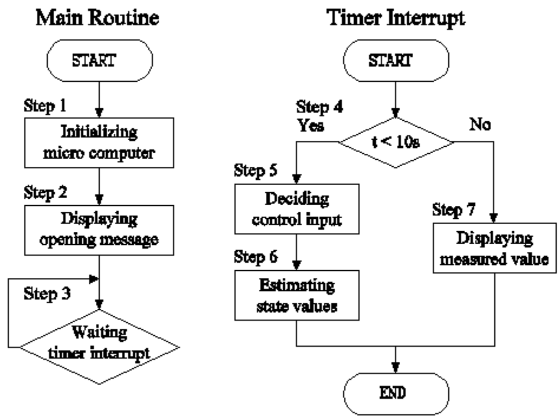


Fig. 6. Control Algorithm

3 CONTROL ALGORITHM

The system configuration which consists of the digital controller and the digital VSS observer is designed as shown in fig. 4. In this section, control algorithm will be designed to write in C language for the proposed controller using the HEW.

3.1 Design of Digital Controller

This sub-section discusses the designation of the digital controller. The linear system of the TWUSM is shown as following equation:

$$\dot{\mathrm{y}}\ (\mathrm{t})\ =\ \mathrm{Ax}(\mathrm{t})\ +\ \mathrm{Bu}(\mathrm{t}) \tag{1}$$

Eq. (1) can be discretized to get the following:

$$\mathrm{x}(\mathrm{k}+1) = \varphi\mathrm{x}(\mathrm{k}) + \gamma\mathrm{u}(\mathrm{k}) \tag{2}$$

The filter tracking error is defined as shown in following equation:

$$\mathrm{s}(\mathrm{t}) = \left(\frac{\mathrm{d}}{\mathrm{dt}} + \lambda\right)^{(\mathrm{n}-1)} \mathrm{e}(\mathrm{t}) \tag{3}$$

where, n is the relative degree of our system: the number of times we have to differentiate the output, y, before the input, u, appears explicitly. So, eq. (3) can be rewritten as:

$$\mathrm{s}(\mathrm{t}) = \ddot{\mathrm{e}} + 2\lambda\dot{\mathrm{e}} + \lambda^2 e = \Lambda^T e(t) \tag{4}$$

where, ΛT = [λ^2 2λ 1],and $e(k) = r(k) - x(k)$. From that we get:

$$\begin{aligned}
\Delta s &= s\left(k+1\right) - s\left(k\right)\\
\Delta s &= \Delta^T\left[e\left(k+1\right) - ek\right]\\
\Delta s &= \Delta^T\left[\left(r\left(k+1\right) - x\left(k+1\right)\right) - \left(r\left(k\right) - x\left(k\right)\right)\right]\\
\Delta s &= \Delta^T\left[\Delta r + x\left(k\right) - \varphi x\left(k\right) - \Gamma u\left(k\right)\right]\\
\Delta s &= \Delta^T\left[\Delta r + \left(I - \varphi\right)x\left(k\right) - \Gamma u\left(k\right)\right]
\end{aligned} \tag{5}$$

where, $\Delta r = r(k+1) - r(k)$

Next, Lyapunov function is selected as follows:

$$\mathrm{V} = \frac{1}{2} s^2(\mathrm{k}) \tag{6}$$

To get an ideal control input, s(k) should be kept equal to zero. So, eq. (5) must satisfy $\mathrm{s}\,(\mathrm{k}) \triangle \mathrm{s} \leq -\mathrm{M}\,|\mathrm{s(k)}|$. We take the time difference,

$$\begin{array}{l} \Delta V = \frac{1}{2} s^2\left(k+1\right) - \frac{1}{2} s^2\left(k\right) \\ \Delta V = \frac{1}{2}\left(s\left(k+1\right) - s\left(k\right)\right)\left(s\left(k+1\right) + s\left(k\right)\right) \\ \Delta V = \Delta s\left(\Delta s + 2s\left(k\right)\right) \\ \Delta V \leq s\left(k\right)\left\{-Msgn\left(s\right)\right\} + \frac{1}{2}\left\{-Msgn\right\}^2 \\ \Delta V \leq -Ms\left(k\right) + \frac{1}{2} M^2 \leq 0 \end{array} \tag{7}$$

Therefore, if $M < 2|s(k)|$ and the Lyapunov function is negative, the digital controller can be stable.

From eq. (5), the following equation is obtained:

$$\Lambda^{\mathrm{T}} \Gamma u\left(k\right) = -\Delta s + \Lambda^T\left[\Delta r + \left(I - \varphi\right) x\left(k\right)\right] \tag{8}$$

If $M = k|s(k)|$, we have control law as following:

$$\begin{array}{l} u\left(k\right) = k_d s + \left(\Lambda^T \Gamma\right)^{-1} \Lambda^T\left[\Delta r + \left(I - \varphi\right) x\left(k\right)\right] \\ \quad + \left(\Lambda^T \Gamma\right)^{-1} ks \end{array} \tag{9}$$

3.2 Design of Digital VSS Observer

This subsection discusses the design of the VSS observer. The continuous time system presented as:

$$\begin{array}{l} \dot{\mathrm{x}}\left(\mathrm{t}\right) = \mathrm{Ax}\left(\mathrm{t}\right) + \mathrm{Bh}\left(\mathrm{t}\right) + \mathrm{Bu}\left(\mathrm{t}\right) \\ y\left(t\right) = Cx\left(t\right) \end{array} \tag{10}$$

where, h is a nonlinear term or uncertainty parameter. By discretizing the above equation, we get:

$$\begin{array}{l} \mathrm{x}\left(\mathrm{k}+1\right) = \varphi \mathrm{x}\left(\mathrm{k}\right) + \Gamma \mathrm{d}\left(\mathrm{k}\right) + \Gamma \mathrm{u}\left(\mathrm{k}\right) \\ y\left(t\right) = Cx\left(k\right) \end{array} \tag{11}$$

Since $(C,\ \varphi)$ is observable, constant matrix, L, exists, and a matrix, φ_0, can be defined by the following equation:

$$\varphi_0 = \varphi - LC \tag{12}$$

where, the eigenvalues of φ_0 can be made arbitrarily by approriate choice of L. Therefore, the following equation could exist:

$$P = \varphi_0^T P \varphi_0 + Q, \tag{13}$$

Table 2. Controller Parameter

k_d	2.5×10^{-4}
k	1×10^{-4}
ω_n	2.2×10^3
T_s	1×10^{-3}
K_f	2.97
ζ	0.18
λ	100

$$FC = \Gamma^T P \tag{14}$$

State estimate error, e, is defined as:

$$e\left(k\right) = \hat{x}\left(k\right) - x\left(k\right) \tag{15}$$

and F estimate error α is defined as:

$$\alpha\left(k\right) = F\hat{y}\left(k\right) - y\left(k\right) \tag{16}$$

where, $\widehat{\mathrm{x}}(\mathrm{k})$ and $\widehat{\mathrm{y}}(\mathrm{k})$ are the estimated value of x(k) and y(k), respectively.

Using these eqs., the design of the VSS observer can be obtained as following:

$$\begin{array}{l} \dot{\hat{\mathrm{x}}}\left(\mathrm{k}+1\right) = \varphi_0 \hat{\mathrm{x}}\left(\mathrm{k}\right) + \mathrm{Ly}\left(\mathrm{k}\right) + \Gamma \mathrm{u}\left(\mathrm{k}\right) + \Gamma \delta\left(k\right) \\ \delta\left(k\right) = \left\{ \begin{array}{l} -\frac{\alpha}{\|\alpha\|}\rho ....for.....\alpha \neq 0, \\ 0.................for......\alpha = 0 \end{array} \right. \end{array} \tag{17}$$

where, ρ is a constant. The following error equation can be obtained by derivation of eq.

$$\begin{array}{l} e\left(k+1\right) = \hat{x}\left(k+1\right) - x\left(k+1\right) \\ e\left(k+1\right) = \varphi_0 \hat{\mathrm{x}}\left(\mathrm{k}\right) + \mathrm{Ly}\left(\mathrm{k}\right) + \Gamma \mathrm{u}\left(\mathrm{k}\right) \\ + \Gamma \delta\left(k\right) - \varphi \mathrm{x}\left(\mathrm{k}\right) - \Gamma \mathrm{d}\left(\mathrm{k}\right) - \Gamma \mathrm{u}\left(\mathrm{k}\right) \\ e\left(k+1\right) = \varphi_0 \mathrm{e} - \Gamma \varphi - \Gamma \mathrm{d} \\ e\left(k+1\right) = \left\{ \begin{array}{l} \varphi_0 e - \Gamma \frac{\alpha}{\|\alpha\|} - \Gamma d......for......\alpha \neq 0 \\ \varphi_0 e - \Gamma d................for......\alpha = 0 \end{array} \right. \end{array} \tag{18}$$

4 EXPERIMENTAL RESULTS

The TWUSM experimental setup is shown in Fig. 7, the SH7125 microcomputer and the drive circuit is shown in fig. 8. In this work, the control cycle is set at 10 ms, the data sampling time is set at 20 ms, the reference position of the TWUSM is a sinusoidal waveform, and the reference position frequency is set at 0.2 Hz. The drive frequency, f, is set at 41 kHz, the initial position is set at y = 0.0 rad. Control parameters are shown in table 2.

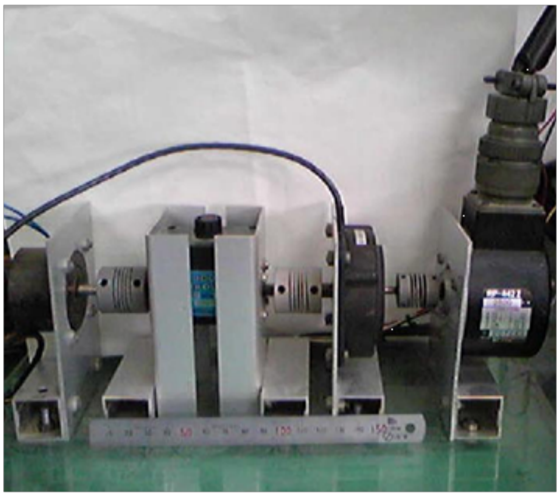


Fig. 7. Configuration of the USM

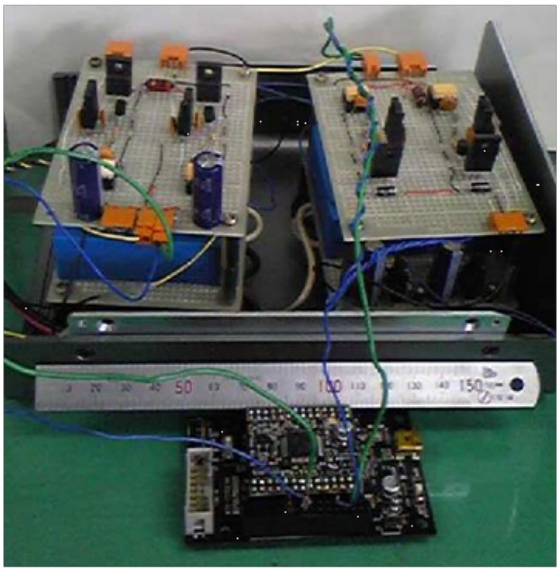


Fig. 8. Microcomputer and Drive Circuit

The experimentation has been done with two cases classified by difference of the applied load torque. The first case is no applied load torque; and, a load torque of 0.2 Nm is applied in the second case.

The experimental results obtained by the proposed digital controller are shown in fig. 9 for the first case and fig. 10 for the second case. To check the performance of the proposed digital controller as well as to confirm that the digital VSS observer really increases the performance of the control, like as our previous work [24], a PI controller (with KP = 10 and KI = 0.8) has been additionally conducted experimentation for comparison. The confronted results are shown in fig. 11 and fig. 12 for the two cases of the applied load torque as same as the proposed controller, respectively.

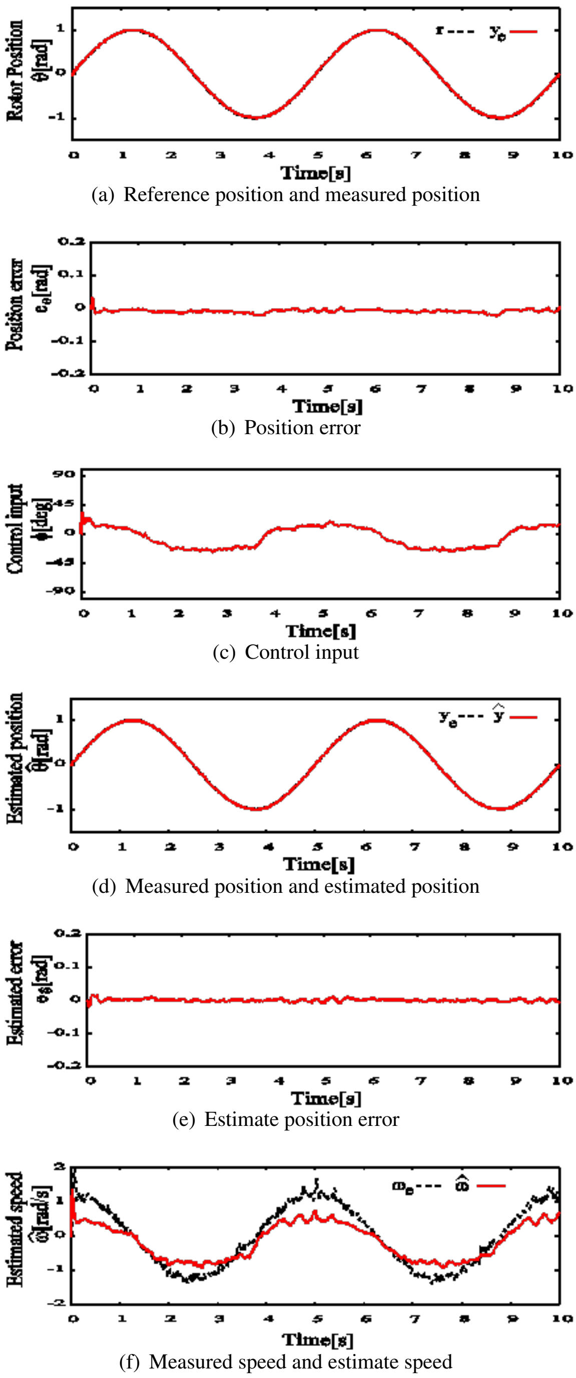
After comparison, some points are able to mark: fig. 9(a) and fig. 10(a) indicate very good control performances for both no load and applied load cases. Due to the loaded torque, the performance of the second case is not as good as one of the first case. The difference of two cases in term of position error can be seen clearly in fig. 9(b) and fig. 10(b) as the position error shown in fig. 10(b) is larger than that shown in fig. 9(b). This difference is due to the loaded torque. Though, the position error is still acceptable. However, the proposed controller method is obviously superior to the conventional PI controller according to the results shown in fig. 11(a), fig. 12(a), fig. 11(b), and fig. 12(b).

Fig. 9(d) and fig. 10(d) show good position estimations of the proposed digital VSS observer. Not like the above-mentioned differences of the motor performance and position error, the digital VSS observer works well in both experimentation cases. As for the PI controller, VSS observer does good work in the first case, but under loaded torque case, the estimated errors is too much and the whole system is predicted to be no longer reliable if the applied load getting stronger. Also, fig. 10(e) quotes very good estimated error compared to that presents in fig. 12(e). It means than under loaded torque condition, the proposed digital VSS observer works more stable than the one of the PI controller.

Fig. 9(f) and fig. 10(f) point out that: 1) the measured speed waveforms of the two cases are like dotted lines, and 2) the measured speed waveforms are more fluctuant than the estimated speed waveforms. The quantization error is reduced evidently in the estimated speed by the digital VSS observer.

5 CONCLUSION

The TWUSM has excellent operating performances and many other useful features. However, it also has very complicated speed characteristic which restricts the application of the TWUSM. In this paper, a digital position



(a) Reference position and measured position

(b) Position error

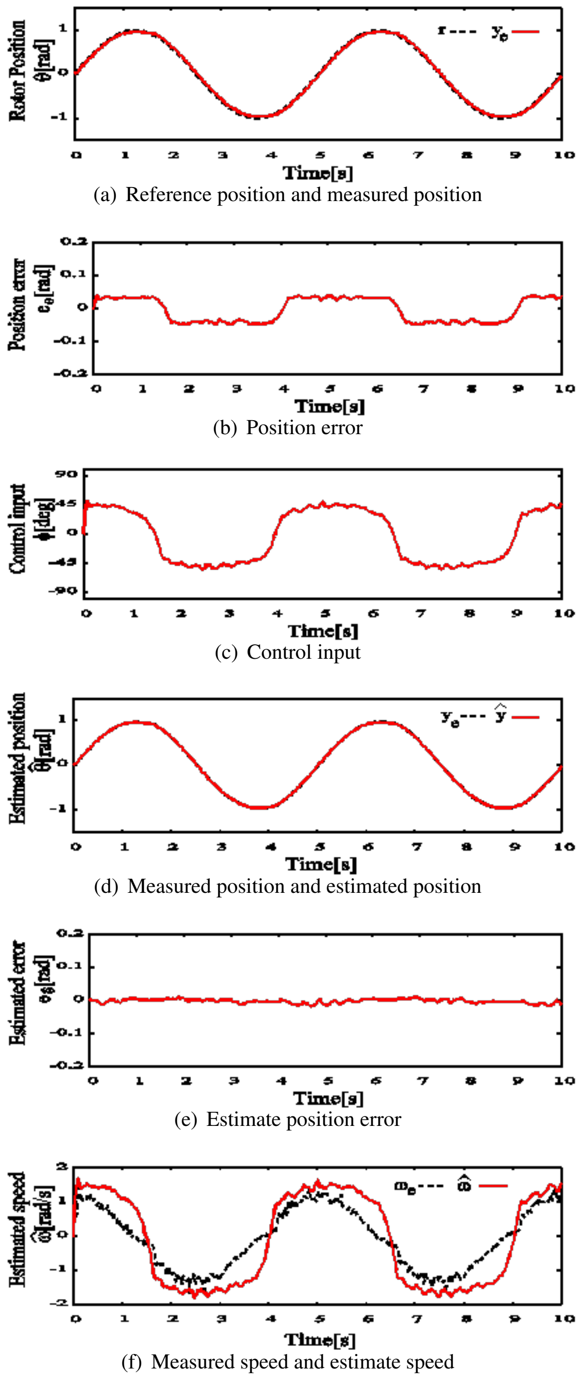
(c) Control input

(d) Measured position and estimated position

(e) Estimate position error

(f) Measured speed and estimate speed

Fig. 9. Experimental results with the proposed digital controller (τ_L=0.0Nm).



(a) Reference position and measured position

(b) Position error

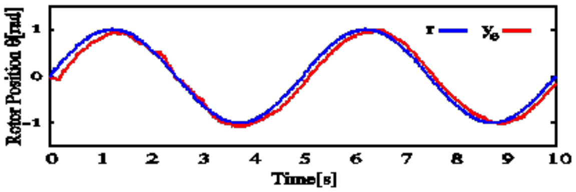
(c) Control input

(d) Measured position and estimated position

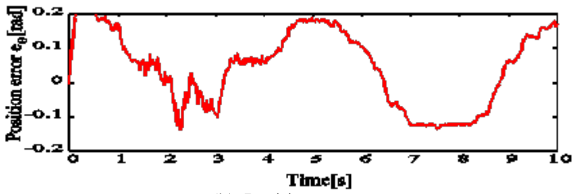
(e) Estimate position error

(f) Measured speed and estimate speed

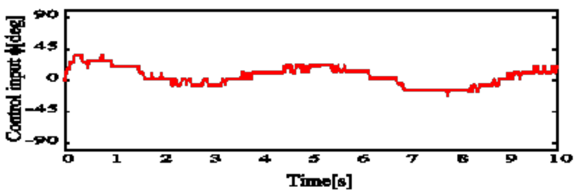
Fig. 10. Experimental results with the proposed digital controller (τ_L=0.2Nm).



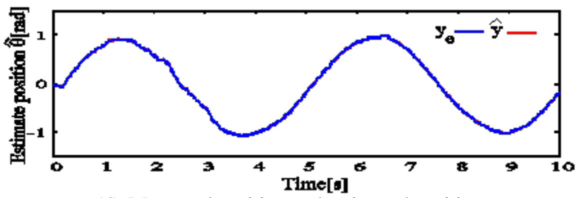
(a) Reference position and measured position



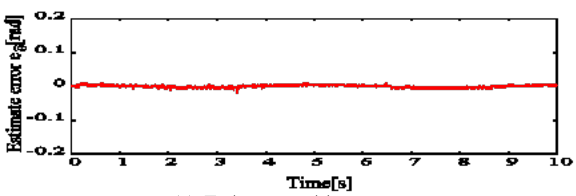
(b) Position error



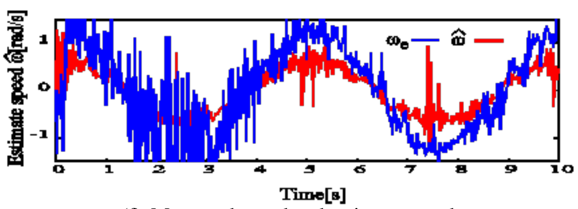
(c) Control input



(d) Measured position and estimated position

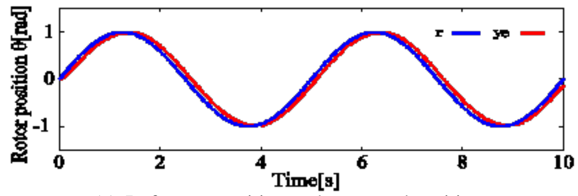


(e) Estimate position error

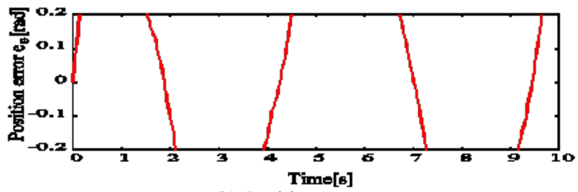


(f) Measured speed and estimate speed

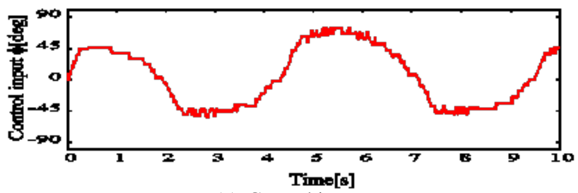
Fig. 11. Experimental results with a PI controller (τ_L=0.0Nm).



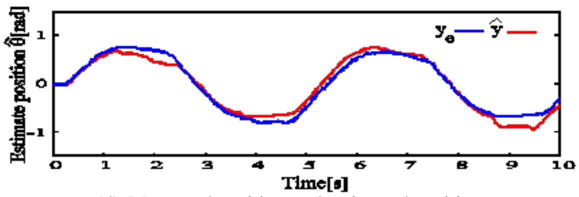
(a) Reference position and measured position



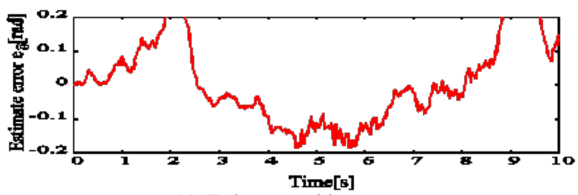
(b) Position error



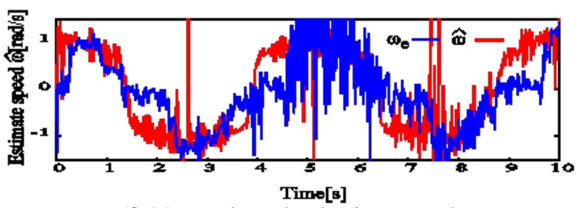
(c) Control input



(d) Measured position and estimated position



(e) Estimate position error



(f) Measured speed and estimate speed

Fig. 12. Experimental results with a PI controller (τ_L=0.2Nm).

controller has been proposed utilizing a digital VSS observer with the possibility of decreasing the quantization error created by a rotary encoder. A SH7125 microcomputer was employed to digitally implement the proposed method.

According to the experimental results, the digital controller has been provided a good position control for the TWUSM. The proposed digital VSS observer has also reduced the quantization errors and provided good position estimation. In additional, the proposed digital controller is superior to a conventional PI controller.

However, currently, a filter is not yet employed to reduce the chattering that disturbs the estimation. That problem will be considered as our future work. At that time, we will also analyze the chattering effect of the estimation.

In summary, the experimental results demonstrate very good tracking performances. Good dynamic performances have been obtained by the proposed control method.

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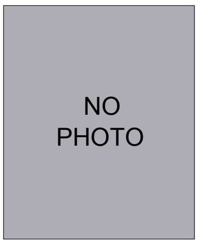

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