A STUDY ON THE SPEED CONTROL OF AC SERVO MOTOR BY TIME CONSTANT

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ABSTRACT - This paper describes the controller for the improving speed control of the AC servo motor. The microprocessor provides an output to the difference in command. The servo system improves the characteristics of speed control. When the motor is running at the same speed as set by the reference signal, the speed encoder also provides a signal of the same frequency. Thus, the microprocessor controlled digital techniques enable to realize the flexible performance and control which was possible with time constant of linear acceleration/deceleration.

We can know that optimal speed of machining center is 75msec in 30000mm/min and actually, 75msec is using on machining center. Finally experimental results prove excellent performance of this control system. This can be reduced error with more exact measure of actual speed. The system can be adaptable to CNC machine.

1. INTRODUCTION

Recent developing power semiconductors, microprocessor technology has greatly influenced the operation and performance of motor drive systems. Interest in the use of motor and computer controlled machines has been steadily increasing due to the reduced manufacturing costs that automation has to offer.

AC servo motor system is extensively applied to robot actuator, Machining center, computer numerical control (CNC) machine and precise industrial robot. AC servo systems are competing with DC servo systems for motion control. Because of their favorable electrical, mechanical properties, good dynamics and a high efficiency, AC servo motor has been covered most servo-applications in robotics, machine tools and positioning devices. General Motor is using not analog-method because digital-method is precise control.

This paper deals with the performance analysis with changing speed of AC servo motor by time constant of linear acceleration/deceleration. AC servo motor which is used in this paper is synchronous Motor and the study examines the effective changing speed of the AC servo motor drive. This paper examines the application of Time constant control methods. and 15000mm/min, 30000mm/min speed measure are experimented and compared. Finally, by experimentation changing time Constant, the optimal speed condition of machining center is obtained on 30000mm/min by 75msec, 75msec is using on machining center, that is 75msec can achieve smooth, precise performance. From the experimental results, it is confirm that various control is obtained by time constant control.

2. THEORY OF AC SERVO MOTOR

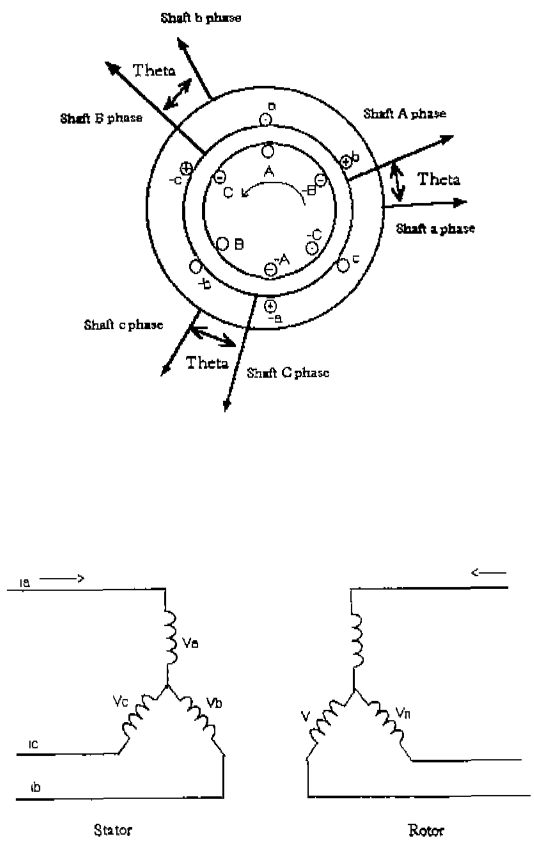


Fig. 1 Structural diagram of three-phase motor

Fig.1 shows the structural diagram of three-phase motor. Voltage equation of stator winding is expressed as the following equation;

$$\begin{pmatrix} V_a \\ V_b \\ V_c \end{pmatrix} = r_1 \begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix} + P \begin{pmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{pmatrix} \quad \text{----(2.1)}$$

Voltage equation of rotor winding is given by;

$$\begin{pmatrix} V_A \\ V_B \\ V_C \end{pmatrix} = r_2 \begin{pmatrix} i_A \\ i_B \\ i_C \end{pmatrix} + P \begin{pmatrix} \lambda_A \\ \lambda_B \\ \lambda_C \end{pmatrix} \quad \text{----(2.2)}$$

Phase flux to stator is given by;

$$\begin{pmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{pmatrix} = \begin{pmatrix} L_{aa} & L_{ab} & L_{ab} \\ L_{ab} & L_{aa} & L_{ab} \\ L_{ab} & L_{ab} & L_{aa} \end{pmatrix} \begin{pmatrix} i_a \\ i_b \\ i_c \end{pmatrix}$$

$$+ L_{aA} \begin{pmatrix} \cos\theta_2 & \cos(\theta_2 - \frac{4}{3}\pi) & \cos(\theta_2 - \frac{2}{3}\pi) \\ \cos(\theta_2 - \frac{2}{3}\pi) & \cos\theta_2 & \cos(\theta_2 - \frac{4}{3}\pi) \\ \cos(\theta_2 - \frac{4}{3}\pi) & \cos(\theta_2 - \frac{2}{3}\pi) & \cos\theta_2 \end{pmatrix} \begin{pmatrix} i_A \\ i_B \\ i_C \end{pmatrix}$$

----(2.3)

Phase flux to rotor can be expressed as:

$$\begin{pmatrix} \lambda_A \\ \lambda_B \\ \lambda_C \end{pmatrix} = L_{aA} \begin{pmatrix} \cos\theta_2 & \cos(\theta_2 - \frac{2}{3}\pi) & \cos(\theta_2 - \frac{4}{3}\pi) \\ \cos(\theta_2 - \frac{4}{3}\pi) & \cos\theta_2 & \cos(\theta_2 - \frac{2}{3}\pi) \\ \cos(\theta_2 - \frac{4}{3}\pi) & \cos(\theta_2 - \frac{4}{3}\pi) & \cos\theta_2 \end{pmatrix}$$

$$\begin{pmatrix} i_A \\ i_B \\ i_C \end{pmatrix} + \begin{pmatrix} L_{aa} & L_{ab} & L_{ab} \\ L_{ab} & L_{aa} & L_{ab} \\ L_{ab} & L_{ab} & L_{aa} \end{pmatrix} \quad \text{-----(2.4)}$$

Output P of AC Servo Motor is obtained as follow:

$$P = \frac{3}{2}\,(V_{2d} i_{2d} + V_{2q} i_{2q})$$

$$= \frac{3}{2}\{-\lambda_{2q} i_{2d}(s\omega) + \lambda_{2d} i_{2q}(s\omega)\} \quad \text{----(2.5)}$$

$-(s\omega)2/Pole\ number$: Rotor flux and the torque T of motor is,

$$T = \frac{3}{2} \cdot \frac{Pole\ number}{2}\,(\lambda_{2q} i_{2d} - \lambda_{2d} i_{2q})$$

$$= \frac{3}{4} \cdot Pole\ number \cdot L_{12}(i_{1q} i_{2d} - i_{1d} i_{2q})$$

---------(2.6)

Where mechanical torque can be described by the following:

$$T = J\omega_2 + B'\omega_2 + T_L \quad \text{---(2.7)}$$

<u>Principle of Torque of AC SERVO MOTOR</u>

In this paper, synchronous AC Servo Motor is Permanent-Magnet Synchronous Motor is used because of high efficiency, control. Fig.2 shows structure of Two Poles Servo Motor.[5]

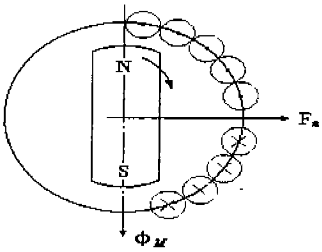


Fig. 2 Two poles servo motor

$F = iBL$[N] is occured when current flows on the armature and torque which is proportioned by resultant voltage, F_a and flux, Φ_M is generated. Current of each armature winding on three-phase is shown in Ep.(2.8).

$$I_M = I_M \sin\theta$$
$$I_V = I_M \sin(\theta - \frac{2}{3}\pi)$$
$$I_W = I_M \sin(\theta - \frac{4}{3}\pi) \quad \text{----(2.8)}$$

So magnetic flus density of air gap which crossed with armature of each phase are given as follows :

$$B_{gM} = B_M \sin\theta$$
$$B_{gV} = B_m \sin(\theta - \frac{2}{3}\pi)$$
$$B_{gW} = B_m \sin(\theta - \frac{4}{3}\pi) \quad \text{-----(2.9)}$$

In this case, Torque which generated on the Ac Servo Motor is given by

$$T = K[\, B_{gM} \;\; B_{gV} \;\; B_{gW}] \begin{bmatrix} I_M \\ I_V \\ I_W \end{bmatrix}$$
$$= \frac{3}{2} K B_m I_m \quad \text{------(2.10)}$$

Accelerated torque which related with motor speed is given by

$$T = T_a + T_m \quad \text{---------------------------(2.11)}$$
$$T_a = \frac{V_m}{60} \times 2\pi \times \frac{1}{t_a} \times J_m \times (1 - e^{ks \cdot ta}) + \frac{V_m}{60} \times 2\pi \times \frac{1}{t_a} \times J_m \times (1 - e^{ks \cdot ta}) \div \eta \quad \text{------(2.12)}$$
$$V_r = V_m \times \left\{1 - \frac{1}{ta \cdot ks}(1 - e^{ks \cdot ta})\right\} \quad \text{----------(2.13)}$$

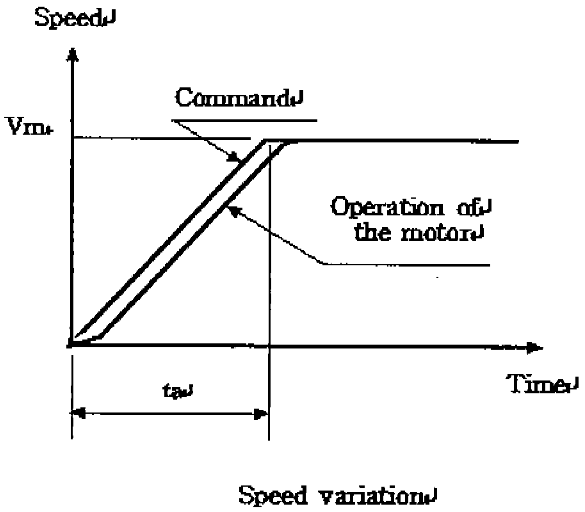


Fig. 3 Shows time constant of a linear function.

3. CONTROL SYSTEM

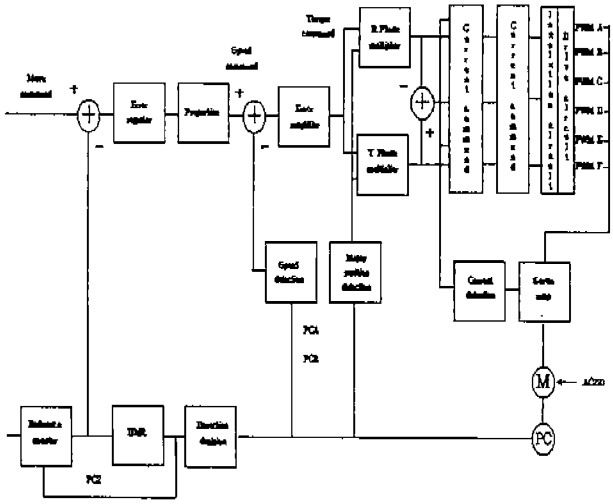
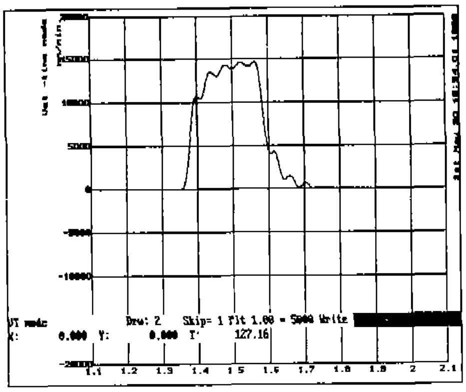


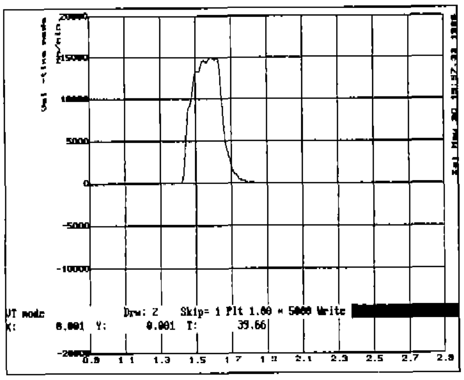
Fig. 4 Schematic of system

4. EXPERIMENTAL RESULTS

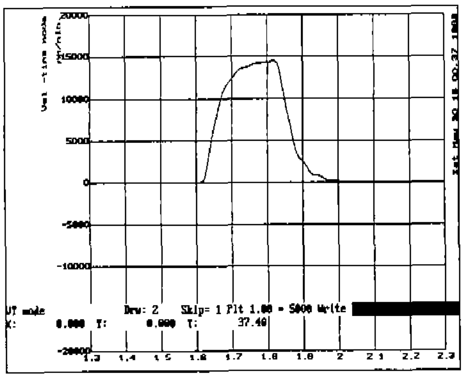
In this paper, control characteristics of speed of AC Servo Motor using time constant is experimented on machining center, Fanuc.



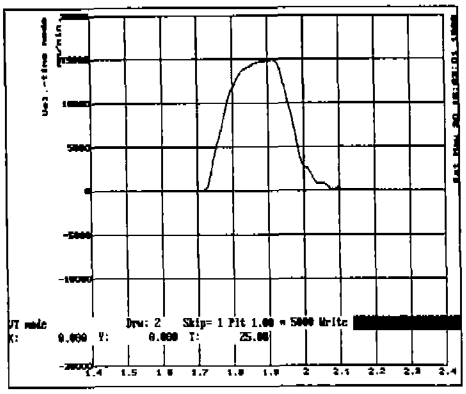
(a-1) 50msec · 15,000mm/min



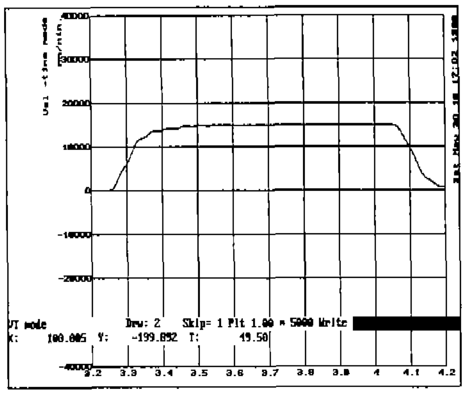
(a-2) 75msec · 15,000mm/min



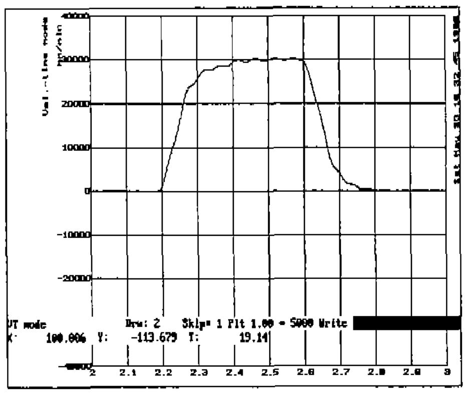
(a-3) 100msec · 15,000mm/min



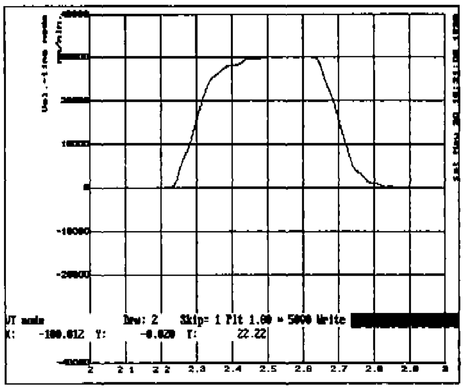
(a-4) 125msec · 15,000mm/min



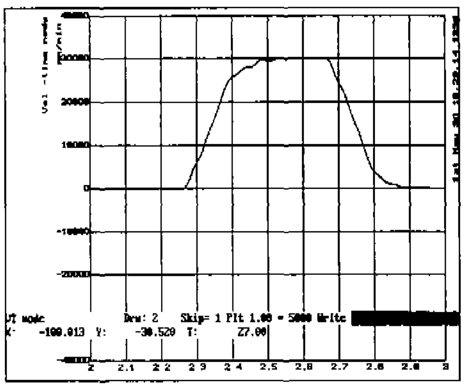
(a-5) 150msec · 15,000mm/min



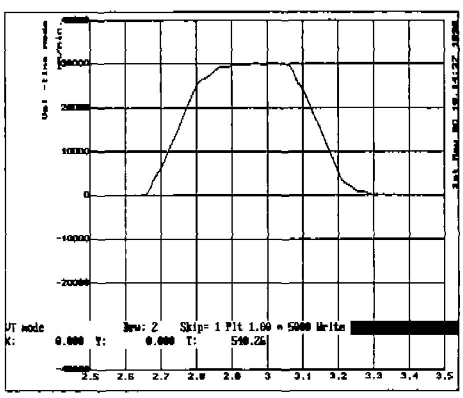
(b-1) 75msec · 30,000mm/min



(b-2) 100msec · 30,000mm/min



(b-3) 125msec · 30,000mm/min



(b-4) 150msec · 30,000mm/min

Fig. 5 Results of Experimentation

(a)15,000mm/min (b)30,000mm/min)

Control characteristics of speed of AC Servo Motor is experimented at 50msec, 75msec, 100msec, 125msec, 150msec on 15,000 mm/min, 30,000mm/min. Fig.a-1 shows waveforms including overshoot, unstable component. Fig.a-3,4,5 shows that the more time constant is long, the more unstable component disappears and response characteristics is bad. Time constant 75msec is chosen in a machine tool as a optimal time constant.

5. CONCLUSION

In this paper, precise speed control of AC Servo Motor by time consant of linear acceleration/ deceleration has been realized. Excellent control performance has been obtained. This technique can produce smooth output and optimal value time constant will also be considered in the X-Y Cartesian type Robot actuator and CNC.

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