

A Digital AC Servo Motor Controller for the Industrial Auto Trimming Sewing Machines

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Abstract

Generally, the required control functions for the industrial auto trimming sewing machines are the sewing speed control with pedal input, the up/down stopping-position control of the needle, the automatic sewing according to the memorized sewing pattern including the number of stitches, and etc.

We developed a new type of AC servo motor controller, which suffices for all the above functions. The developed controller is working well, and the performances are very good for the practical use.

1. Introduction

From the operational and economical point of view, every industrial control system is required to have the characteristics such as maintenance-free, energy saving, low noise and vibration, and low cost. "Electromagnetic clutch and brake" type motor control system, which was popularly used for the control of the industrial auto trimming sewing machines has the following problems intrinsically.

- (1) Much maintenance is required due to the abrasion of clutch and brake.
- (2) It needs extra power consumption according to the existence of free run when the sewing machine is not in operation.
- (3) Excessive noise and vibration is generated due to mechanical contacts between rotor and clutch (or brake).

Recently, for the purpose of overcoming the above problems and increasing the performances of the industrial auto trimming sewing machine control system, AC

servo motor and its controller has begun to be used [1]. In accordance with this trend, we developed a new type of AC servo motor controller for the industrial auto trimming sewing machines as shown in Fig.1. It suffices for all the required functions and solves the above mentioned problems. In this paper, we describe the construction of our controller and present the experimental results using NIPAR sewing machine (the industrial auto trimming sewing machine made by Daewoo Heavy Industries, Ltd.).

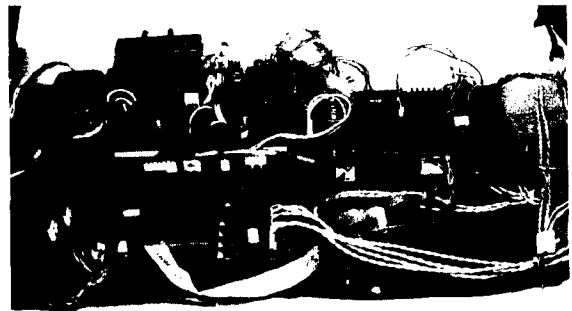


Fig.1 An industrial auto trimming sewing machine controller

2. Construction of our controller

The schematic diagram of our sewing machine control system is shown in Fig.2. And the ratings and specifications of AC servomotor used is shown in Table.1.

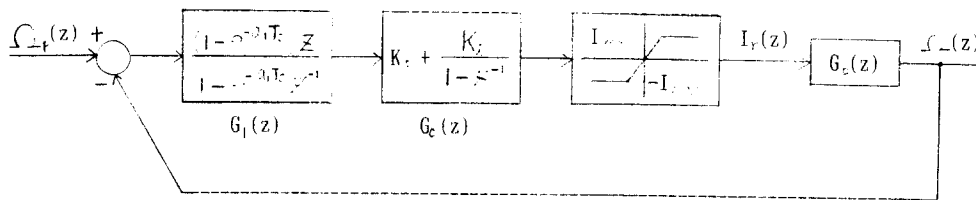


Fig.2 Block diagram of speed loop (PI controller)

$\Omega_r(z)$: the speed command of motor,
 $I_r(z)$: the current command of motor,
 $G_f(z)$: the transfer function of digital filter and zero order hold used,
 $G_c(z)$: the transfer function of digital PI controller and zero order hold,
 $G_c(z)$: the transfer function between the speed and the current of motor,
 a_1 : the cutoff frequency of digital filter,
 K_p : proportional gain,
 I_{max} : maximum allowable motor current,
 $\Omega(z)$: the actual speed of motor,
 T_s : sampling time,
 K_i : integral gain.

2-1-2. Stopping-position control of needle

The accuracy of stopping-position is one of the important measures which decide the performances of the controller [5]. The "needle down" position means the state that the needle is in the sewing object. In this position, the sewing object can be rotated for proper alignment before continued operation. The "needle up" position means the state that the needle is out of the sewing object, which is required when the sewing process is complete and the operator wishes to remove the sewing object. In our controller, the stopping-position (up/down) of needle can be preset by operator with toggle switch, and the position information is detected by a synchronizer attached at the head of sewing machine. When the stopping command is detected, the position control of needle stopping is performed following the steps below.

- Step 1. Decelerate to the minimum speed (200 rpm).
- Step 2. Maintains the minimum speed before the desired stopping-position is detected.
- Step 3. After the desired stopping-position is detected, decelerates to zero speed as soon as possible.

2-2. Current control

The current loop is simplified using Signetics IC

"NE5570", which is specifically designed for brushless DC servo motor control. It is composed of a serial port, an 8-bit D/A converter, a decode logic, a PWM comparator, an over-current sense, and etc [6]. The current command from the speed loop is received through the serial communication port every 2 msec and the current feedback is done from DC-link current using a current transformer. The well known feedforward plus PI controller is used as current controller. Fig.4 shows the block diagram of current loop.

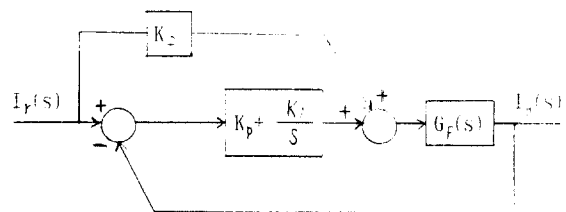


Fig.4 Block diagram of current loop (feedforward plus PI controller)

$G_f(s)$: the transfer function between DC-link current and phase voltage of motor,
 $I_r(s)$: current reference of DC-link,
 $I_d(s)$: actual DC-link current, K_f : feedforward gain,
 K_p : proportional gain, K_i : integral gain.

The switching frequency of PWM is 2 KHz and the rotor position, sensed by hall sensor, is used for determining the motor phases (or U, V, and W phase) which are commutated by the PWM output at each switching

instant. Fig.5 shows the detected DC-link current and Fig.6 shows the motor current waveform during sewing operation.

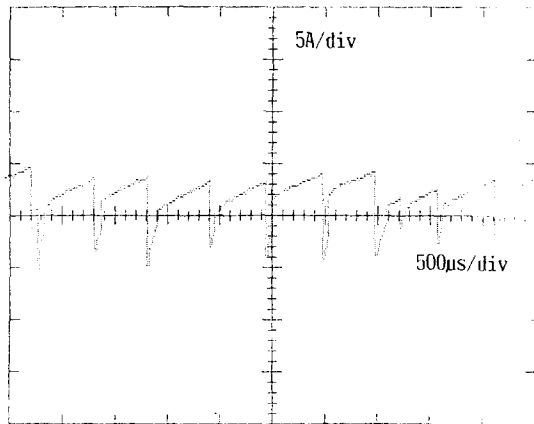


Fig.5 Detected DC-link current (3000 rpm)

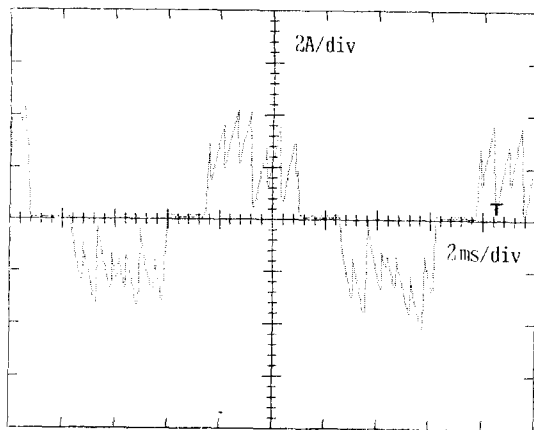


Fig.6 Motor current waveform (3000 rpm)

2-3. Sewing sequence control

For the convenience of sewing, it is necessary for the controller to perform the actions such as backtack, trim, wiping, and foot-lift, automatically. These actions are done by solenoids. Backtack is necessary for pattern sewing and the corresponding speed is between 1500 rpm and 2500 rpm. One of the eight different sewing patterns and the number of stitches can

be preset by using the operating box. The configuration of operating box is shown in Fig.7. Trim, wiping, and



Fig.7 The configuration of operating box

foot-lift are necessary for easy exchange of the sewing object after sewing. Trimming speed is set as a value between 100 rpm and 300 rpm, and it has to be set carefully for the successful operation of trim. This setting condition mainly depends on the mechanism of sewing machine and the thickness of thread. The setting is usually done by operator through experiment. The timings for trim, wiping, and foot-lift are shown in Fig.8.

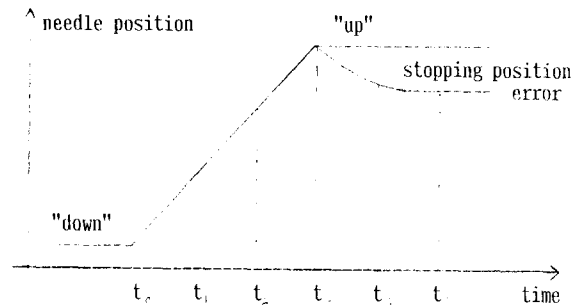


Fig.8 The timing diagram for trim, wiping, and foot-lift

the time interval between down position and trimming start ($t_1 - t_0$) : 10 msec
trimming time ($t_2 - t_1$) : 75 msec
wiping time ($t_3 - t_2$) : 45 msec
foot-lift time ($t_4 - t_3$) : 12 sec

2-4. Protection circuit

When over-current, over-voltage, or under-voltage is detected, our controller disables the PWM outputs for the protection of power device. The regenerative energy generated by motor and sewing machine when fast deceleration is taken, is radiated through regenerative resistor.

3. Experimental results

To test the performances of our controller, we applied it to NIPAR sewing machine. Fig.9 shows the industrial auto trimming sewing machine used in the experiment. The pulley ratio (motor to sewing machine)

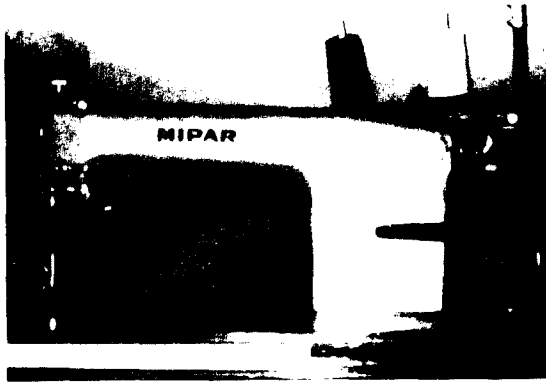


Fig.9 The industrial auto trimming sewing machine used in the experiment

is 1.5, that is, if motor rotate at the speed of 3000 rpm, then the speed of sewing machine becomes 4500 spm (stitch per minute) . We tested all the functions mentioned above. The results were very satisfactory to the practical use. Table 2 shows the experimental results for stopping-position accuracies.

Table 2 Experimental results for stopping-position accuracies

	Electromagnetic clutch /brake control system	AC servo motor control system
needle up position errors	$-5^{\circ} \sim -5^{\circ}$	$-2^{\circ} \sim -2^{\circ}$
needle down position errors	$10^{\circ} \sim 10^{\circ}$	$-3^{\circ} \sim -3^{\circ}$

In our experiment, trim was best at trimming speed of 200 rpm. Also, we could accomplish the following functions, which were impossible with the Electro-magnetic clutch and brake motor control system because of the reasons given in parenthesis.

- (1) Half stitch reverse sewing (it was impossible due to the inability of reverse rotation).
- (2) Accurate inching sewing (repeated inching sewing used to decrease the inching speed).
- (3) Continuous sewing at medium speed (it had problems such as the generation of excessive heat and the abrasion of clutch).

4. Conclusion

In this paper, we presented the construction of controller for industrial auto trimming sewing machines and the experimental results. Adopting digital speed control scheme and using special chips, 8795BH and NE5570, we could have enhanced reliability, lowered the cost, and reduced the size of controller. Experimental results show that our controller has a good performance and high reliability for the industrial auto trimming sewing machine control.

References

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