CHARATERISTIC IMPROVEMENT OF 5 PHASE STEP MOTOR BY USING MICRO-STEP DRIVER IN X-Y AXIS SOLDERING MACHINE

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ABSTRACT – In this paper, micro step driving method is used for the high performance motion control and low vibration and low noise in an X-Y axis soldering machine for factory automation. The improvement of the electrical and mechanical driving characteristic of a stepping motor is achieved by applying microstep driver.

1.INTRODUCTION

Recently the stepping motor is used in many industrial areas such as office automation, mechatronic machining tools, factory automation, and so on. The stepping motor is an electrical motor which converts a digital electrical input into a mechanical motion. Compared with the other systems, the control systems, which use stepping motors, have several significant advantages. They do not require feedback components for position control or speed control because position error is non-cumulative. So the stepping motors can be open-loop controlled and have a wide control range of speed by increasing digital input frequency which is advantageous than other motors. In these respects, stepping motors are compatible with modern digital equipment. They can be interfaced with digital circuits easily and used in many industrial fields.

Besides these advantages, stepping motors have some problems. They have vibration at low speeds, fixed step angles and resonance at specific frequency and they are very noisy. Because of these problems, it is impossible to control the stepping motor precisely.

These problems can be reduced by using micro-step driving method which enables to reduce the stepping motor's vibration, noise and resonance at low speeds due to rotor inertia and long settling-time whenever the rotor stops.

In this study, the improvement of the 5 phase hybrid stepping motor characteristics is achieved by using micro-step driving method satisfying the specific condition of low vibration, low noise in X-Y axis soldering machine. Open-loop control method is used to simplify the hardware system.

A micro-step driver system is implemented with a 5-phase hybrid stepping motor, which has a pentagon winding type, Power MOSFETs, and some devices to improve the system characteristics.

2.MATHEMATICAL MODELING

In the driving of stepping motors, one natural step can be divided into many smaller steps by means of electronics. This method is known as the micro-step drive. If a 2-phase hybrid stepping motor is driven from a two-phase sine wave supply, instead of square wave, it is expected that the rotor motion is very smooth. It is also possible that the sum of torque always can be 0.

Each supplied phase currents are expressed as

$$I_a = I_R \cos\phi \qquad (1)$$

$$I_b = I_R \sin\phi \qquad (2)$$

where I_R is the maximum input current.

The torque produced by a current i_A in winding A is given by

$$T_A = -k\, i_A \sin\theta \qquad (3)$$

Similarly, the torque developed by the current i_B is given by

$$T_B = k\, i_B \cos\theta \qquad (4)$$

where k is the torque constant.
The total torque is

$$T_{AB} = T_A + T_B$$
$$= k\,I_R(-\cos\theta\sin\phi + \sin\theta\cos\phi) \qquad (5)$$

Equation (5) is simplified as

$$T_{AB} = k\,I_R\sin(\phi\text{-}\theta) \qquad (6)$$

The equilibrium position is $T_{AB}=0$. Therefore, the torque equilibrium is $\phi = \theta$.

It shows that the rotor position can be controlled by each phase currents. The micro-stepping method is to optimize each phase current for dividing fixed steps to fine divided steps. So the important point is how to control the phase current precisely.

3. MICRO-STEP FOR 5-PHASE MOTOR

To drive the 5-phase stepping motor using the micro-step method, the input signals have the sinusoidal wave forms with 72° phase shift between 5 phase currents. Therefore, the total torque T is the sum of $T_1 \sim T_5$. Equation (7) shows the torque equation.

$$T = \sum_{i=1}^{5} T_i$$
$$T_i = T_{Hi}\sin(\theta + (i-1)\times\frac{2\pi}{5}), \quad i = 1\sim 5 \qquad (7)$$

where T_{Hi} is holding torque. The holding torque expressed as

$$T_{Hi} = k_i i_i = \sin(\varphi + (j-1)\times\frac{2\pi}{5}), \quad j = 1\sim 5 \qquad (8)$$

where φ is one step angle of the micro-step.
By these equations, the torque equilibrium will be produced. Therefore, a mechanical step angle can be electrically divided into micro-step angles .

4. SYSTEM CONFIGURATION

In this study, the micro-step driver system consist of microprocessor, gate driver and PWM generation part. The block diagram in Fig.1 represents the whole drive system for the micro-step driving.

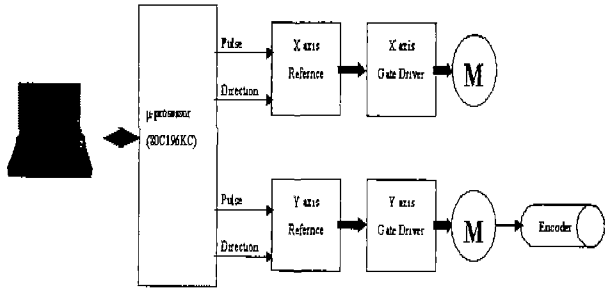

Fig. 1 The whole system of the micro-step driver

For the control of the position and the speed of the X-Y axis soldering machine, the microprocessor INTEL 80C196KC is used. The optical encoder is coupled to the motor to measure the step positional information. The system is robust against noise and can be interfaced easily with microprocessor because all circuits are digital system.

Fig. 2 represents the block diagram of the reference signal part, the PWM generator and the gate driver. The 5 ROMs have 4 step sampled reference signal tables respectively to adjust step resolution. These tables have sinusoidal waves with a 72° phase shift between them. Fig. 3 shows a reference phase current which is sampled 512 times.

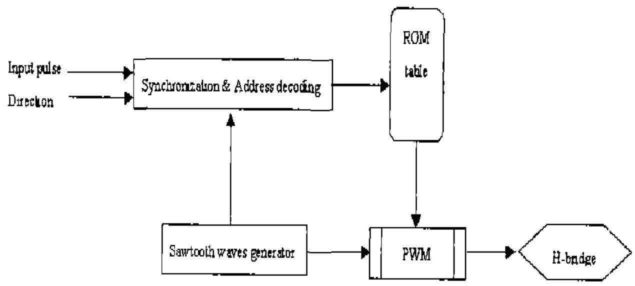

Fig. 2 The system for micro-step driving

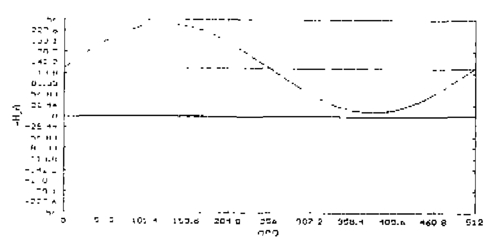

Fig. 3 reference phase current wave

In the PWM generator, the sawtooth waveform signals ,which is made digitally by counter, are compared with the sampled reference signal for the PWM signals. The counter makes digital sawtooth wave and discrete sinusoidal waves are read from ROMs by synchronizing a 4Mhz reference clock. Discrete sinusoidal waves and sawtooth waves are synchronized with the raising edge of the inverted reference clock Then PWM signals go into H-bridge gate driver. H-bridge gate driver consist of power MOSFETs, a FET gate driver IR2110.

5. EXPERIMENT AND RESULT

In this study, PK569-NBK(Oriental Motor Co) is used. The following table 1 is for the motor data.

Table 1 Motor Data

Number of phase	5 Phase
Step angle	0.72° step
Holding torque	16.6 *kgcm*
Rotor inertia	560 gcm^2
Motor current	1.4A/phase
Winding resistance	1.7Ω

Fig. 4 shows a phase current waveform when the resolution of the micro-step driver is 16, and the motor speed is constantly 0.001PPS. Fig. 5, 6 show the cases of the 64, and 128 adjusted resolutions respectively, and the motor speed fixed 1RPM. These figures represent that the waveforms follow the reference waveform shown in Fig. 3

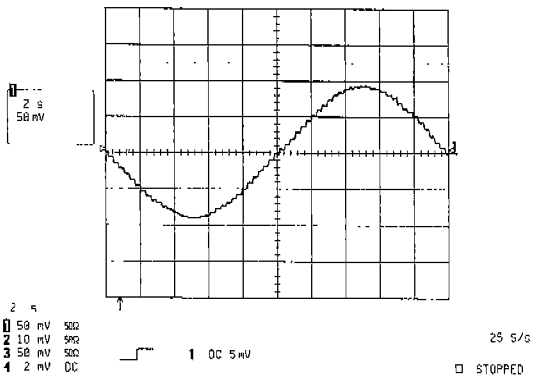

Fig. 4 phase current (0.001PPS, 16 resolution)

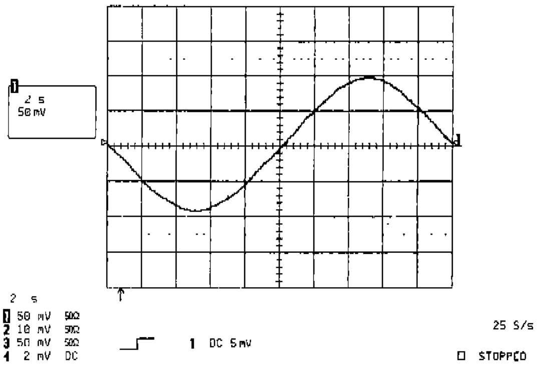

Fig. 5 phase current (0.001PPS, 64 resolution)

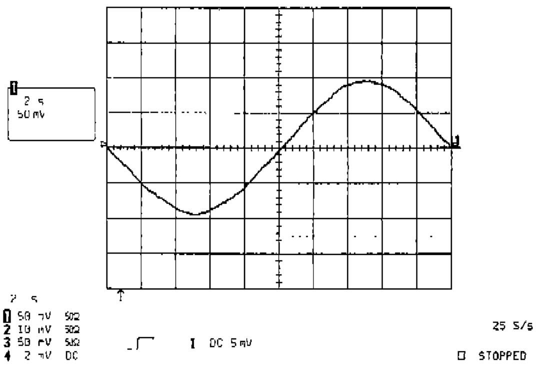

Fig. 6 phase current (0.001PPS, 128 resolution)

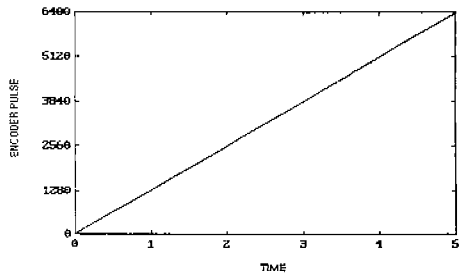

Fig. 7 The rotor position (128 resolution)

Fig.7 is the encoder output waveform from 128,000PPR high resolution encoder. While the stepping motor is driving, the encoder measures every fine step position information. As the resolution increase, the phase current become smoother and the rotor position becomes linear. It shows that the vibration is reduced when the motor drive is at low speed, and the rotor movement is very smooth in the normal step driving. Fig. 8 is the picture of the X-Y axis soldering machine used in this study.

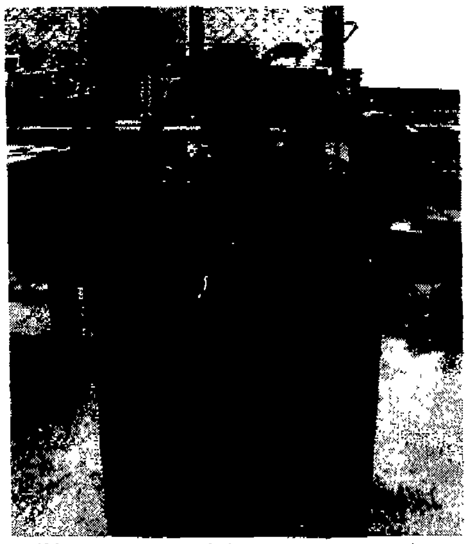

Fig. 8 Picture of the soldering machine

5. CONCLUSION

In this study, the micro-step driving method for 5 phase hybrid stepping motor was utilized in X-Y soldering axis machine. It is open-loop system and consists of digital circuits so that it can be easily interfaced with the microprocessor.

Compared with normal step driver, the micro-step driver improves the characteristic of the soldering machine. Vibration at low speed, noise and resonance has been reduced, and the torque characteristic has been improved at low speed region.

6. REFERENCES

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