2003 International Symposium on Advanced Intelligent Systems
September 25-28, 2003, Jeju, Korea

Nano Drive Technology for Stepping Motors Based on Computational Intelligence

Kaoru Hirota*, Naoyoshi Yubazaki**, Akira Muto**, Kenji Okumura**
*:Tokyo Institute of Technology, Dept.of CI & SS
4259 Nagatsuta, Midori-ku, Yokohama 226-8502 JAPAN, hirota@hrt.dis.titech.ac.jp
**: Mycom Inc. Minami-shimobano-cho 12, Saga-hirotawa, Ukyou-ku, Kyoto

Abstract - Nano drive control of five phase stepping motors is developed based on computational intelligence technology and it enables to drive into 5 million equiangular parts per revolution with keeping normal speed and torques. The experimental results of realizing high resolution/accuracy with low vibration and decreasing both heat loss and electric power consumption are mentioned.

I Introduction

"Nano Drive" (registered trademark by Mycom, Inc.) control of 5 phase stepping motors by intelligent control method enables to divide into 5 million equiangular parts per revolution with keeping normal speed and torque. It also realizes very low vibration and decreasing both the motor heat loss and electric power consumption keeping with high accuracy and high resolution. Photo 1 shows the externals of 5 phase stepping motors and driver "INS50 series" by Nano Drive control.

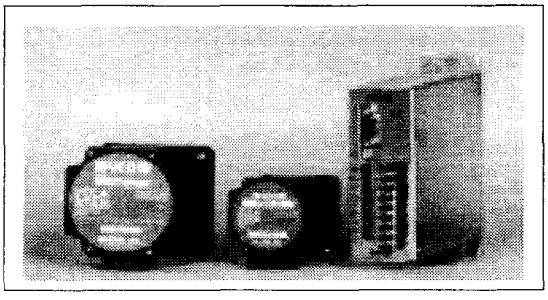

Photo 1 Nano Drive control "INS50 series"

II Intelligence Control

Intelligence control is the control method, that follows with the following procedures:

① Because the relation between control quantity and output of devices is not linear, the characteristics of output devices should be expressed by a data set in advance.,

② By regarding the characteristics of output devices as liner, the control data is stored. If there is a surplus for the control, the interpolation among data is made and a new data set is created for the control.

③ The control characteristics is put into memory in a tabular form.

④ The characteristics of the output device is verified by actual controlling value.

⑤ The control performance is improved by repeating (usually twice) the steps ① to ④

Intelligence control makes it possible to realize a control system with high resolution and high response because the control instruction requests the knowledge matching with the characteristics of output devices.

III Nono Drive Control

As shown in Fig. 1, a stepping motor is the motor that receives pulse signal through a driver to divide basic step angle, that carries excitation sequence control to motor coil phase and power control

In case of 5 phase stepping motors, the step angle (basic step angle) per pulse is 0.72 degree. In that case, output is the step angle in proportion to the numbers of pulses.

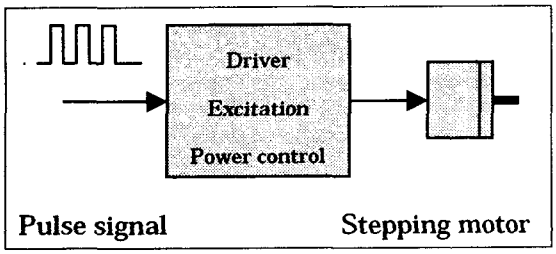

Fig.1 Stepping Motor Control

Based on the intelligence control method, Nano Drive control of 5 phase stepping motor realizes to divide into maximum 10,000 equiangular parts (as of July 2003) for a basic step angle, and it enables a high-resolution control of 5,000,000 equiangular parts per revolution.

IV Nano Drive Control by Intelligence Control

Nano Drive control by intelligence control is the control method that follows the following procedure:

① Because the control value of electric current or voltage is not linear to the output of 5 phase stepping motor, the output data for the control value is made clear and recorded in advance.

② The characteristics of 5 phase stepping motor is compared to the liner characteristics and the control amount of PWM (Pulse Width Modulation) value is estimated in accordance with the linearity, where if the PWM frequency is high enough there might be a surplus for the control to interpolate the characteristics between data and a new data set is created.

③ The control value (PWM value) for each pulse is put into memory table.

④ The output characteristics of 5 phase stepping motor is verified by using real control values.

⑤ The resolution is improved by repeating (usually twice is enough) ① to ④

V. Control Instruction and Output Characteristics

The basic step angle is 0.72 degree in the case of 5 phase stepping motor and its driver. Therefore the motor step angle against the number of control pulses will be stabled in multiples of the basic step angle by repeating over-shoot and under-shoot as shown in Fig. 2. These over-shoot and under-shoot may generate un-smooth revolution, resulted in the motor vibration. Hence, it is necessary to improve angle resolution to suppress the over-shoot and

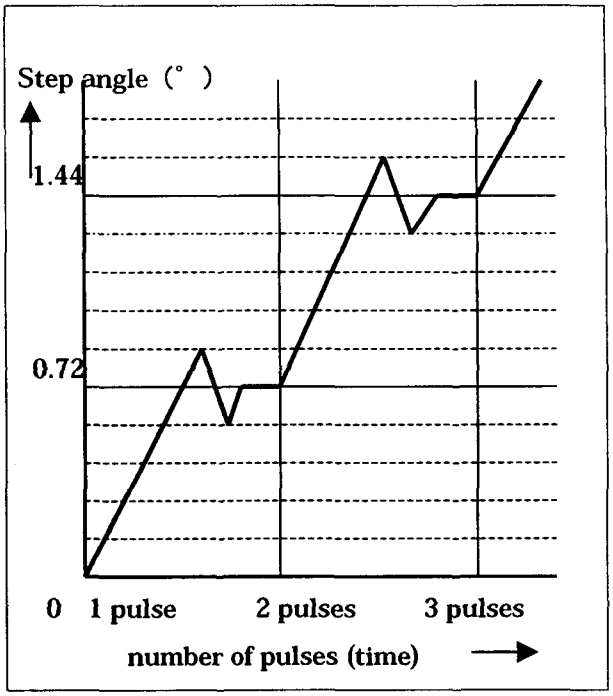

Fig. 2 Pulse Signal and Step Angle

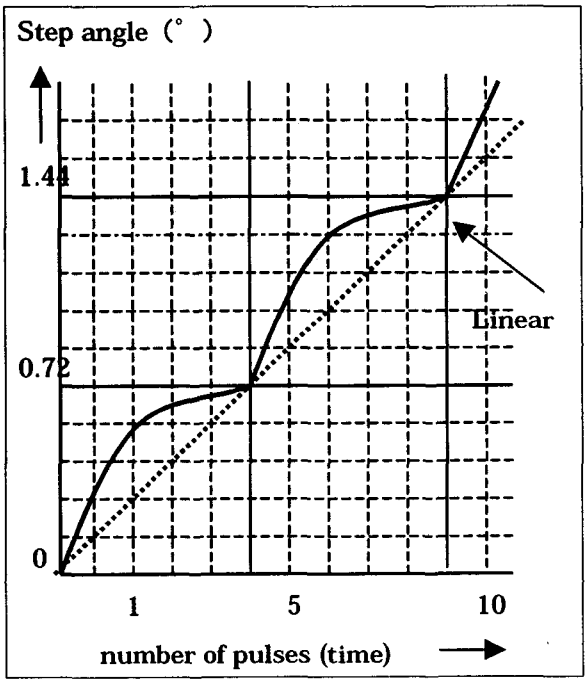

Fig. 3 Pulses and Step Angle in case of 5 mode PWM values

under-shoot.

In the proposed system, the basic step angle 0.72 degree is divided in to 2 to 10,000 parts. To realize such division, the same number of PWM value-mode is necessary. It is not easy to obtain the linearity needed to realize equiangle division as shown in fig.3, where 5 PWM value-mode simple case is illustrated.

VI Making Data/Table of Output Characteristics

The PWM value data should be observed and adjusted correctly corresponding to equiangular displacement in order to get required liner characteristics for divided equianlge. In the Nano Drive control presented, these proper conditions are put into data. Furthermore, sub-divided angle division data will be generated in the case if interpolation is done in-between obtained data After this data acquisition, the PWM value corresponding control value, that changes one pulse from another, is stored at memory and in the table.

VII Hardware Design for Nano Drive Control

The hardware is designed for the proposed Nano Drive control as shown in Fig. 4.

The hardware is realized based on the combination of memory circuits and logic circuits using ASIC, where main components are comparators and counters. Since there is no operational circuit, high-speed processing and area/size reduction is easily realized. In such a way, a reasonable price controller is possible to obtain.

The function of each part is summarized as follows.

① Part A; "Knowledge table" in Fig.4 stores the knowledge base that corresponds to output characteristics (angle and torque) of the stepping motor. There is a mapping area where the desired resolution is achieved.

② Part B; "SV-BOX" has knowledge base related with the optimal operation patterns for the driving device to be operated. It protects the disordered output pulse when the resolution is changed during the operation. It also confirms the correctness of value of feeding pulses.

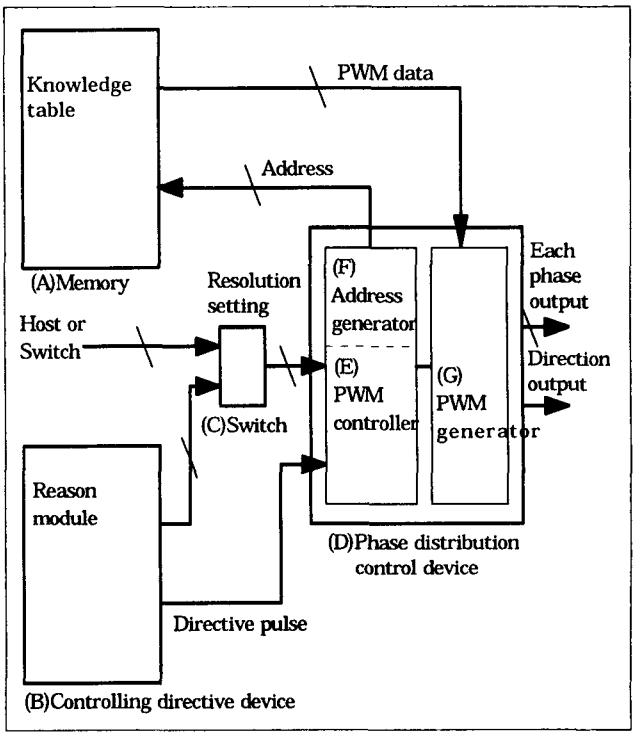

Fig. 4 Nano Drive Control Hardware Architecture

③ Part C; "Switch" changes the angle resolution that is indicated by the user freely.

④ Part E; "PWM controller" controls PWM cycle-time in accordance with the resolution indicated by the user.

⑤ Part F; "Address generator" indicates the address to refer angle position data corresponding to each pulse. In the case of CW (clock wise) revolution, the address is incremented, and decremented in the case of CCW (counter clock wise) revolution.

⑥ Part G; "PWM generator" generates PWM output, where width changes slightly in accordance with the PWM width data

obtained from the knowledge table.

VIII Performance of Nano Drive Control

The performance of stepping motors is generally evaluated by speed/torque characteristics, starting speed, step angle accuracy, equianlge property in high resolution, motor vibration, and motor heating loss. The proposed Nano Drive control realizes far better results in all above items than that of conventional ones. The performance about equiangular step and vibration character are mentioned in the followings.

A. Equiangular Step in High Resolution

A high-resolution driver for stepping motors is generally called as "micro step driver" and it excites the motor by sign wave like alternating current, resulted in smooth rotation. Accordingly the torque is decreased as the resolution increases and the angle resolution is up to usually 250 divisions of basic step angle. (Currently the maximum 500 divisions is achieved.) The equiangular step should also be improved.

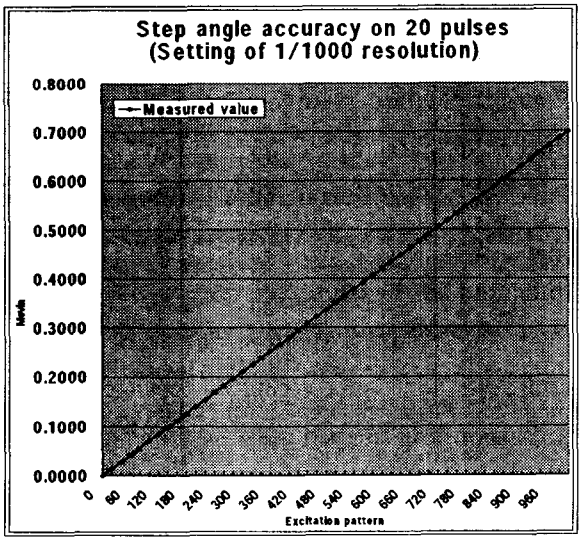

Fig.5 Equiangular Step by High Resolution

An experimental result of the proposed Nano Drive control is shown in Fig. 5, where the step angle accuracy for each 20 pulses is illustrated under the condition of 1000 divisions of the basic step angle (0.72 degree), Equiangular step in Fig.5 should be confirmed.

B. Motor Vibration Control

Motor vibration is caused by uneven speed, uneven torque, shaft vibration, and so on. Fig. 6 shows the locus of circular movement by a timing belt driven, i.e., direct motor vibration free, gate type robot in Photo 2, where the upper side is the result by Micro step driver and the lower by Nano Drive control.

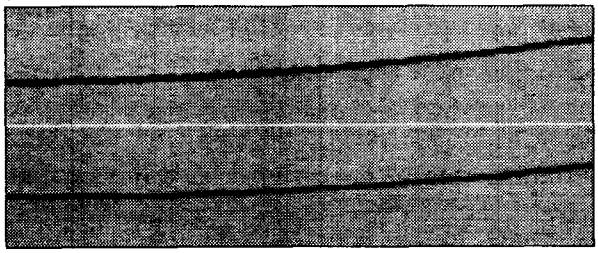

Fig. 6 Vibration of Micra (up) and Nano (down)

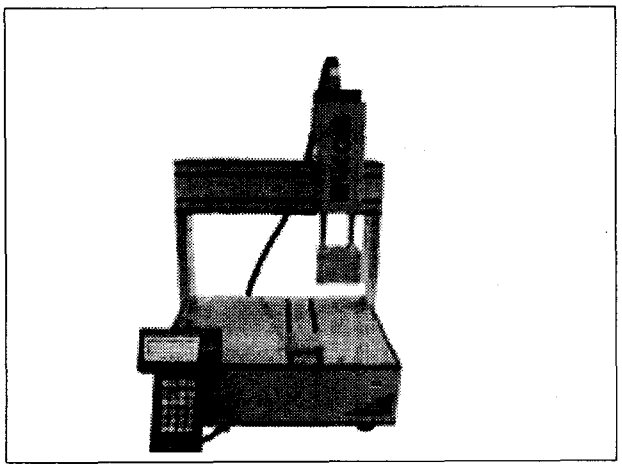

Photo 2 Gate Type Robot

IX Conclusions

Nano Drive control enables users to set freely the resolution up to 5,000,000 divisions per revolution. Hence if 1mm pitch lead screw is used in mechanism, 0.2nm unit positioning is available per pulse. The positioning per pulse can be set more precisely if two lead screws are differentially driven,

The products are now planning to release in the real market.