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Feature

Development of Three-phase Stepping Motor

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1. Introduction

Stepping motors are rapidly becoming popular as actuators for digital control due to the ease of controlling open loop servo systems.
The HB type stepping motor is widely used and its market will likely grow, especially for information communication equipments and industrial equipments as the information infrastructure and networks progress.
Among such equipments, copy machines are being upgraded from analog to digital as well as from standalone machines to network machines. In order to produce high quality copies, smooth rotational characteristics has been required for the actuator.

2. Background of Development

The actuator used to drive the scanner head in PPC and LBP copying machines must advance the head at a constant speed to prevent image distortion. In particular, low vibration is essential at low speeds ($1s^{-1}$ or less) when the effect of rotational variation becomes more pronounced. The key to improved picture quality of equipment is to suppress actuator vibration at low speeds.
When developing the stepping motor for such applications, the two-phase stepping motor is usually combined with an anti-vibration micro driving circuit to improve the vibration characteristics, nevertheless is often inferior to a five-phase motor on the characteristics. A five-phase motor is superior to a two-phase motor on low-vibration characteristics at low-speed, but is expensive if it is a set of drive circuit and motor, so a five-phase motor seem to be only top-quality use.
Therefore, when manufacturers design machinery, the selection between two-phase or five-phase is based on the trade-off between vibration characteristics and cost.
Manufacturers desire superior vibration characteristics that are better than not only that of two-phase micro drive unit but even that of five-phase full/half drive unit, but at a comparable cost to that of the two-phase motor.
The newly developed "STEPSYN" three-phase HB stepping motor series combines the benefits of both the two-phase unit and five-phase unit, and the product family includes the PM rotor type stepping motor.

3. Features of Three-phase "STEPSYN"

3.1 HB Stepping Motor Series

Fig. 1 shows the outside view of the typical stepping motor of each size. The HB stepping motor series has 4 sizes of 42 mm sq., 50 mm sq., 56 mm sq. and 60 mm sq. Each size is supplied in two different total lengths and three different current characteristics, totaling 6 models for each size.
Typical models of each series in the product lineup are shown in Table 1. This series

has the following characteristics.
(1) Low vibration
Priority is given to magnetic balance to reduce vibration, and a twelve-pole stator is used. The pinion structure is used to reduce the torque ripple. The vibration characteristics are thus better than those of the five-phase full/half step drive and the two-phase micro drive.
(2) Low acoustic noise
We have redesigned the built-in structure to make it stronger against vibration. The internal structure has been made stronger and Sanyo Denki's unique optimum magnetic circuit design is applied, thus suppressing noise.
(3) High torque characteristics
The design concept is the same as that of the "STEPSYN" H-series, and a high torque is delivered in a compact configuration.
The pulse rate versus torque characteristics of typical motors of the four sizes are shown in Fig. 2.
(4) Lead wire-less (Connector-type input terminal)
The shape of the connector of the power input terminal simplifies installation of the stepping motor into machinery and reduces the installation workload for users.

3.2 PM Rotor Type Stepping Motor

The PM rotor type has a unique rotor. The outside view of the rotor is shown in Fig. 3; the HB type rotor is structured by stacks having the salient-poles with pinions sandwich a magnet. On the other hand, in the PM rotor type, the cylindrical magnets are placed on top of the stacks acting as back yokes, and are magnetized as NS poles in the radial direction.
The PM rotor type is superior to the HB type in the following aspects.
(1) Ultra low acoustic noise
Noise is reduced by about 10 dB [A] over the entire range, from low speed to high speed that the motor can follow. Noise values are compared in Fig. 4.
(2) High speed follow-up performance
The high speed response performance is improved. The system speed can be increased because the newly developed motor can rotate at up to $84s^{-1}$.
The rotation speed versus torque is compared for the new motor and two-phase HB stepping motor for the same torque in Fig. 5.

4. Application Example

A commercial PPC machine was used for the test, in which a 56 mm sq. stepping motor was installed. The movement of the scanner head was measured when the scanner was advanced at a constant speed. The three-phase micro step drive, two-phase micro step drive, five-phase half step drive and five-phase full step drive were compared. Actual measurements of the scanner head are shown in Fig. 6.
Because the scanning speed of the scanner block is controlled by the linear speed, which depends on the scaling factor of either reduction or enlargement, the scanner motor must run at a constant speed at all times. Generally, the magnification factor of reduction/enlargement (changes depending upon conditions, but for most high performance machines) ranges from 25% to 400%. The rotation speed of the actuator in use corresponds to 10 to $0.6s^{-1}$ of variable magnification.
As shown in Fig. 6, the rate of variation of velocity remains the same for the rotation speed of 1.5s -1 for all types of driving, but the rate of variation becomes remarkably different at rotation speed of $1.0s^{-1}$ or less. The velocity variation rate is better in the three-phase micro step drive compared with the two-phase micro step drive and the five-phase full/half step drive as the result of reduced vibration.

Because reducing the vibration directly improves the picture quality of the manufacturer's product, the three-phase micro step drive is a very effective way of reducing the vibration.

5. Conclusion

We have outlined the three-phase stepping motor.
Reduction of vibration is a serious issue in various industrial machinery. The three-phase "STEPSYN" stepping motor series are ideal for replacing five-phase stepping motors to reduce the cost, and are suitable for replacing two-phase stepping motors to improve the vibration characteristics.
This newly developed three-phase system extends the choice for users from the conventional two-phase or five-phase system, and so is likely to lead to the creation of a new market.

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Table 1 List of Typical Models

Model number						Units	Conditions
	(single-ended)	103H5332-0340	103H6332-0340	103H7332-0340	103H7832-0340		
	(dual-ended)	103H5332-0310	103H6332-0310	103H7332-0310	103H7832-0310		
Outside view		42□×39^L	50□×51.3^L	56□×53.8^L	60□×53.8^L	mm	NOM.
Drive system		Bipolar	Bipolar	Bipolar	Bipolar	-	Star connection
Number of phases		3	3	3	3	phases	
Basic step angle		1.2	1.2	1.2	1.2	degrees	
Rated current		3	3	3	3	A/phase	
Winding resistance		0.84	1.3	1.4	1.5	Ω	±10% at 25℃
Winding inductance		0.5	1.6	1.8	1.8	mH	±20% at 1kHz
Holding torque		0.196	0.44	0.69	0.94	N・m	MIN. I=3A, 2-phase excitation
Rotor inertia		0.053×10^{-4}	0.12×10^{-4}	0.2×10^{-4}	0.4×10^{-4}	kg・m 2	NOM.
Maximum starting pulse rate		2000	1800	1800	1400	pulse/s	MIN. During no-load*
Maximum slew pulse rate		14000	5200	3500	2800	pulse/s	MIN. During no-load*
Mass		0.3	0.5	0.65	0.78	kg	NOM.

*Drive circuit: STK673-010 E=24 V[DC] 3A/phase Full step

Fig.1 Outside view of the three-phase "STEPSYN"

Fig.2 Pulse rate versus torque characteristics of typical models of the series

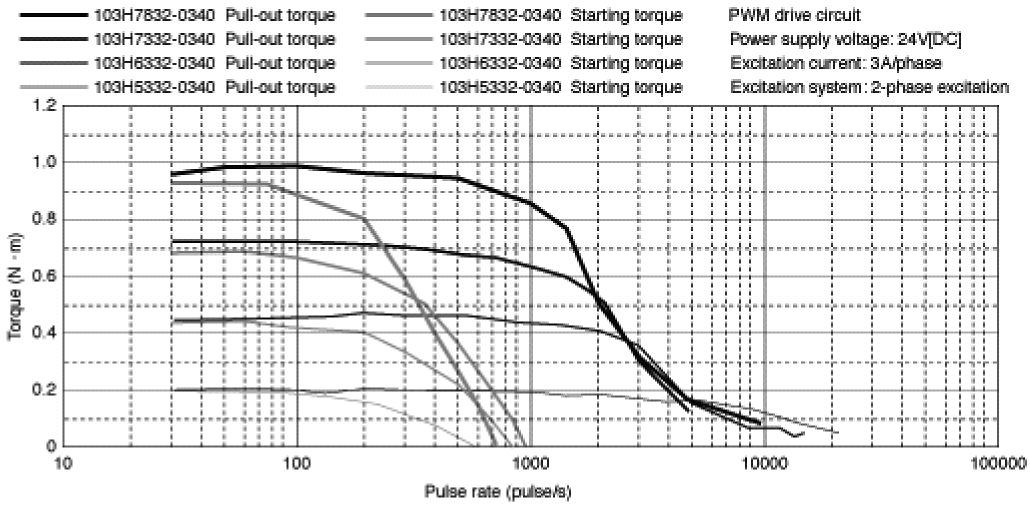

Fig.3 Comparison of rotor of each type

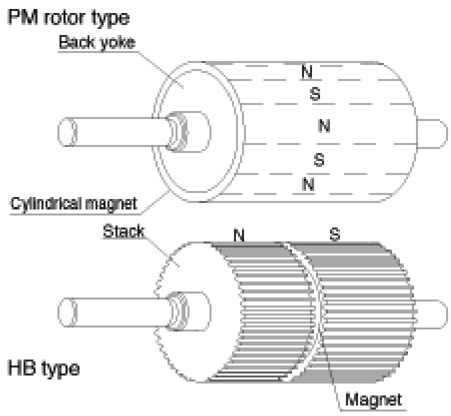

Fig.4 Comparison between the different rotor types

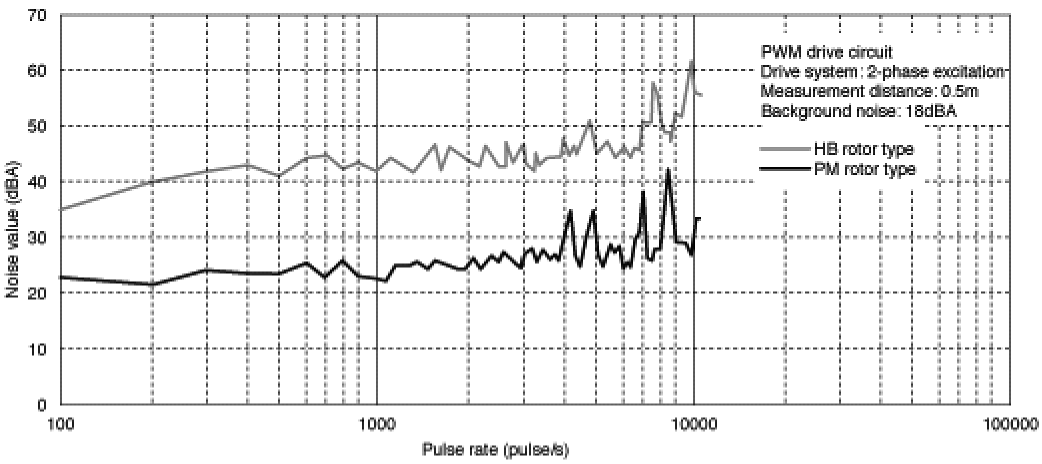

Fig.5 Rotation speed versus torque chracteristics of typical models of the series

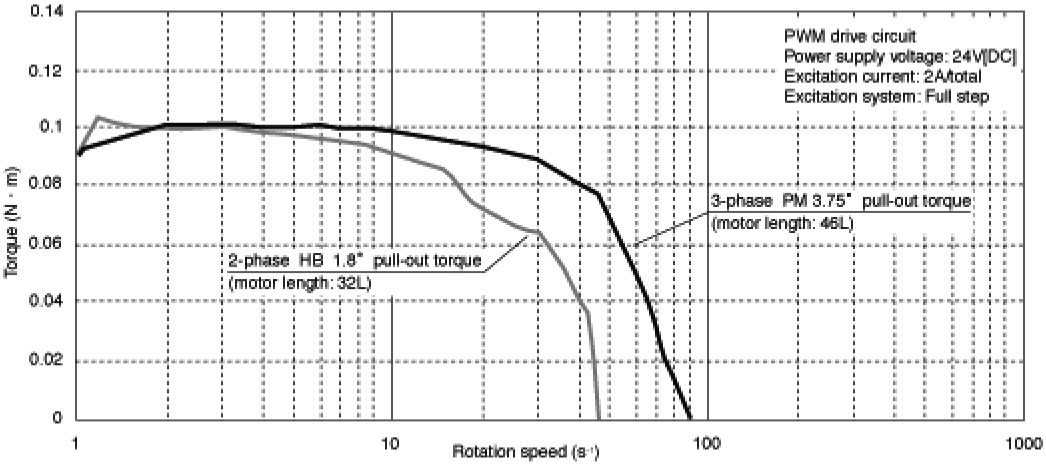

Fig. 6 Evaluation of PPC scanner block after installation into actual machines