

Optimized Magnetic Circuit Steps Up Motor's Performance

Manufacturers employ hybrid stepping motors in office automation equipment, industrial equipment, medical machines, and game machines for these parts can be easily controlled in position and speed. In hybrid stepping motor, power control as well as position and speed control is required, and the high-performance trend is based on high torque. Each motor manufacturer employs the expanded outer diameter of a rotator, which exerts the most remarkable influence, as a high-torque method. As a result, products that are square in outside shape lead the others so as to ensure winding space with a two-phase motor, which has the eight internal main poles of a stator, in the center.

For user needs, environmental factors such as high efficiency (low input and high output) for low power consumption and low noise for improvement in installation environment has been increasing in recent years. The advanced driving technology such as micro-step driving that is effective for low noise and low vibration has been popularized. Thus, lower-rotation fluctuating characteristics have been required. These diversified user needs in-



The KA50 and KA60 series of hybrid stepping motors

cluding the conventional positioning precision are being addressed.

This time, a round-shaped hybrid two-phase stepping motor for which the symmetric property of a magnetic circuit was pursued to ensure the high performance during actual operation was produced on a commercial scale. To optimize a magnetic circuit, three-dimensional electromagnetic field analysis was applied in the development process and a robust method was employed for development.

The following paragraphs tackle the features and main characteristics of two

hybrid two-phase stepping motors. These are the KA50 series with $\phi 50\text{mm}$ outside dimensions and the KA60 series with $\phi 60\text{mm}$ outside dimensions.

Conventional Application Technology

Fig.1 shows the magnetic circuit of a hybrid stepping motor. The local sectional drawing viewed from the axial direction is shown in (a), and the A-O-B sectional drawing of this illustration is shown in (b).

As shown in Fig.1, the hybrid stepping motor consists of a stator and rotator. In the stator, exciting winding is installed in the main pole's outer circumference of a stator's iron core consisting of multiple stator's main poles (eight main poles in the figure) that have multiple pinions (six pinions in the figure). In the rotator, a permanent magnet is supported in the center of two iron cores that have multiple pinions arranged in the outer circumference at an equal pitch. The hybrid stepping motor rotates when the magnetic field generated during the application of an electric current to the winding of a stator acts on the magnetic field generated using a permanent magnet.

In the conventional model, the torque was mainly improved by expanding the outside diameter of a rotator, and a square shape (of 42sq. mm and 56sq. mm) was employed to ensure the installation space of exciting winding. Low vibration also corresponds to the reduction in the distortion of stiffness characteristics. The detent torque that is the main factor of distortion is reduced using a vernier slot system. Japan Servo Co., Ltd. employs its own variable pitch vernier slot system. This technology was developed to remove the fourth harmonic component of gap permeance that is the main cause of detent torque and suppress the reduction in a fundamental wave component to the minimum. It is confirmed that this technology has a remarkable effect on high torque and low vibration.

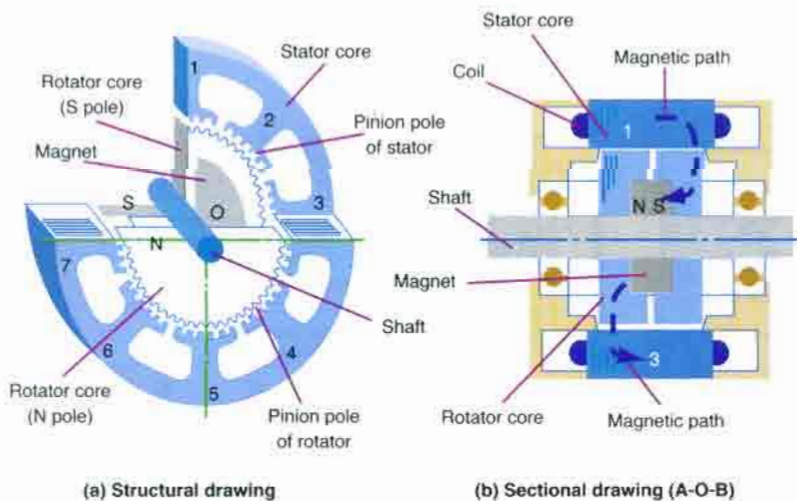


Fig. 1: Magnetic circuit of hybrid stepping motor

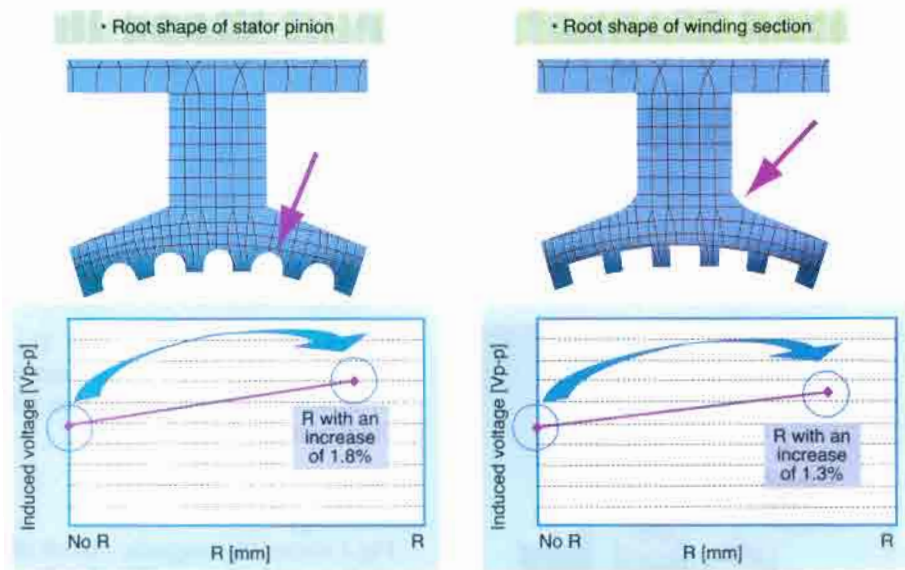


Fig. 2: Influence of shape difference on characteristics (analysis result)

Optimized Magnetic Circuit

A hybrid stepping motor has excellent characteristics in torque generation efficiency and resolution. In a device, it is used for the section requiring higher precision. Based on the advanced driving technology that has been recently popularized, improvement in performance is set as the basic concept of the KA series. Moreover, the symmetric property of the magnetic circuit between phases A and B is made complete, and a round format was employed as outside shape so as to unify the correlative generation torque.

The target of definite characteristics was set to an increase in torque of 30 percent and a decrease in detent torque (cogging torque) of 30 percent with respect to the conventional square motor to be treated. Additionally, a magnetic circuit was optimized with the pinions of stator and rotator's iron cores in the center.

In the magnetic circuit of a hybrid stepping motor, the magnetic flux from the magnet supported using a rotator core overlaps with the field magnetic flux of stator winding, and the magnetic circuit is used as a three-dimensional magnetic circuit that is fed back to the other rotator core. A very complicated magnetic path also forms the hybrid stepping motor because it has a multi-polar structure as compared with other motors. Judging from the time element and analytical precision, it was difficult to apply the electromagnetic field analysis of a stepping motor, which was formed using such a complicated magnetic path, to the actual development by the conventional analytic tool. The reasons were because a magnetic path is three-dimensional and complicated and because an air gap is narrow ($50\mu\text{m}$).

This time, many design parameters for optimizing a magnetic circuit could be in-

vestigated in a short time by using an analytic tool that Hitachi Limited and Hitachi Laboratories Ltd. developed.

Fig.2 shows one of the examples of a pole's peripheral block on detailed shape characteristics. As the analysis result of an induced voltage value that is the alternate parameter of torque, improvement is made by about 1.8 percent by changing the root shape of a pinion at the tip of a stator's main pole. Improvement is made by about 1.3 percent by changing the root shape of a main pole and winding section. It could thus be confirmed that the detailed shape in a magnetic circuit influences characteristics. Analysis was combined with a robust method for parameter design because the detailed shape difference of a pole section influences characteristics and because the corresponding items range over a wide field. Factors in eight items were selected to optimize a magnetic circuit including the factor of dispersion in manufacturing due to the increase in an induced voltage and the reduction in detent torque.

Characteristics of KA series

For the reduction effect of the correlative deviation based on the symmetry of a magnetic circuit characterized by KA series, the induced voltage deviation (indicating the deviation of generation torque per identical current) between phases A and B is 0.8 percent as compared with the conventional square-shaped model. On the other hand, the induced voltage deviation of a square-shaped model is 3.6 percent. This shows that a round-shaped model has a predominant position. As shown in Fig.3, detent torque is also improved by 40 percent, and the distortion of stiffness characteristics is reduced for each phase.

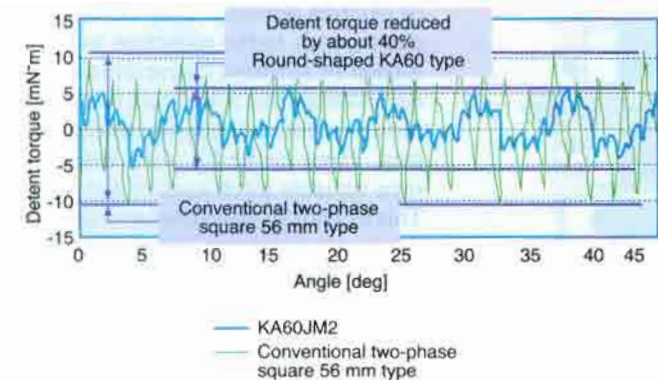


Fig. 3: Comparison of detent torque characteristics

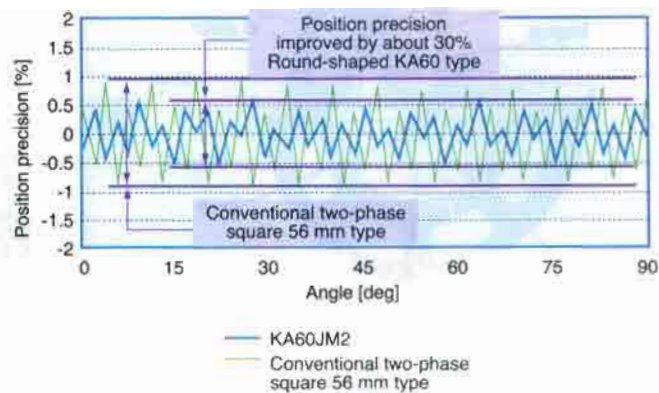


Fig. 4: Comparison of angular precision