Wider Applications of Permanent Magnet Synchronous Motor (PM Motor)

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Abstract

For overall industrial equipment and systems, the demands for higher efficiencies and a further compact design are ever present. Similar demand exists in the field of motor. In order to cope with such market needs, we worked on wider applications of Permanent Magnet synchronous motors (PM motors) because PM motors have features of high efficiency and a compact size.

In 1967, we commercialized the PM motor for application on synthetic fiber machines for the first time in Japan. Since then, we began applying our PM motors for Electric Vehicles (EVs) in the 1980s, and then in the 1990s, for elevator hoist machines and injection molding machines. Recently, we newly developed a high capacity and high speed PM motor and are working on high rotation speed applications.

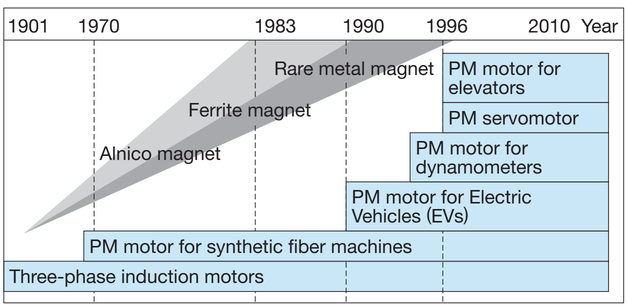
1 Preface

Since the Permanent Magnet synchronous motor (PM motor) employs permanent magnets, there is no generation of secondary excitation loss and it also features high efficiency. Against the background of the rising concern on energy saving and climate change, though induction motors have been a mainstream choice in the industry for a long time, PM motors have recently become the most popular motors in the industry.

Starting with the application for synthetic fiber machines in 1967, we have been manufacturing the PM motors for approximately 50 years. Table 1 shows the history of our PM motors. We have so far been working on higher capacity and an optimum design for machinery systems. We produced various types of customized products for the industrial markets. We recently worked on meeting market demands for a high capacity and high-speed PM motors. As such, we are promoting the development of PM motors focusing on new application fields. This paper introduces some examples of PM motor applications to general industrial fields.

Table 1 History of our PM Motors

The history of our motors relating mainly to the PM motors is shown.



2 Application to Elevators

With urbanization, multi-story buildings are increasing and elevator traction machines are required to raise speed and load capacities. In addition to the demand for new installations, demand for replacing traction machines is expanding for the renovation of existing elevators. For both new installation and renewal, demand for a compact and lightweight model is increasing in order to reduce installation space and shorten construction time. There are many various demands in the elevator markets. In order to meet such various market needs, we worked on improving our offerings of the PM motor traction machines: from slow speed to ultra high speed or from small capacity to high capacity.

For one of the feature products of our traction machines, we have a traction machine specially designed for renovation, featuring a lifting speed of 45 to 105 m/min and a loading capacity of 450 to

1000 kg. Fig. 1 shows the application range of the traction machines for renovation and Fig. 2 shows an external appearance of the PM3.5T. These machines are being used to replace an existing traction machine which uses an induction motor and offer the following features:

(1) A PM motor is adopted because it can generate a large torque to secure gearless characteristics. As a result, maintenance for gears is eliminated.

(2) Divided delivery and on-site assembly is possible.

(a) Replacement of the sheave is easy onsite.

(b) Delivery using the existing elevator is possible.

(3) Performance characteristics are improved.

(a) Due to the adoption of a gearless design, overall system efficiency is improved. Since a PM motor is used, efficiency of the motor itself is raised (Efficiency: 85% at the rated load of 750 kg – 105 m/min). Low noise level (Noise level: 50 dB(A) at the rated load with the motor only).

(b) As a result of the magnet shape optimization by electromagnetic field analysis, we realized low-torque ripples and improved riding comfort.

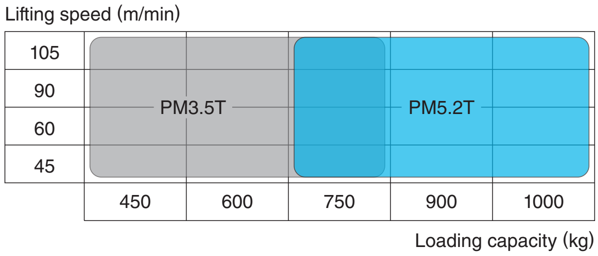


Fig. 1 Application Range of Traction Machines for Renovation

The product lineups are shown for the PM3.5T featuring a lifting speed of 45 to 105 m/min and a loading capacity of 450 to 750 kg and the PM5.2T featuring a lifting speed of 45 to 105 m/min and a loading capacity of 750 to 1000 kg.

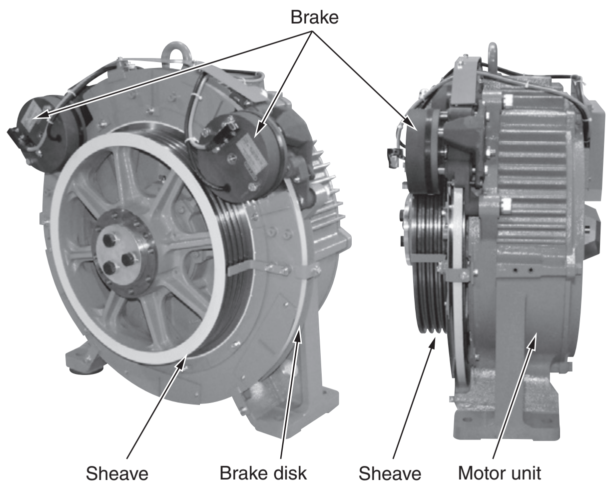


Fig. 2 PM3.5T for Renovation

External appearance of the PM3.5T are shown.

3 Application to Low-Inertia Servomotor

Servomotors applicable to high-speed reciprocal motion in equipment like injection molding machines and press machines are required to have a low inertia and a high power rate. Until now, we had been proposing PM servomotors suitable for mechanical systems. In order to realize a higher-power density on the conventional model, we adopted the core mold insulation.

To realize a high power density, cooling efficiency becomes a very important factor. As an effective measure for the improvement of cooling efficiency, molding is a useful method. In this connection, we have developed a new mold fill-up technique. For a servomotor having a long core such as a low-inertia servomotor, this technique has been used to fill up all of the inner spaces and gaps of the stator core slots and coil ends with the mold resin.

Fig. 3 shows an external appearance of the PM servomotor. Heat generation in coils of core slots is efficiently transferred to the stator core. Since the core slots and coil ends are filled with mold resin uniformly, the generated heat staying around the coils, where cooling efficiency is worse, is efficiently transferred to the stator core and the frame through mold resin. Fig. 4 shows the heat transmission around the coil ends. When this technique was adopted, cooling efficiency was substan-

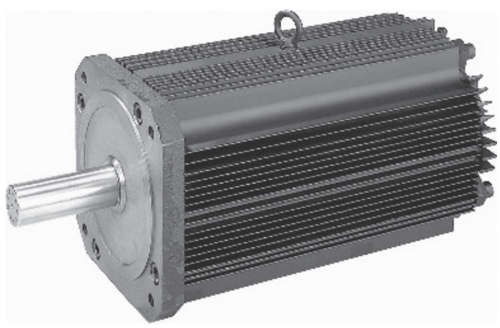


Fig. 3 PM Servomotor

External appearance of a PM servomotor is shown. This is a long-length motor, the core length of which exceeds 500 mm.

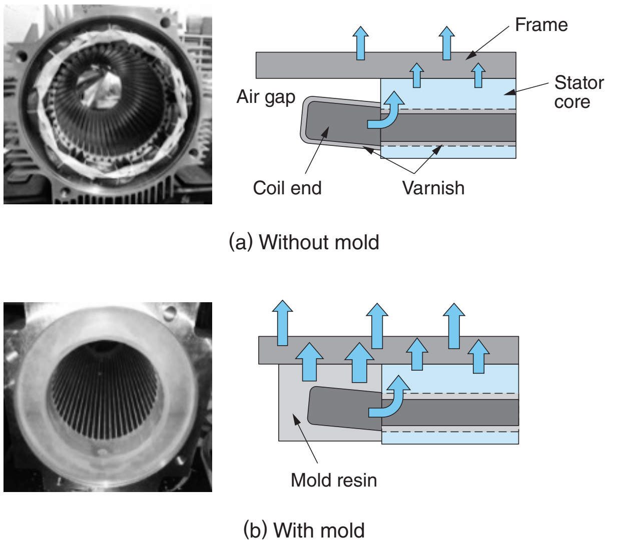


Fig. 4 **Heat Transmission around Coil Ends**

Cooling efficiency is improved by filling up air gaps with mold resin.

Table 2 **Specifications of High-Capacity High-Speed PM Motor**

Specifications of high-capacity high-speed PM motors are shown.

Item	Specifications
No. of poles	2
Rated output	250 kW
Rated rpm	20,000 min^{-1}
Frequency	333.3 Hz
Rated torque	119.4 N·m
Cooling system	Air-cooling
Bearing	Magnetic bearing

tially improved and the power density was practically raised by approximately 30% based on the result of comparison among our products.

4 Application to High-Speed Machines

For fluid machinery like blowers and compressors, high-speed revolution performance is required to raise the energy conversion efficiency. In such a case, however, a high-speed motor tends to get the loss density higher as the output density is increased. We, therefore, created new product lineups of high-capacity high-speed PM motors with the rated output of 250 kW and revolving speed of 20,000 min^{-1}, realized by the use of magnetic bearings. These types of motors are aiming at such applications. **Table 2** shows the specifications of the high-capacity high-speed PM motor and **Fig. 5**

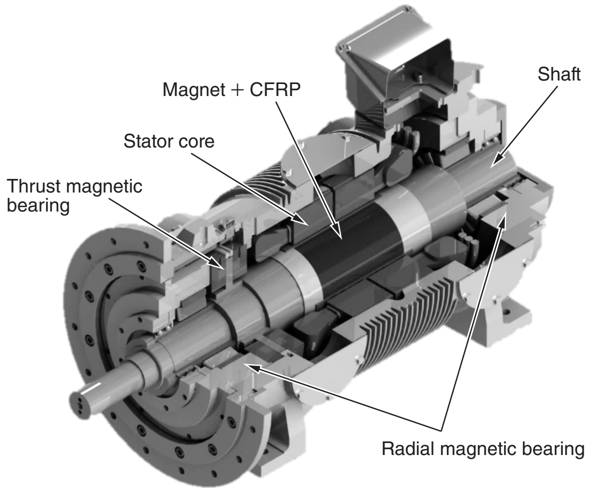


Fig. 5 **Cut Model of High-Capacity High-Speed PM Motor**

A cut model of a high-capacity high-speed PM motor is shown.

shows a cut model of this high-capacity high-speed PM motor. The major features are as itemized below.

(1) Adoption of magnetic bearings

Magnetic bearings are adopted to cause magnetic levitation for a revolving body. By virtue of this technology, high-speed-related issues such as lower mechanical losses and lubricating oil-free and a grease-free operation were solved and realized.

(2) Adoption of Carbon Fiber Reinforced Plastics (CFRP)

As a measure taken to avoid the scattering of rotor magnets, the CFRP rings are adopted. They secure anti-centrifugal force strength against high-speed revolution and low-loss performance is realized for the rotor by using nonmagnetic rings.

(3) Adoption of an air-cooling system by an externally cooled blower

Since the inner direct air-cooling system using externally cooled blower is adopted, high-speed performance is realized by effective cooling to suppress internal temperature rise.

(4) Adoption of thin silicon steel sheets

Since thin silicon steel sheets are used for this type of motor, heat generation caused by high frequencies can be suppressed to improve output and efficiency.

By applying this type of motor to high-speed fluid machines, it can realize a speed-increasing gearless direct drive system. The high-speed had been realized in the conventional system by speed – increasing gears and couplings. This latest system can offer the following advantages:

(1) Energy saving

Since ① losses caused by speed-increasing gears are eliminated and ② motor efficiency is improved by adopting the latest loss reduction technology, we realized the improvement of overall system efficiency.

(2) Space saving

Since the cooling mechanism, such as speed increasing gears, auxiliary machines for lubrication oil, water cooling, and oil cooling, is eliminated, equipment configuration became simple and more compact.

(3) Maintenance labor saving

As a result of the adoption of the gearless system, no maintenance is required for speed-increasing gears. For motors also, the adoption of magnetic bearings makes it unnecessary to carry out replacement of bearings because the bearings are of a non-contact type by virtue of magnetic levitation. In addition, lubrication oil supplementary labor is unnecessary because of the oil-less feature. Thus, a maintenance-free feature is realized.

(4) Low vibration and low noise level

Since magnetic bearings free from mechanical contact are used, vibration is low compared with conventional blowers. Since speed-increasing gears are omitted, mechanical noise level is lowered and a low noise level feature is realized.

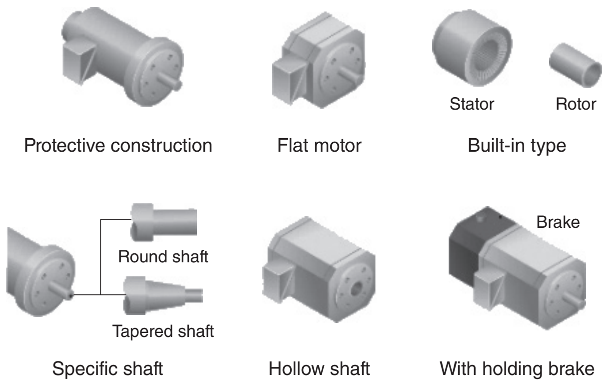


Fig. 6 Example of PM Motor Customization

An example of a PM motor customization is shown.

5 Postscript

We introduced some examples of PM motor applications in this paper. In addition to these, we worked on the development of a variety of customized models. Fig. 6 shows an example of PM motor customization.

Going forward, we will continue to work on higher efficiencies, a more compact design, and improved performance because of the required motor specifications in the markets rising. We will continue to propose a variety of customized products in order to meet the requirements of our customers.