Development of the P6 Large Capacity AC Servo Motor

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1. Introduction

As injection molding machine becomes electric and spin coaters for liquid crystal manufacturing become larger, AC servo motors with large output are demanded. Induction motors that have been used in the past when large output is required are not small enough to meet the demands for down sizing of the machines they are used on. It is necessary to unite the miniaturization and weight reduction of the motor with generation of large output.

This document introduces the features of the permanent magnet type large capacity AC servo motor developed to satisfy such market demands. This servo motor uses an interior permanent magnet type (IPM) rotor. Four models were developed: 37kW, 45kW, 55kW, and 75kW. The standard specification of power-supply voltage is AC400V with only the 37kW accommodating AC200V and 400V.

This text, first of all, shows the lineup and the motor main specifications. Next we will show that the new product is small and lightweight, and more effective than a conventional induction type servo motor. In addition, we will describe the development of achieving low cogging torque as well as the reduction in the use of permanent magnets compared with the conventional surface mounted permanent magnet type (SPM) rotor by improving the IPM rotor shape and enlarging the reluctance torque component.

The maximum rotations are 3000min^{-1} for the 37kW, 45kW and 55kW motors, and 2000min^{-1} for the 75kW motor, all are considered as high speed for their applications.

2. The Main Specifications of the Product

Table 1 shows the main specifications of each motor. The standard specification product supports the rated output of 37kW-75kW, with a flange dimension of 275mm sq. and 320mm sq. and the power-supply voltages of both 200V and 400V, and the maximum rotations of 2000min^{-1} and 3000min^{-1}. The servo driver used is our “PQ” type M driver that has the added the controls for the IPM motor.

3. Features of the Product

3.1 Rotor Structure

In general, IPM motor has a drawback of tending to increase cogging torque and torque ripple because magnetic energy inclination based on the airgap permeance distribution is used to generate reluctance torque. This was one factor that disturbs the generation of high torque. We have overcome this drawback and developed an original IPM rotor, which enabled a high torque, low cogging torque, and low torque ripple and adopted it in this product. In the IPM rotor adopted for this product, the permanent magnet arrangement in the rotor iron core and the rotor iron core shape itself have been designed so as to minimize the torque ripple generated when cogging torque and armature current pass, while enlarging the ratio of the q-axis direction inductance and d-axis direction inductance as well as the reluctance torque.

Table 1 Main Specification of Each Motor

Flange Sq.	[mm]	275				320		
Power Supply Voltage	[V]	200		400				
Motor Model		P60B2837 KB***	P60B2837 KH***	P60B2845 KE***	P60B2845 KN***	P60B3255 KE***	P60B3255 KN***	P60B3275 KE***
Rated Output	[kW]	37		45		55		75
Total Length（w/o brake）	[mm]	640		715		750		850
Weight of Motor	[kg]	165		190		245		290
Rated # of Rotation	[min^{-1}]	1500	2500	1500	2000	1500	2000	1500
Maximum # of Rotation	[min^{-1}]	2000	3000	2000	3000	2000	3000	2000
Rated Torque	[N･m]	235.5	141.3	286.5	214.9	350.1	262.6	477.5
Instantaneous Maximum Torque	[N･m]	588	450	715	550	875	700	1200
Moment of Inertia of Rotor	[kg･m^2]	794×10^{-4}		1010×10^{-4}		1770×10^{-4}		2270×10^{-4}

3.2 Comparison of the Induction Motor vs. the Conventional Synchronous Motor

Table 2 shows the specification comparison between the standard induction motor with the rated output of 37kW (SANYO DENKI “S” series) and this newly developed product. The dimension of the flange sq. became smaller from 320mm to 275mm and the total length became shorter from 689mm to 640mm, and the weight of the motor became lighter by 25%. The instantaneous maximum torque increased by 25%, and an efficiency as high as 94.9%.

Additionally, this developed product decreased the use of permanent magnet compared with the conventional surface magnet type synchronous servo motor by adopting the IPM rotor. To be clear, approximately a 17% reduction in the 37kW and 45kW motors and approximately 29% reduction in the 55kW and 75kW motors. In case of the permanent magnet type synchronous motor, the larger the machine capacity becomes, the more significant the percentage of the cost of materials of permanent magnet to the total cost of materials. Therefore the use of the IPM rotor has brought good results in reduction of the cost of materials of the motor as well.

3.3 Characteristic of Cogging Torque

Cogging torque is 1% of the rated torque ratio with the 37kW motor and 0.76% of rated the torque ratio with the 55kW motor. This low cogging torque of the IPM motor is achieved without a skew arrangement of the permanent magnet or skew of the armature slot.

Table 2 Comparison between the Conventional Product and the Developed Product (w/o brake)

		Developed	Conventional
Type of Motor		Synchronous Motor	Induction Motor
Model of Motor		P60B2837K	S20V3237K
Dimension	□×LL[mm]	□275×640	□320×689
Capacity	$\times 10^4$[cm^3]	4.84	7.06
Weight	[kg]	165	220
Moment of Inertia of Rotor	[kg・m^2]	794×10^{-4}	2744×10^{-4}
Instantaneous Maximum Torque	[N・m]	588	470
Efficiency	%	94.9	91.5

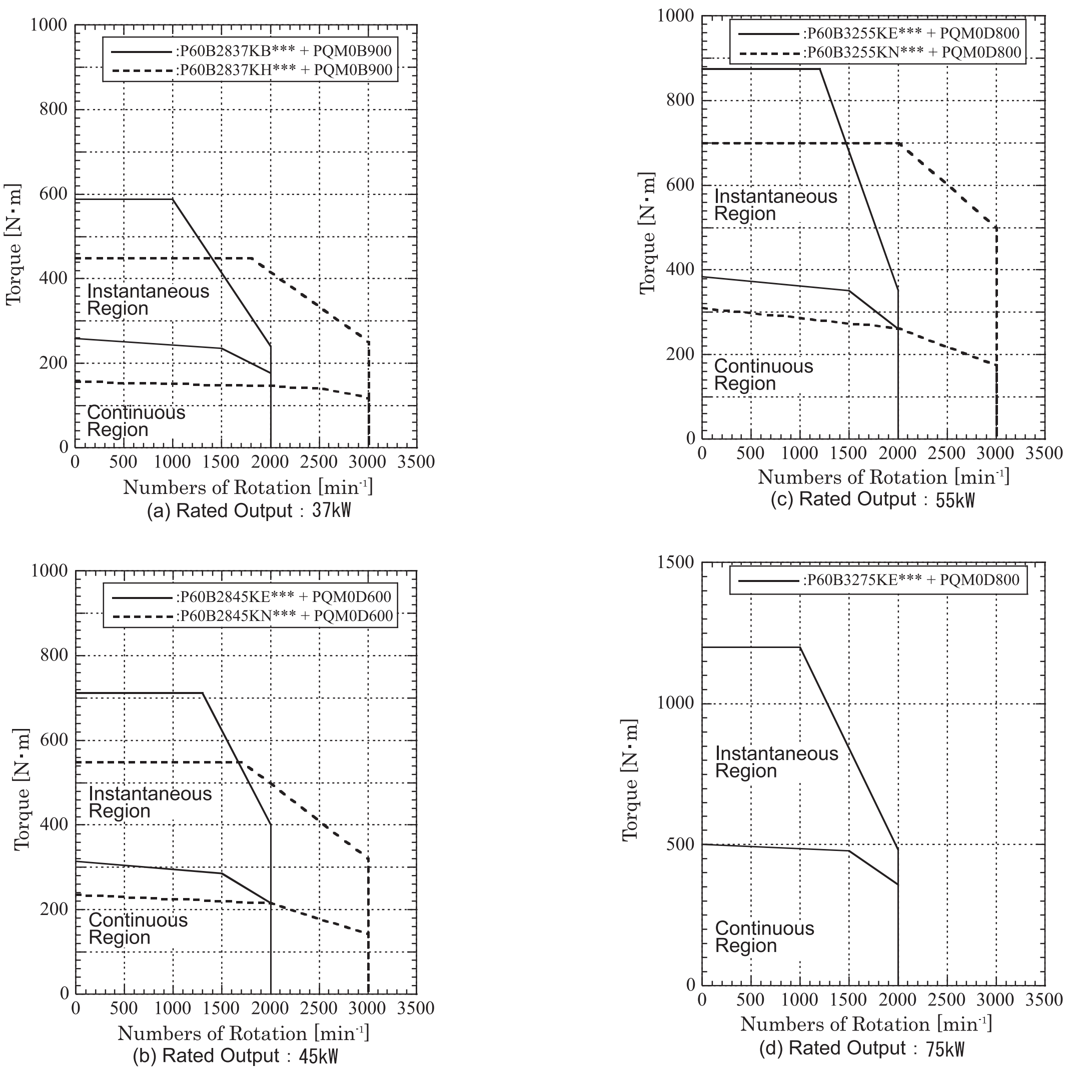

Fig.1 Torque—Characteristics of the number of rotations

3.4 Torque—As Compared to Motor Rotations

Fig.1 shows the torque vs. the characteristic of number of rotation of each motor. The maximum number of rotation of $2000min^{-1}$ and $3000min^{-1}$ are in the current lineup as a standard product. Solid lines shown in Figure 1 are the standard specifications of the $2000min^{-1}$ product, and the broken lines are the standard specifications of the $3000min^{-1}$ products. The characteristic of the 37kW motor shown in Figure 1(a) is for a 200V power-supply voltage whereas the characteristics of 45kW, 55kW, and 75kW machines are for a 400V motor. The reason we were able to achieve the maximum number of rotations, $3000min^{-1}$, in this output class is that we had succeeded to reinforce the centrifugal force measures against the permanent magnet with the use of the new IPM motor and to maintain the torque even at high-speed rotation by using the reluctance torque.

The torque density of this developed product (torque generation for each unit weight of a motor) is, at the rated torque: about 1.5Nm/kg, and at the instantaneous maximum torque: about 3.6Nm/kg, which are industry-leading class high torque density. So you can see that a large torque has been realized with a small size and lightweight design.

4. Conclusion

The main specifications and features of 37kW, 45kW, 55kW and 75kW motors were described for the P6 large capacity AC servo motor. This large capacity AC servo motor is an interior permanent magnet synchronous AC servo motor, which has achieved reduced size and high efficiency compared with the conventional induction type servo motor and the surface mounted permanent magnet synchronous AC servo motor. I think that this servo motor can contribute to miniaturization, high-speed and energy saving of the machine devices which needs large capacity servo motor.

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