Development of the Flange Size 180 mm “SANMOTION R” Series Low Inertia AC Servo Motor

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1. Introduction

Injection molding machines that produce plastic products are primarily electrically powered, which saves more energy and is cleaner than the conventional hydraulic type. Furthermore, the market demands improvements to productivity with high-cycle production, and high precision and high quality that realize thin-wall molding and stable molding of complex shapes for achieving light weight.

The performance of electric injection molding machines is greatly dependent on the performance of the servo motor. Especially, it is essential to realize higher torque for the injection axis to accelerate instantaneously to high-speed rotation. There are also increasing demands for space saving and energy saving equipment, and smaller size and lighter weight are required for environmental consideration.

This document introduces the features of the “SANMOTION R” series low inertia AC servo motor developed in order to respond to these market needs. The new model has improved performance with high speed, high torque, and high acceleration, and at the same time, it has realized smaller size and lighter weight. To achieve high speed and high torque while maintaining low inertia, we have optimized the magnetic circuit in the motor. In addition to the conventional fan cooing method, a resin mold is applied to the motor coil to enhance heat dissipation, realizing the reduction in motor temperature rise.

The standard specifications of the new model are power supply voltage 200 V, four rated output types (5.5 kW, 7.5 kW, 11 kW, 15 kW), and with a holding break.

The new model is a successor of our conventional “SANMOTION Q” series low inertia AC servo motor [1].

2. Improvements in Performance and Features of the Product

2.1 High-speed, high-torque, and high angular acceleration design

Fig. 1 shows a comparison of the rotor inertia moment (hereinafter called rotor inertia) within our series, and Fig. 2 shows a comparison of the peak angular acceleration. Fig. 3 shows a comparison of the acceleration performance without load (only rotor inertia).

The low inertia series has lower rotor inertia and larger peak torque than the middle inertia series, so a large angular acceleration can be obtained. The acceleration time is 45% shorter than the Q2 series middle inertia motor, which realizes a high acceleration performance. As described later, the new model is much smaller and lighter than the conventional Q4 series, and the rise in temperature has also been reduced.

Generally, low inertia can be achieved by making the rotor diameter slim, but when the amount of magnets is reduced, the area of the air gap is reduced at the same time, which causes the peak torque to be lowered. This results in a design where the total length of the motor is elongated, which makes it difficult to achieve small size or light weight. Furthermore, while it is advantageous to increase the number of motor poles for small and light design, it increases the frequency of high-speed rotations, which increases reactance drop and prevents sufficient torque from being attained at high-speed rotations.

To address these challenges, the new model organically combines a numerical analysis simulation and empirical validation as well as the theoretical calculation, thus achieving small size, light weight, and high angular acceleration.

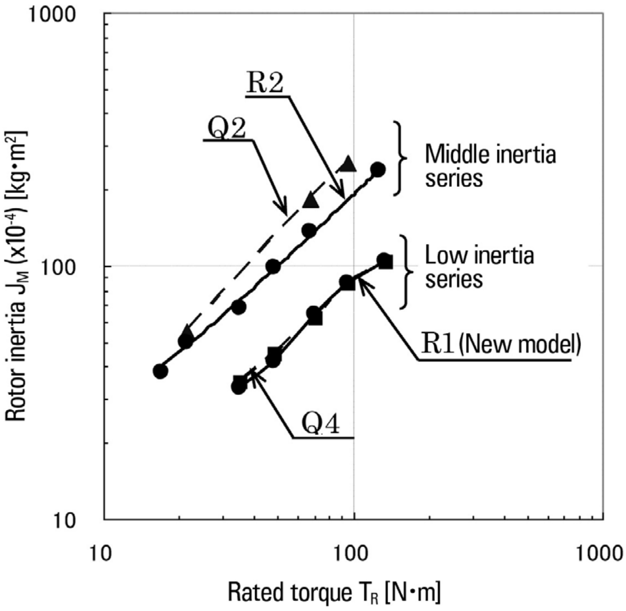

Fig. 1: Comparison of rotor inertia

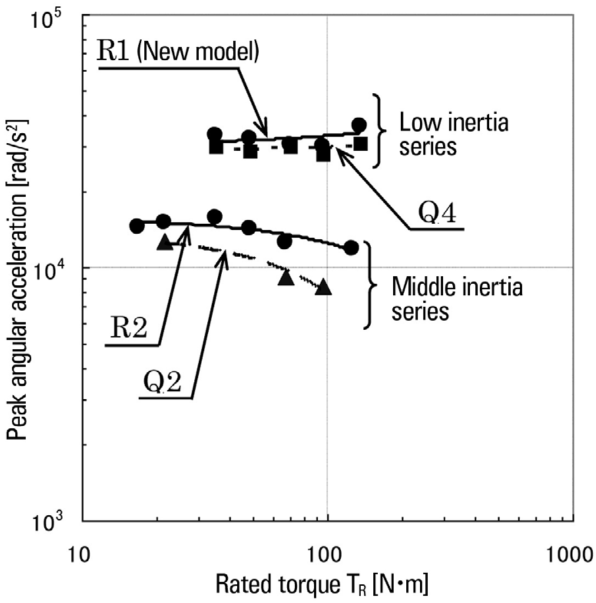

Fig. 2: Comparison of peak angular acceleration

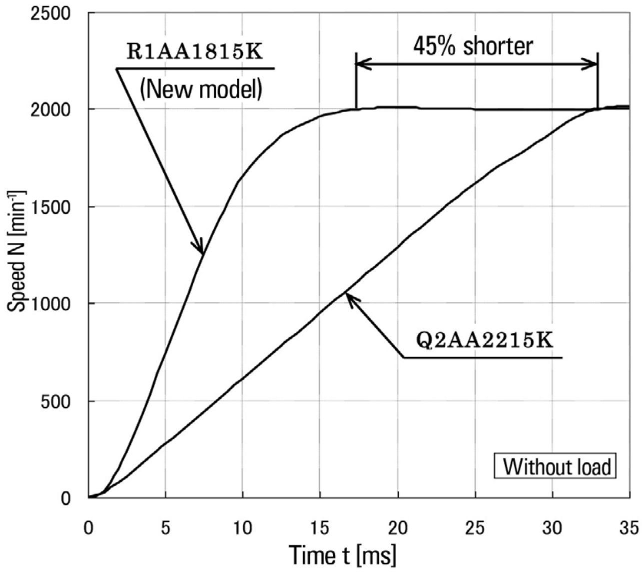

Fig. 3: Comparison of acceleration performance (motor temperature: cold)

Fig. 4 shows a comparison of the torque versus speed characteristics for the new model and conventional model based on the actual measurement. To minimize the rotor inertia and maximize the peak torque, we have optimized the magnet material, rotor diameter, and the shape and length of the stator core.

As a result, the peak torque has increased 5% compared to the conventional model, and the torque at a high-speed rotation has increased 11% as well. Thus, with the new model, the torque-speed characteristic range has also been enlarged.

Furthermore, the new model takes a low cogging torque into consideration in addition to a high speed and a high torque. In addition to making a design where the cogging torque is minimized using the numerical analysis simulation, we have optimized the shape of the magnet and stator core, which affects the cogging torque, based on the results obtained from experiments and verifications.

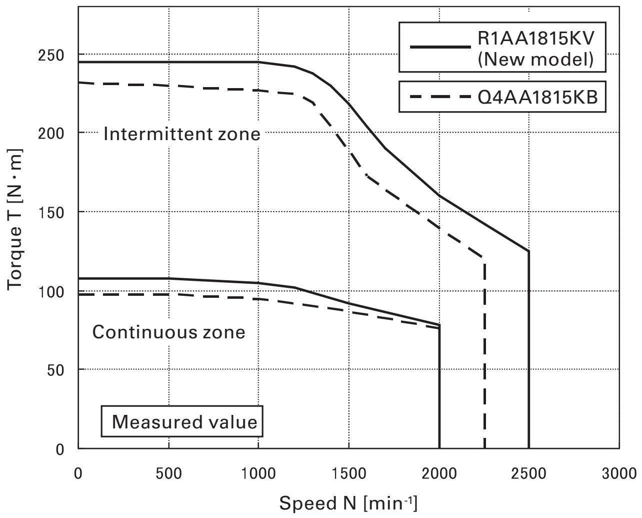

Fig. 4: T-N characteristics
(When combined with a 300 A amplifier)

2.2 Small size and light weight design

Table 1 shows a comparison of total length and mass between the new model and the conventional model. Up to 12% shorter total length and up to 21% lower mass are realized.

To reduce the total length, we have optimized the magnetic circuit and the winding specification to minimize the length of the stator core. The lower mass is achieved by applying the thin wall frame that has been used for the "SANMOTION R" mid capacity AC servo motor (2), as well as by reducing the total length.

Table 1: Comparison of total length and mass for the servo motors

Rated output	Comparison of total motor length (mm)		Comparison of motor mass (kg)	
	New model	Conventional model	New model	Conventional model
5.5 kW	352	392	27	35
7.5 kW	387	427	39	45
11 kW	457	517	52	66
15 kW	535	607	64	75

* From 5.5 to 15 kW. Including the cooling fan length and mass.

2.3 Design for reduction in temperature rise

The new model has improved heat dissipation by applying a resin mold to the motor coil to reduce motor temperature rise caused by the smaller motor size.

Generally, the total length tends to be longer with low inertia motors, so it had been impractical to fill the resin mold due to restrictions in production facilities. This issue was solved this time by utilizing resin mold technology gained in Sanyo Denki to produce injection molding machines in-house exclusively for low inertia motors.

By applying a resin mold, the temperature rise value at a continuous rated output has been reduced 18% compared to the conventional model. As a result, an emphasis is put on the peak torque, and it can be used without a cooling fan under operating conditions where continuous rated output is low.

For example, if a cooling fan on a motor of 15 kW rated output is removed, peak torque (Tp = 230 N · m) can be obtained, and at the same time, up to 24% of the total length can be reduced.

Furthermore, due to the reduction in the temperature rise around the encoder realized by the enhanced heat dissipation, the reliability of the electronic parts has been greatly improved.

3. Product Lineup

Table 2 shows the standard specifications of the new model, and Fig. 5 shows its appearance. Fig. 6 through Fig. 9 show the torque versus speed characteristics for the four models with continuous rated output 5.5 kW through 15 kW.

A 17-bit resolution (up to 20-bit resolution can be supported) serial communication absolute encoder is mounted as a standard encoder.

Other than that, an incremental encoder and a batteryless absolute encoder can also be mounted. The encoder is mounted using only Oldham coupling for a configuration where the encoder is removable.

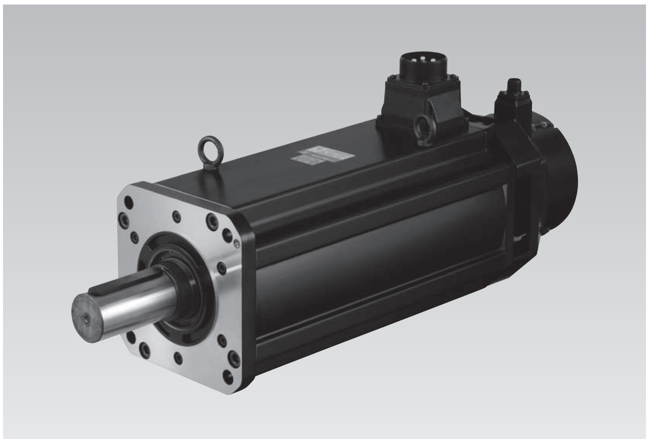

Fig. 5: Appearance of the new model (R1AA1815K)

Table 2: Standard specifications for the new model

Motor model no. / 〈〉 Flange squared dimensions			R1AA18550H 〈□180 mm〉	R1AA18750H 〈□180 mm〉	R1AA1811KR 〈□180 mm〉	R1AA1815KB 〈□180 mm〉
Item	Symbol	Units				
Rated output	P_R	kW	5.5	7.5	11	15
Rated speed	N_R	min^{-1}	1500			
Maximum speed	N_{max}	min^{-1}	3000		2500	2000
Rated torque	T_R	N·m	35	48	70	95.5
Continuous stall torque	T_S	N·m	37	48	70	95.5
Peak stall torque	T_P	N·m	110	135	195	230
Rotor inertia (including encoder)	$J_M \times 10^{-4}$	$kg \cdot m^2 (GD^2/4)$	33	42	64	86
Motor mass (including encoder)	W_E	kg	27	39	52	64
Holding brake torque	T_B	N·m	42 or higher	54.9 or higher	75 or higher	120 or higher
Brake mass	W	kg	2.8	4.5	7.1	8.9
Cooling fan power	PF	W	39/33 200 V AC ± 10% Single phase 50/60 Hz			
200 V AC compatible amplifier model no.			RS1A30A/RS2A30A			
200 V AC power specifications			200 to 230 V AC +10, -15%, 50/60 ± 3 Hz			

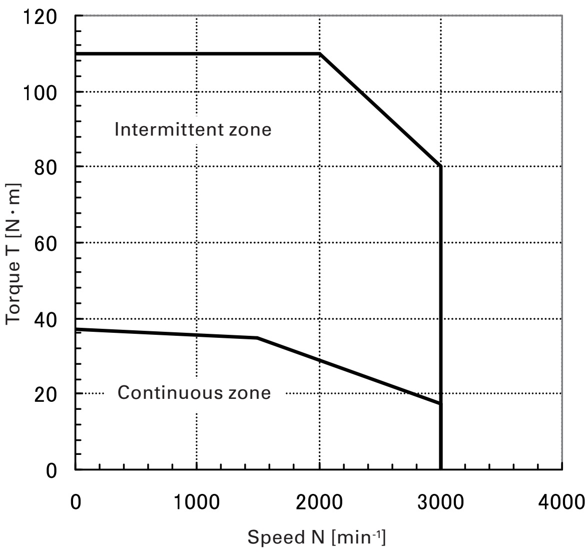

Fig. 6: T-N characteristics (5.5 kW)
(When combined with a 300 A amplifier)

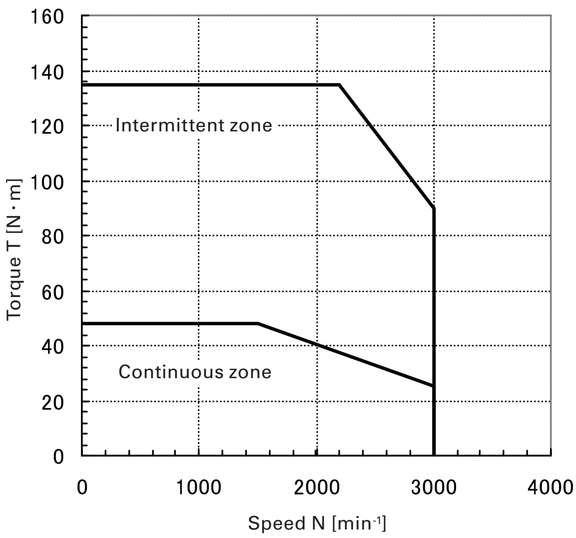

Fig. 7: T-N characteristics (7.5 kW)
(When combined with a 300 A amplifier)

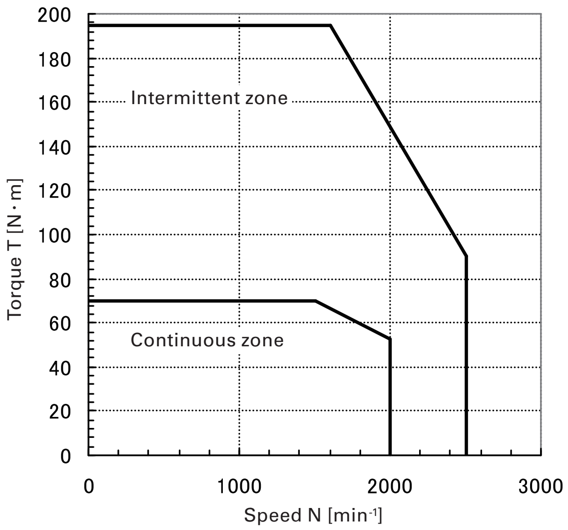

Fig. 8: T-N characteristics (11 kW)
(When combined with a 300 A amplifier)

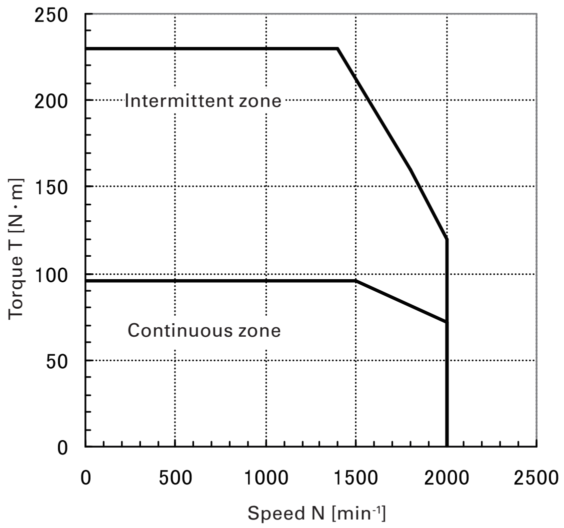

Fig. 9: T-N characteristics (15 kW)
(When combined with a 300 A amplifier)

4. Conclusion

This document introduced the “SANMOTION R” series 180 mm square size flange low inertia AC servo motor.

The new model is a low inertia AC servo motor designed to be small size and light weight, as well as to realize improved performance with its high speed, high torque and high acceleration features. This product can greatly contribute to achieving high speed, high pressure and less space occupation for devices such as spring forming machines and press machines, as well as injection molding machines that are becoming increasingly electric-powered.

Documentation
(1) Shintarou Koichi, and others: “Development of Low Inertia & Large Capacity AC Servo Motor: “SANMOTION Q”, SANYO DENKI Technical Report No. 18, November 2004.
(2) Tooru Takeda, and others: “Development of the Flange Size 180 mm “SANMOTION R” Series Mid-Capacity AC Servo Motor”, SANYO DENKI Technical Report No. 32, November 2011.


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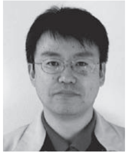
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