Development of the Flange Size 180mm "SANMOTION R" Series Mid-Capacity AC Servo Motor

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1. Introduction

Plastic molded products are used in consumer electronics, OA equipment, and vehicle parts, as well as a wide variety of other fields, making them essential in our lives. Currently, there is a greater need for thinness and light weight in plastic molded parts, and in order to make this possible, high speed, high response, high accuracy, and high reliability are demanded from injection molding machines. The performance of injection molding machines is greatly dependent on the performance of the equipped servo motor. For the servo motors that realize the agile operations of molding machines and smooth movements that suppress vibrations, environmentally friendly servo motors that take into account energy saving are required.

This document introduces the features of the "SANMOTION R" Series mid-capacity AC servo motor developed in order to respond to these market needs.

First, we will show improvements in performance of the new model. The new model is designed to be smaller size and light weight, but it is also designed for high speed, high torque, low cogging torque, and low loss. For improvements of these types of performance while also achieving small size and light weight, we organically combined theoretical calculations in addition to numerical analysis simulations (CAE) and tolerance analysis [1]. We will show improvement in performance including the above described. Next, we will introduce the product lineup. The standard specifications include 5 models with power voltage AC 200 V and the following rated outputs: 3.5 kW, 4.5 kW, 5.5 kW, 7.5 kW, and 11 kW.

The new model is a successor to the Sanyo Denki conventional model "SANMOTION Q" series, and the models expand the lineup of the "SANMOTION R" mid-capacity AC servo motors [2] sold starting from 2009.

2. Improvements in Performance and Features of the Product

2.1 Small size and light weight design

Fig. 1 shows the appearance of the new model. Compared to the conventional model, the total motor length has been greatly shortened to achieve smaller size. Table 1 shows a comparison of total length and mass between the new model and the conventional model. As the table shows, the new model achieves both a shorter total length and a reduction in mass.

In order to achieve small size and light weight motors (shortened total length and reduced mass), the design policy followed the following guidelines:

(1) Apply high energy magnets and optimize magnetic circuits for small size and light weight.
(2) Make components thin-walled for light weight.
(3) Improve bearing mechanism (shorten the distance between supports) for small size.
(4) Employ thin encoders for small size.

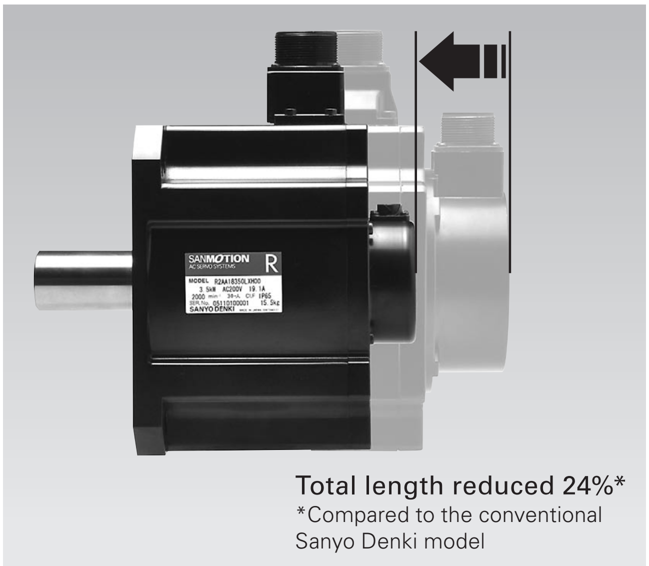

Fig. 1: Appearance of the new model (3.5 kW motor)

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
3.5 kW	155.0	203.0	15.5	17.7
4.5 kW	172.0	218.0	19.5	20.0
5.5 kW	228.0	282.0	27.7	30.0
7.5 kW	273.0	332.0	35.7	40.0
11 kW	385.0	No product	40.0	No product

* 11 kW has a built-in cooling fan (includes the cooling fan length)

Normally, making the components thin-walled invites excessive deformation and insufficient strength due to decline of part rigidity, and shortening the distance between bearing supports invites an increase in fluctuations in the output shaft. In the new model, these issues were addressed by organically combining theoretical calculations with numerical analysis simulations and tolerance analysis, and the design was optimized for the torque characteristics, part strength, and output shaft accuracy.

Fig. 2 shows an example of analysis of stress and deformation that occurs when thermal press fitting the thin-walled frame and the iron core stator. The design was performed taking into consideration manufacturing processes. Based on the dimensions and shape set through theoretical calculations, verifications are performed so that the part strength is maintained within the safety factor according to numerical analysis simulations while also making sure that the part accuracy is not affected by frame deformation that occurs during the thermal press fitting process. Furthermore, by performing vibration tests, verification was performed on strength over the entire motor and resonance frequency.

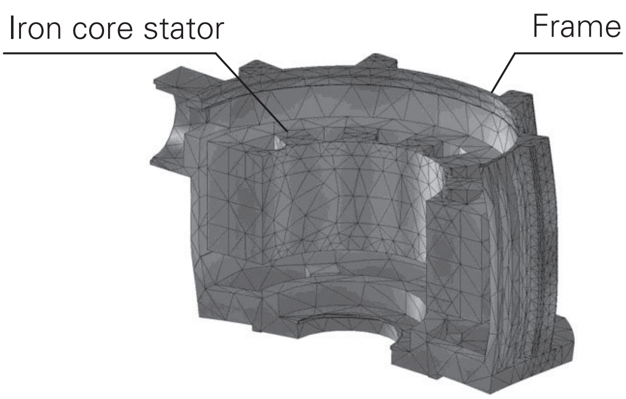

Fig. 2: Analysis example of stress and deformation (1/2 model) (Deformation in the frame that occurs during thermal press fitting)

Fig. 3 shows an example of tolerance analysis for output shaft fluctuations. This clarifies the dimensional tolerances that affect output shaft fluctuations, leading to the tolerances with the smallest fluctuations. These results are applied in the dimension control values in the manufacturing process.

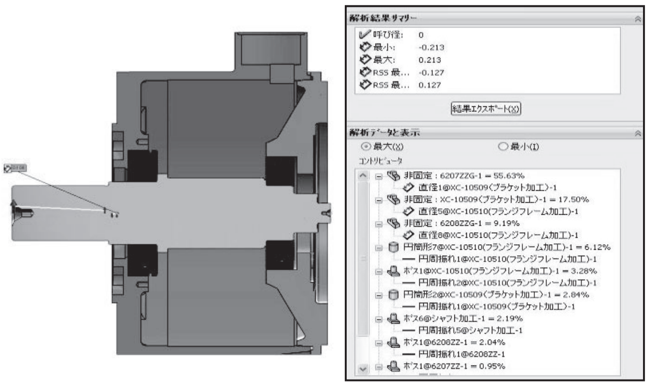

Fig. 3: Example of tolerance analysis for output shaft fluctuations (3D tolerance analysis model and results)

The use of high energy magnets is effective in improving torque, but due to an increase in magnetic flux density, precautions must be taken against increases in cogging torque and iron loss. The design considerations for cogging torque and iron loss are discussed later.

2.2 Expansion of the torque versus speed characteristics region

Fig. 4 shows a comparison of the torque versus speed characteristics for the new model and conventional model. By using high energy magnetics and optimizing the winding specifications and the magnetic circuit composed of the magnet and iron core stator, both high torque and high speed can be achieved, and the torque versus speed characteristics region can be expanded.

Furthermore, Fig. 5 shows the rate of improvement for the instantaneous maximum stall torque (compared to the conventional model). As it shows, the instantaneous maximum stall torque is improved 7-18%, and an instantaneous maximum stall torque of 3.5 times the rated torque is realized, achieving the top output region in the industry.

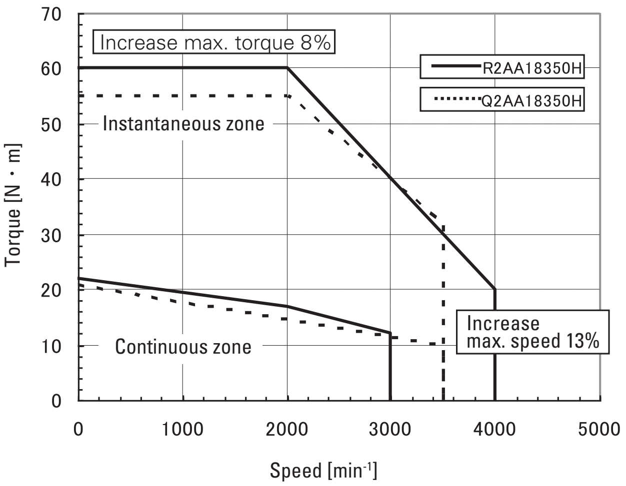

Fig. 4: Torque versus speed characteristics
(3.5 kW motor When combined with 150 A amplifier)

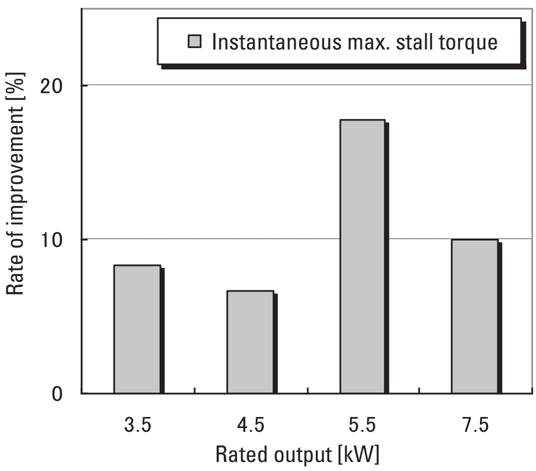

Fig. 5: Rate of improvement for the instantaneous maximum stall torque
(Compared to the conventional Sanyo Denki model)

2.3 Low cogging torque design

As described previously, by using high energy magnets, the design can be made high torque, but consideration must be paid to the increase in cogging torque that results from the increase of the magnetic flux density.

In the new model, the diamensions and shape of the magnet and iron core stator are designed to have the smallest cogging torque, while at the same time, the cogging torque is optimized based on tolerance analysis.

The cogging torque is largely dependent on the accuracy of the stator inner diameter dimensions and the accuracy of the magnet allocation on the rotor. With the new model, the dimension tolerances, which affect cogging torque characteristics, are grasped quantitatively through tolerance analysis, and the tolerance with the smallest cogging torque is set as the dimension control value. The cogging torque amplitude for the new model is 0.8% or less of the continuous stall torque ratio (1/3 of the conventional model), and a low cogging torque is realized.

2.4 Low loss design

Normally, when designing a small size motor, the motor heat rises higher with the reduction in radiation area and increase in generated heat per unit of volume.

In the new model, by using high energy magnets, the number of poles and slots are changed from the conventional model and the balance between copper loss and iron loss is optimized. As a result, the total loss is reduced 25% compared to the conventional product. Furthermore, by using molded resin in the wiring area, the heat generation is improved and the temperature rise during continuous rated output is reduced 6% compared to the conventional model. In this way, the mew model is designed for small size and light weight while reducing loss and the rise in temperature.

3. Product Lineup

Table 2 shows the list of standard specifications of the new model. Fig. 6 through Fig. 11 show the torque versus speed characteristics for the five models with continuous rated output 3.5 kW through 11 kW.

The standard specification encoder is a 17 bit resolution (maximum 20 bit resolution) serial communication absolute encoder, but in addition to this encoder, the incremental encoder and batteryless absolute encoder can also be built in. Furthermore, the Oldham coupling method (configuration where the encoder can be removable) can be selected.

Table 2: Standard specifications for newly developed models

Motor model no. / 〈〉 Flange squared dimensions			R2AA18350D 〈□180 mm〉	R2AA18450H 〈□180 mm〉	R2AA18550R 〈□180 mm〉	R2AA18550H 〈□180 mm〉	R2AA18750H 〈□180 mm〉	R2AA1811KR 〈□180 mm〉
Item	**Symbol**	**Units**						
Rated output	P_R	kW	3.5	4.5	5.5		7.5	11.0
Rated speed	N_R	min^{-1}	2000		1500			
Maximum speed	N_{max}	min^{-1}	4000	3500	2500	3000	3000	2500
Rated torque	T_R	N·m	17	21.5	35	35	48	70
Continuous stall torque	T_S	N·m	22	30	37.3	37.5	54.9	80
Peak stall torque	T_P	N·m	60	75	90	107	140	170
Rotor inertia (Including encoder)	J_M	$kg \cdot m^2(GD^2/4)$	40×10^{-4}	50×10^{-4}	68×10^{-4}		98×10^{-4}	110×10^{-4}
Motor mass (Including encoder)	W_E	kg	15.5	18.5	26.5		34	40
Holding brake torque	T_B	N·m	22	32	42		100	
Brake mass	W	kg	2.4	2.8			6.3	
AC 200 V compatible amplifier model No.			RS1A15/RS2A15			RS1A30/RS2A30		
AC 200 V power specifications			AC 200 V ～ 230 V ＋10，－15%，50/60 ± 3 Hz					

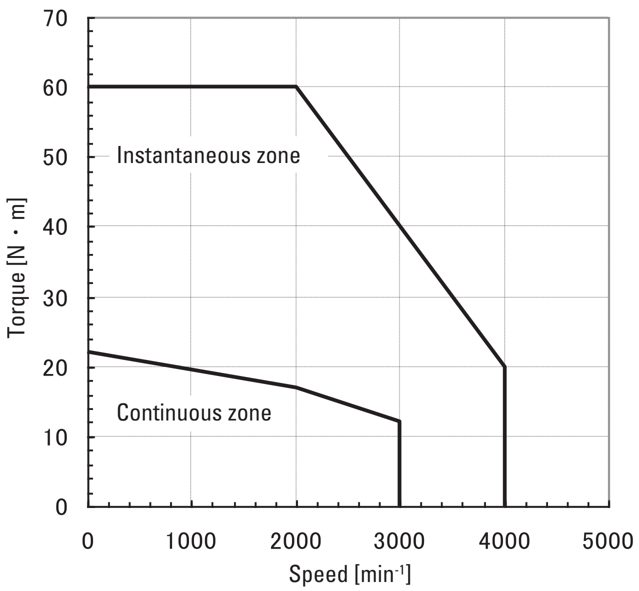

Fig. 6: T-N characteristics (3.5 kW)
(When combined with a 150 A amplifier)

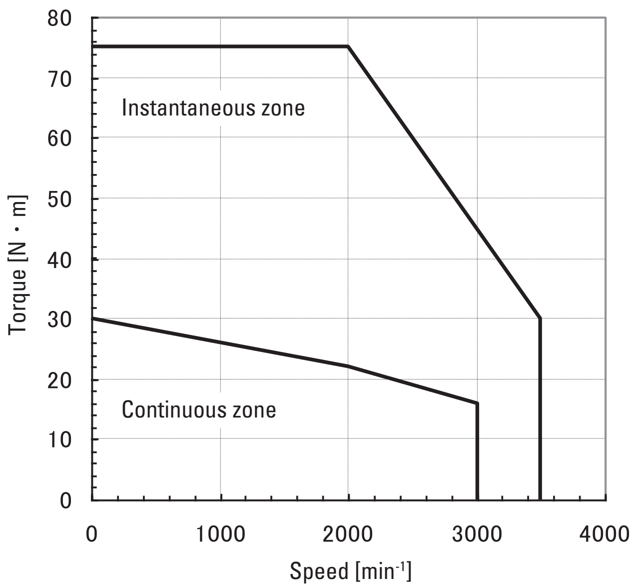

Fig. 7: T-N characteristics (4.5 kW)
(When combined with a 150 A amplifier)

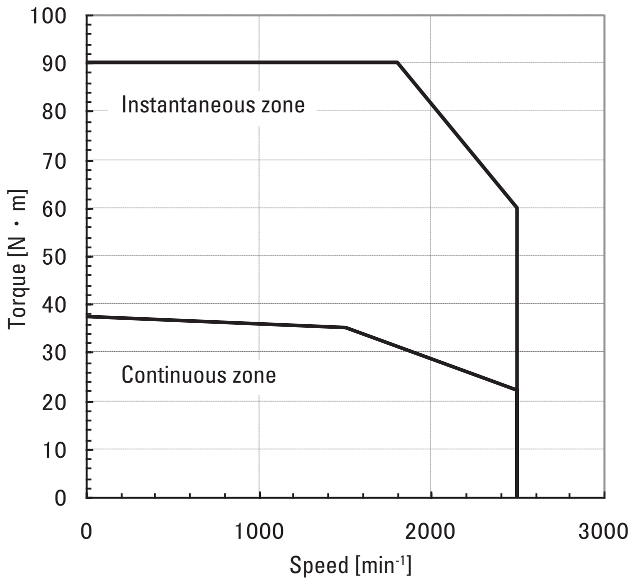

Fig. 8: T-N characteristics (5.5 kW)
(When combined with a 150 A amplifier)

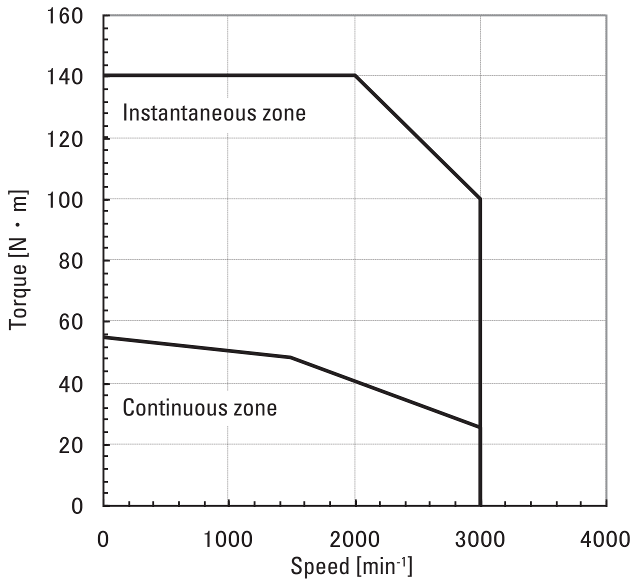

Fig. 10: T-N characteristics (7.5 kW)
(When combined with a 300A amplifier)

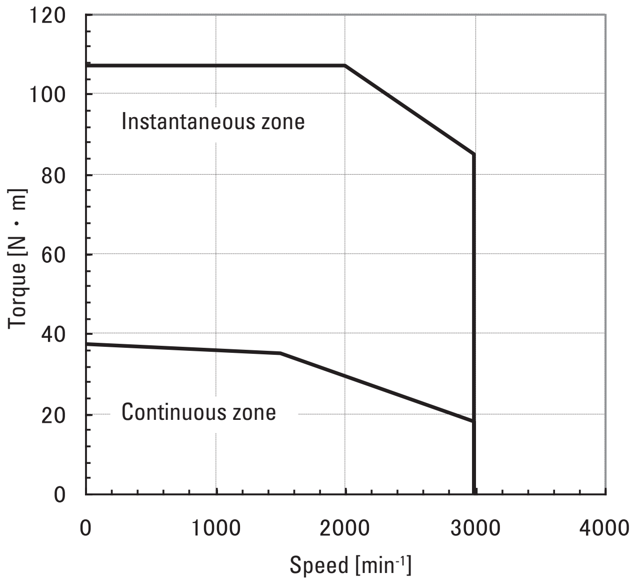

Fig. 9: T-N characteristics (5.5 kW)
(When combined with a 300 A amplifier)

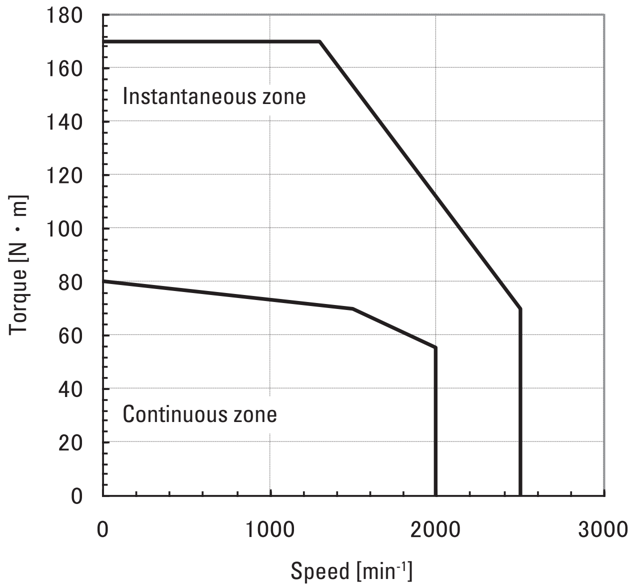

Fig. 11: T-N characteristics (11 kW)
(When combined with a 300 A amplifier)

4. Conclusion

This document introduced the 180 mm square size flange mid-capacity AC servo motor that was developed to expand the models in the “SANMOTION R” series lineup.

The new model is an AC servo motor designed for low cogging torque and low loss that offers both small size and light weight with high speed and high torque.

We think that this servo motor is a product that can greatly contribute to space saving, high performance (agile movements, smooth operations), and energy saving of injection molding machines and industrial machinery devices.

Documentation

(1) Kazuhiro Makiuchi and Tooru Takeda, Dispatch: “Attempt for Optimization of Quality and Cost through Tolerance Analysis”, Nikkei Monozukuri, May 2010.

(2) Shintarou Koichi, et al.: “Development of the Flange Size 130 mm and 220 mm “SANMOTION R” Series Mid Capacity AC Servo Motor”, SANYO DENKI Technical Report No. 27, May 2009.

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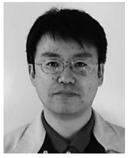

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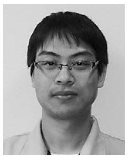

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