Development of the “SANMOTION R1” 100 sq. 1 kW -130 sq. 5 kW AC Servo Motor

Keisuke Nagata Kazuyoshi Murata Takashi Sato Kenta Matsushima

1. Introduction

Improving productivity is essential for reducing costs and achieving a stable supply of industrial products. In recent years, there has been a rapid shift towards machine-based automation in manufacturing workshops, and machine cycle-time now significantly affects productivity. Amidst this, in spring forming machines, printed circuit board drilling machines, compact machining centers and similar applications, faster material feed and positioning for processing are sought in order to reduce cycle time.

The servo motors adopted in these devices are expected to have a higher speed and higher torque in order to instantaneously reach maximum speed, or in other words, to have a wider output range. Moreover, there are strong needs for devices to be both energy- and space-saving, and as such, servo motors are required to have higher efficiency as well as be more compact and lightweight.

This paper introduces the features of “SANMOTION R1”, an AC servo motor developed to satisfy such market needs.

By adopting a magnet with high residual magnetic flux density, an optimized armature core shape, and a printed wiring board, the new model has been made more compact and lightweight than the current model, with a wider output range, higher efficiency, and lower cogging torque.

Two versions of the new model have been added to the lineup; one with a maximum speed of 6000 min^{-1} and the other with a maximum speed of 3000 min^{-1} which also has increased low-speed range peak torque. Both types are available in two different flange sizes (100 mm and 130 mm) and seven different rated outputs varying between 1 kW and 5 kW.

The new model is the successor of our conventional AC servo motor, the “SANMOTION Q1” [1].

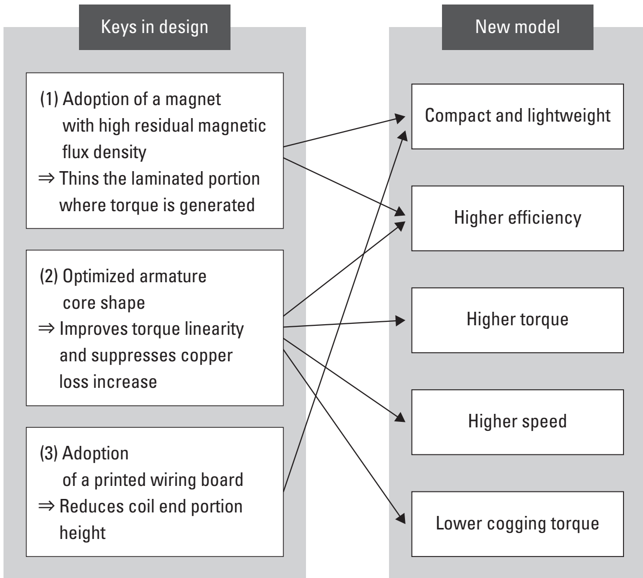


Fig. 1: Design points of the development

2. Design points for improving performance

2.1 Design points of the new model

Compared to the current model, the new model is more compact and lightweight, has a wider output range, higher efficiency and lower cogging torque. This paper draws comparisons with the current model to introduce the design points behind achieving these performance improvements and the concrete details of the performances themselves.

The design points implemented during this development in order to achieve performance improvement are shown in Figure 1.

(1) Adoption of a magnet with high residual magnetic flux density (Br)

By adopting a magnet with higher residual magnetic flux density (Br) than the current model’s magnet, the new model is thinner in the laminated portion where torque occurs, making it shorter in the overall length and lighter in weight.

Moreover, by reducing thickness, the amount of electromagnetic plate and magnet wire for the armature is minimized, reducing iron and copper loss and improving efficiency.

(2) Optimized armature core shape

Figure 2 is a rough sketch showing the shape of the new model's armature core. On the new model, the teeth are tapered, starting from the back yoke side and becoming thinner towards the internal diameter side to facilitate the saturation of magnetic flux. This mitigates magnetic flux saturation and achieves higher torque while securing winding space area and minimizing copper loss increases.

Furthermore, due to the reduced magnetic flux density, iron loss has also been reduced, contributing to higher efficiency.

Moreover, the shape of the core's teeth has been optimized to suppress cogging torque to an absolute minimum.

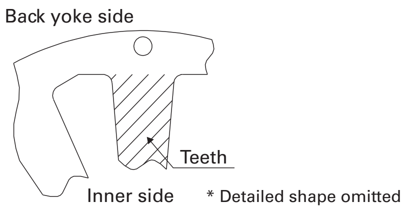


Fig. 2: The armature core of the new model

(3) Adoption of a printed wiring board

Figure 3 shows a cross-section of the coil end portions on the current and new models. On the current model, the coil ends were connected using a connection wire, therefore sufficient space was required. On the new model, coil end connection is done by adopting a printed circuit board to minimize coil end height and shorten overall length.

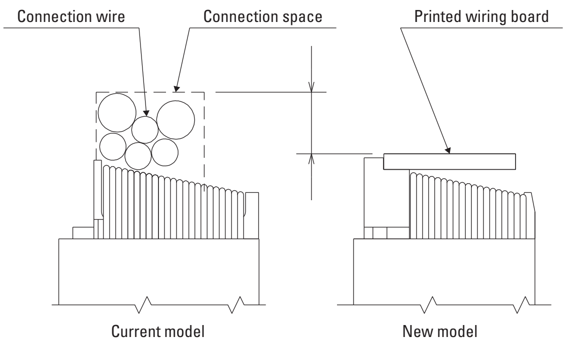


Fig. 3: Coil end connections of the current and new models

2.2 Performance improvements (compared to current model)

2.2.1 Wider output range

Figure 4 shows the relationship between the torque of a 1.5 kW rated output motor and armature magnetomotive force.

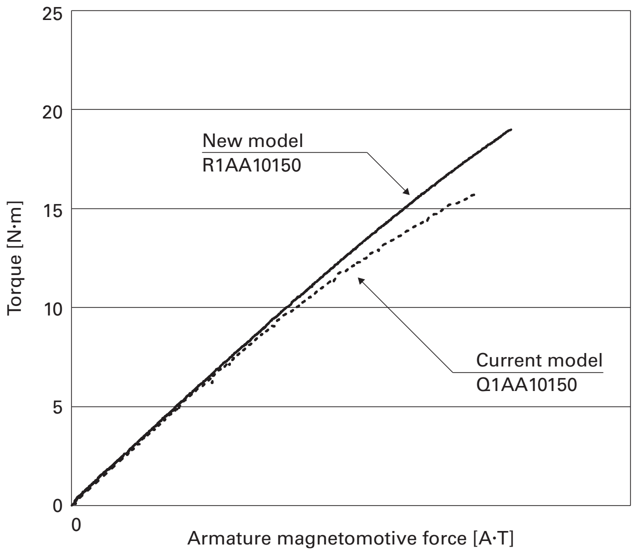


Fig. 4: Armature magnetomotive force - Torque characteristics (1.5 kW)

By optimizing the shape of the new model's armature core, the new model has improved torque linearity relative to armature magnetomotive force when compared with the current model, thus achieving even higher torque.

Formula (1) expresses the terminal voltage for one phase of the surface magnet-type motor and, in order to achieve higher speed, it would suffice to minimize the voltage drop caused by reactance shown in the second term of this formula's right side.

$$\dot{V} = R_\phi \dot{I} + X_L \dot{I} + \dot{E} \quad [\text{V}] \tag{1}$$

However, $$X_L = 2\pi \frac{NP}{120} L_\phi \quad [\Omega] \tag{2}$$

Here,

$\dot{V}$	:	Terminal voltage for one phase	[V]
R_ϕ	:	Phase resistance	[Ω]
$\dot{I}$	:	Armature current	[A]
X_L	:	Reactance	[Ω]
$\dot{E}$	:	Counter-electromotive force	[V]
N	:	Speed	[min^{-1}]
P	:	Pole number	
L_ϕ	:	Phase inductance	[H]

As shown in Figure 4, torque linearity has been improved on the new model, therefore the number of turns on the armature winding can be reduced, even when generating the same amount of torque as the current model. Therefore, phase inductance can be minimalized, which suppresses voltage drop caused by reactance and makes a higher speed possible.

Figure 5 shows the speed-torque characteristics of the current and new models for a 1.5 kW rated output motor.

Compared with the current model, the 6000 min^{-1} type has improved maximum speed by 33%, while the 3000 min^{-1} type has improved peak torque by 22%. The features of the 6000 min^{-1} type and 3000 min^{-1} type will be described later in this paper.

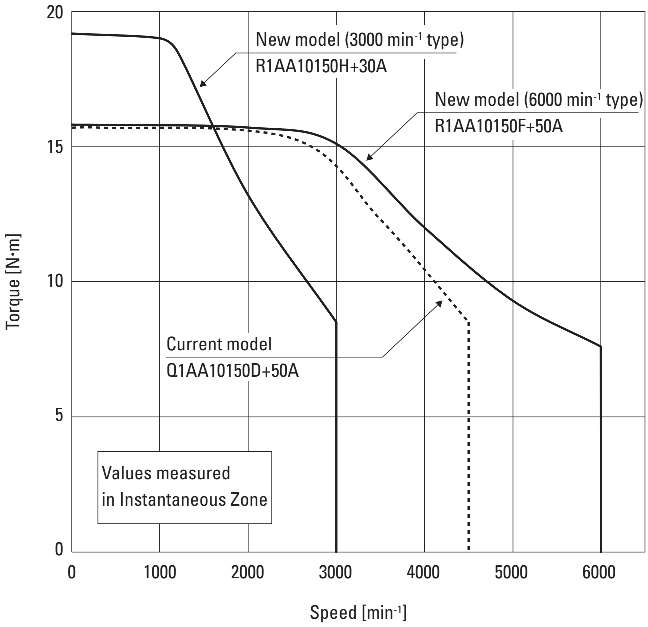


Fig. 5: Speed-Torque Characteristics (1.5 kW)

2.2.2 Higher efficiency

Figure 6 compares the power loss of the current and new models with a rated output of 1.5 kW during rated operation.

Compared to the current model, the new model has 25% less power loss during rated operation, increasing efficiency by 2.4% and contributing to better energy-saving of the device.

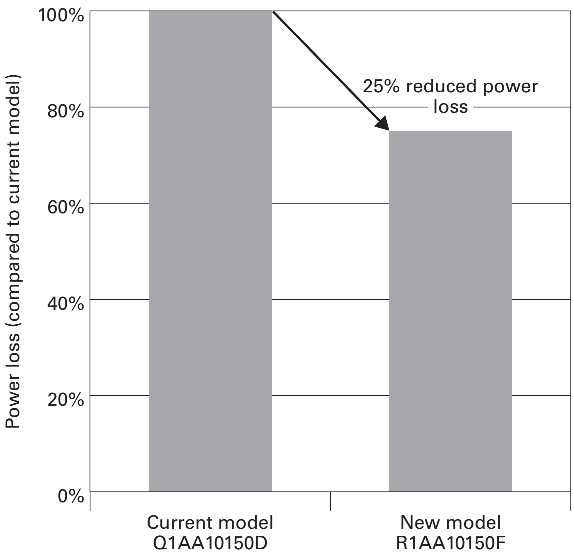


Fig. 6: Power loss comparison (at rated operation, 1.5 kW)

2.2.3 Reduced size and weight

Table 1 gives a comparison of overall length and mass for the various servo motors. Moreover, Figure 7 uses the 2.5 kW rated output motor to compare the overall lengths of the current and new model.

With the same flange size and motor output as the current model, the new model has reduced overall length by 18% on average and as much as 60 mm. Furthermore, mass has been reduced by an average of 21%.

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

Rated output [kW]	Motor length [mm]		Motor mass [kg]	
	New model	Current model	New model	Current model
1	145	184	3.8	5.4
1.5	168	209	5.0	6.5
2	179	234	5.7	8.7
2.5	199	259	6.7	9.4
3	184	205	9.7	11.4
4	208	232	12.2	14.4
5	232	269	14.3	18.1

* Comparison based on specifications without brakes

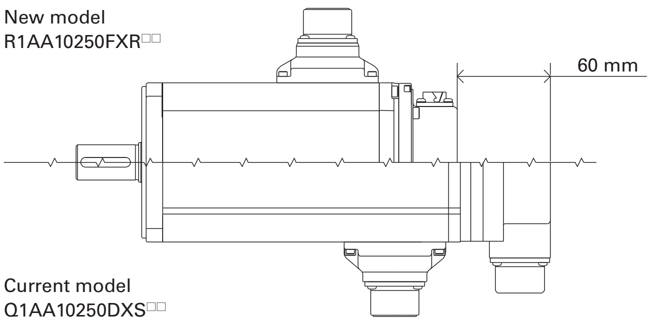


Fig. 7: Comparison of motor length (2.5 kW)

2.2.4 Lower cogging torque

Figure 8 shows the cogging torque waves for a current and new model using 1.5 kW rated output motors. Compared to the current model, the cogging torque of the new model is reduced by around one-third. This means that smoother operation is possible and, ultimately device processing accuracy is improved and vibration reduced.

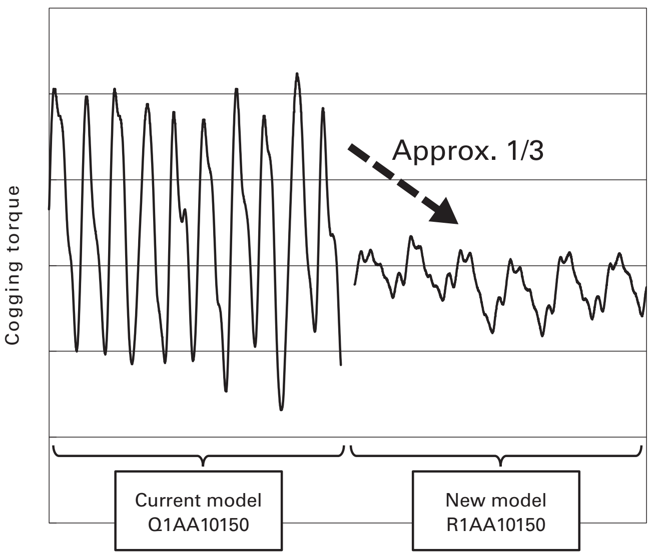


Fig. 8: Cogging torque waveform (rated output 1.5 kW)

3. Specifications and Features

Figures 9 and 10 show an external view of the new model. Tables 1 and 2 show the specifications of the new model, while Figures 11 through 24 show the respective speed-torque characteristics.

The new model consists of two types for each rated output - a type with a maximum speed of 6000 min^{-1} and a type with a maximum speed of 3000 min^{-1}. The features of the two model types are shown below.

(1) 6000 min^{-1} type

Maximum speed is 6000 min^{-1} (a 20-33% improvement compared to the current model), enabling the device to be driven at high speed and contributing to a shorter cycle time.

(2) 3000 min^{-1} type

Peak torque is improved by 1.1 to 1.2 times in relation to the 6000 min^{-1} type. Moreover, by reducing armature current, the combined amplifier capacity is smaller than the 6000 min^{-1} type. This means that, in short pitch drive applications, acceleration/deceleration times are further reduced, as is amplifier capacity, which translates to lower costs.

Fig. 9: New model external view (100 mm square flange)

Fig. 10: New model external view (130 mm square flange)

Table 2: 6000 min^{-1} type specifications

Combined servo amplifier capacity		50 A		75 A		100 A	150 A	
Motor model No.	Unit	R1AA10100F	R1AA10150F	R1AA10200F	R1AA10250F	R1AA13300F	R1AA13400F	R1AA13500F
Rated output	kW	1.0	1.5	2.0	2.5	3.0	4.0	5.0
Rated speed	min^{-1}	3000	3000	3000	3000	3000	3000	3000
Maximum speed	min^{-1}	6000	6000	6000	6000	6000	6000	6000
Rated torque	N·m	3.2	4.8	6.37	7.97	9.7	12.8	16.0
Peak torque	N·m	10.5	15.0	20.0	24.0	29.0	39.0	48.0
Rotor inertia	x 10^{-4} kg·m^2	1.4	2.0	2.3	2.8	7.0	8.8	10.6
Mass (w/o brake / w/brake)	Kg	3.8 / 5.3	5.0 / 6.6	5.7 / 7.2	6.7 / 8.2	9.7 / 11.8	12.2 / 14.7	14.3 / 16.8

Table 3: 3000 min^{-1} type specifications

Combined servo amplifier capacity		30 A		50 A		75 A	100 A	
Motor model No.	Unit	R1AA10100H	R1AA10150H	R1AA10200H	R1AA10250H	R1AA13300H	R1AA13400H	R1AA13500H
Rated output	kW	1.0	1.5	2.0	2.5	3.0	4.0	5.0
Rated speed	min^{-1}	3000	3000	3000	3000	3000	3000	3000
Maximum speed	min^{-1}	3000	3000	3000	3000	3000	3000	3000
Rated torque	N·m	3.2	4.8	6.37	7.97	9.7	12.8	16.0
Peak torque	N·m	12.6	18.0	24.0	27.5	34.8	47.0	55.0
Rotor inertia	x 10^{-4} kg·m^2	1.4	2.0	2.3	2.8	7.0	8.8	10.6
Mass (w/o brake / w/brake)	kg	3.8 / 5.3	5.0 / 6.6	5.7 / 7.2	6.7 / 8.2	9.7 / 11.8	12.2 / 14.7	14.3 / 16.8

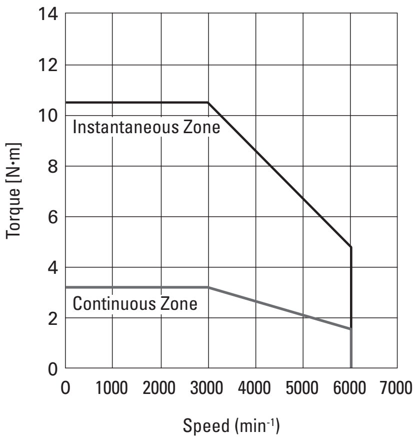


Fig. 11: Speed-Torque Characteristics (R1AA10100F)

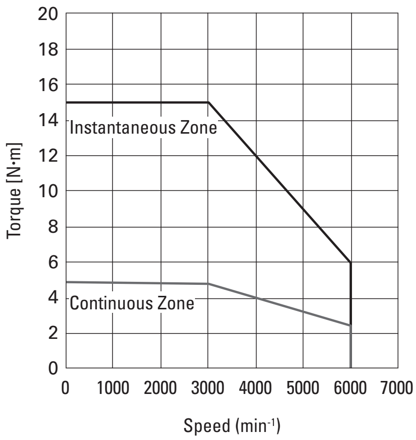


Fig. 12: Speed-Torque Characteristics (R1AA10150F)

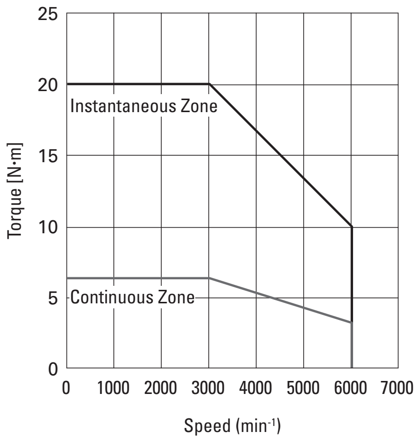


Fig. 13: Speed-Torque Characteristics (R1AA10200F)

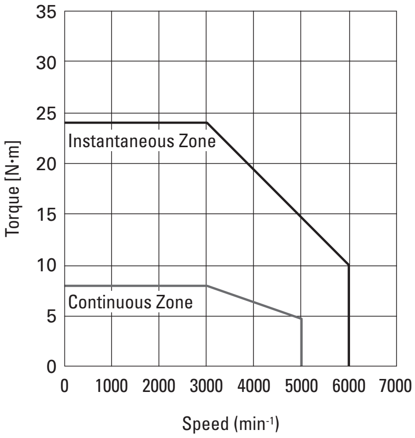


Fig. 14: Speed-Torque Characteristics (R1AA10250F)

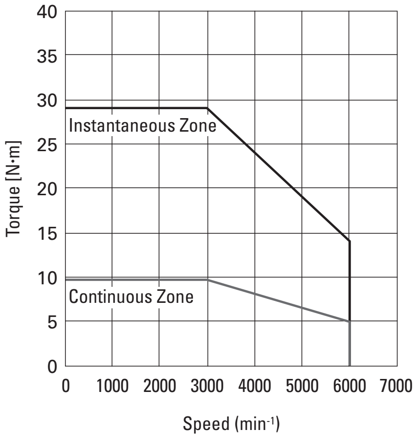


Fig. 15: Speed-Torque Characteristics (R1AA13300F)

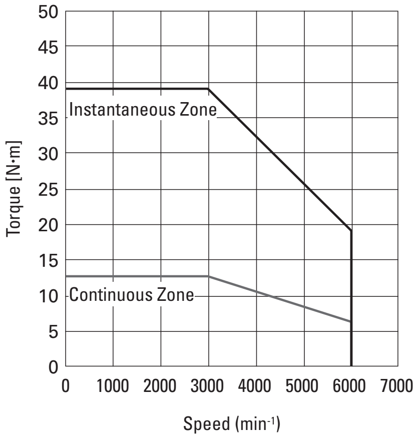


Fig. 16: Speed-Torque Characteristics (R1AA13400F)

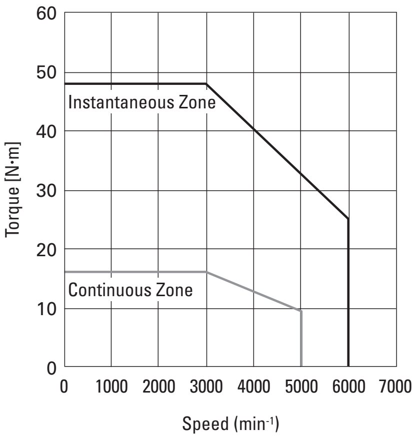


Fig. 17: Speed-Torque Characteristics (R1AA13500F)

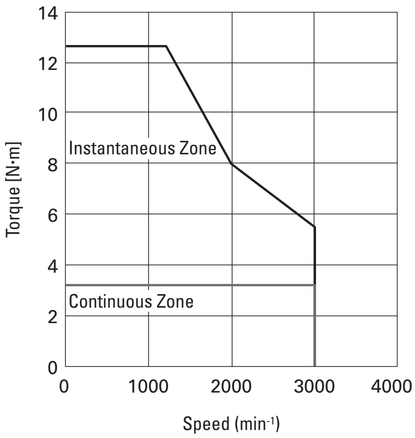


Fig. 18: Speed-Torque Characteristics (R1AA10100H)

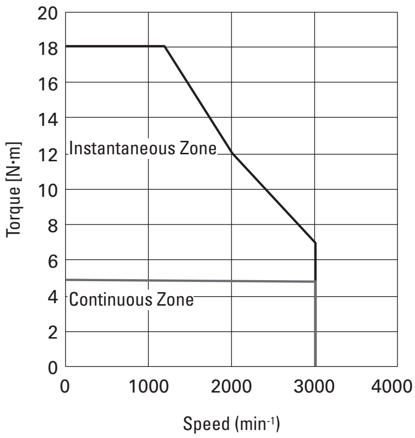


Fig. 19: Speed-Torque Characteristics (R1AA10150H)

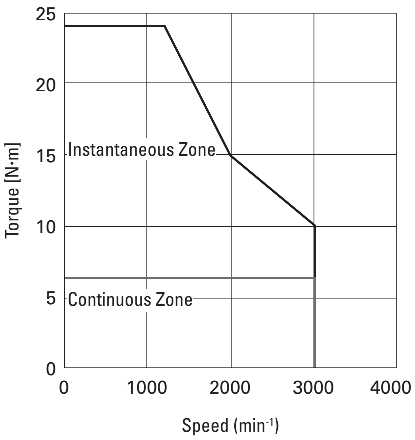


Fig. 20: Speed-Torque Characteristics (R1AA10200H)

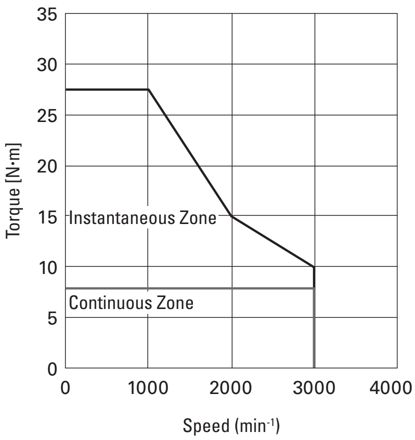


Fig. 21: Speed-Torque Characteristics (R1AA10250H)

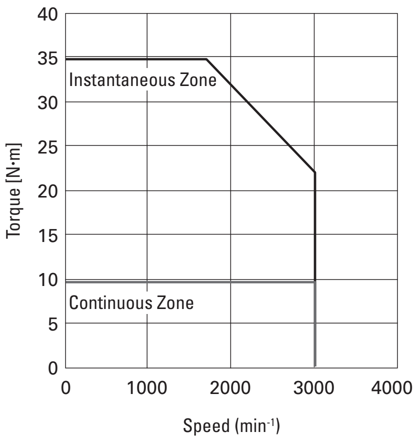


Fig. 22: Speed-Torque Characteristics (R1AA13300H)

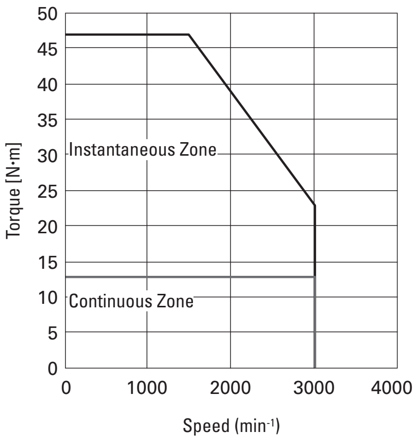


Fig. 23: Speed-Torque Characteristics (R1AA13400H)

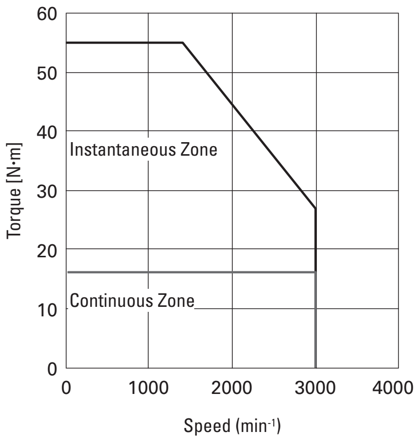


Fig. 24: Speed-Torque Characteristics (R1AA13500H)

4. Conclusion

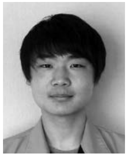
This paper has introduced the "SANMOTION R1", an AC servo motor available with flange sizes of 100 and 130 mm.

By adopting a magnet with high residual magnetic flux density, an optimized armature core shape and a printed circuit board, the new model is more compact and lightweight than the current model, with a wider output range, higher efficiency and lower cogging torque.

Two types of the new model are available; one with a maximum speed of 6000 min^{-1} and the other with 3000 min^{-1}, offering the opportunity to choose the appropriate motor for the specific application and contributing to reduced cycle time and better energy and space-saving devices for customers.

References

(1) Toshihito Miyashita and others: "Q Series AC Servo Motor" SANYODENKI Technical Report, No.14 (2002)



Keisuke Nagata
Joined SANYO DENKI in 2013.
Servo Systems Div., Design Dept. 1
Works on the design and development of servo motors.

Kazuyoshi Murata
Joined SANYO DENKI in 1991.
Servo Systems Div., Design Dept. 1
Works on the design and development of servo motors.

Takashi Sato
Joined SANYO DENKI in 2005.
Servo Systems Div., Design Dept. 1
Works on the design and development of servo motors.

Kenta Matsushima
Joined SANYO DENKI in 2015.
Servo Systems Div., Design Dept. 1
Works on the design and development of servo motors.