Development of an AC Servo Amplifier "SANMOTION R 3E Model"

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1. Introduction

In order to achieve better machine productivity and machining quality, there are many demands being made on servo systems, including improved performance and functions, better energy efficiency and safety function support. Moreover, with servo systems becoming multi-functional and diverse, it is important that they can be used with ease. AC servo amplifier "SANMOTION R ADVANCED MODEL" was developed in 2008 in response to these kind of market demands and is used in a wide-range of customer machinery, contributing to improvements in performance and quality.

This paper introduces features of the new AC servo amplifier "SANMOTION R 3E Model" which was developed as the successor of "SANMOTION R ADVANCED MODEL" on the concepts of "Evolved", "Eco-Efficient" and "Easy to use".

First, the paper introduces the main specifications of the new model. Next, the paper discusses the actions taken to improve servo performance and energy efficiency compared to the conventional "SANMOTION R ADVANCED MODEL" and the user support functions in order to achieve easy use.

2. Main Specifications

Table 1 shows the main specifications of the newly developed "SANMOTION R 3E Model". Fig. 1 shows those models with amplifier capacities of 30 A and 600 A as the representative models.

The lineup consists of a total of 5 models with differing amplifier output capacities. There are the 10 to 50 A of internal power circuit type and 600 A of separate power circuit type.

Combination motors support not only the "SANMOTION R" series mainly but also linear and DD motors.

Encoders, in addition to the Sanyo Denki battery backup type, the battery-less absolute encoder and the wire-saving pulse encoder, the new EnDat 2.2 manufactured by HEIDENHAIN is also supported.

These conform to various overseas regulations and standards such as Europe's low voltage, EMC Directive, North America's UL/cUL and Korea's KC mark.

Moreover, the Safe Torque OFF conforms with "SIL3/IEC61508, PL=e/ISO13849-1" and can be adopted in applications requiring high safety performance such as medical equipment.

The new models maintain external shape, mounting and connector compatibility with conventional models while having significantly advanced servo performance and functions as well as improved energy efficiency and a Safe Torque Off. The new models are linked with the newly developed "SANMOTION motor setup software" and feature an abundance of user support functions that make system start-up, servo adjustment and troubleshooting easy.

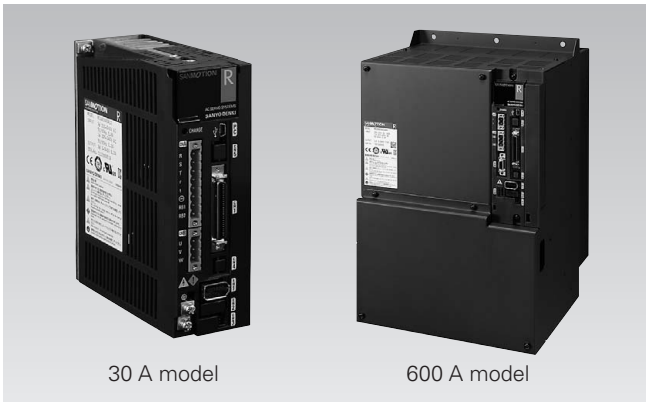

Fig. 1: "SANMOTION R 3E Model" external view

Table 1: Main specifications of “SANMOTION R 3E Model”

Power voltage range	**200 V AC**	200 V to 240 V AC
	100 V AC	100 V to 120 V AC (10 A to 30 A only)
Amplifier output		10 A, 20 A, 30 A, 50 A, 600 A
Application motor		“SANMOTION R” Series “SANMOTION DS” Series
Application encoder		· Absolute encoder (battery backup, battery-less) · Wire-saving pulse encoder · HEIDENHAIN-made EnDat 2.2 encoder
Control mode		Position, velocity, torque control, Model following control
Command input	**Position**	Pulse command (photocoupler insulation)
	Velocity, torque	Analog command
General input/output points		Input x 8 points, output x 8 points
Velocity frequency response		2.2 kHz (high speed sampling mode)
Velocity control range		1:5000 (internal velocity command)
Functions	**Control functions**	· Dual position FB control · Synchronized operation control
	Machine vibration Resonance suppression	· FF vibration suppression control (2 stage) · Vibration suppression control for trajectory control · Adaptive notch filter
	Servo adjustment	· Auto-tuning response – 40 stages · Servo adjustment support function
	Start-up, monitoring, diagnosis	· Virtual motor operation · Encoder/amplifier temperature monitor · Power consumption monitor · Drive recorder
Conforming regulation, etc.		UL/cUL, low voltage directive, EMC directive, function safety, KC mark, etc.

3. Advanced Servo Performance and Function

3.1 High response position and velocity control

Basic position and velocity control systems have 2-degrees of freedom control configuration which is compatible with the AC servo amplifier “SANMOTION R ADVANCED MODEL” . The new models, based on these control systems, are equipped with a function to advance phases in position control systems and speed control systems as well as a function to increase integral gain, thereby increasing feedback response. Moreover, in addition to velocity feedforward compensation, torque feedforward compensation has been added to improve command response. This has made it possible to roughly double the frequency response of velocity control systems (2.2 kHz) as shown in Fig. 2.

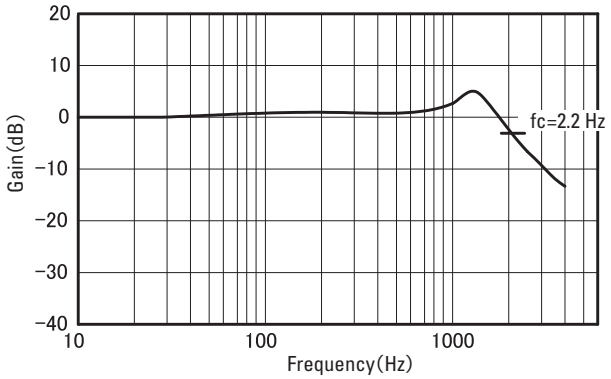

Fig. 2: Frequency response characteristics of velocity control systems

3.2 Model following control

The new models have flexibility in the parameters of their model following control and enable adjustment of the model control system damping coefficient, allowing the relationship between overshoot amount and positioning stabilization time to be set in detail. Moreover, differential compensation has been added to the velocity feedforward of the model control system, and speeding up model following control. Also, fully-closed machine stand vibration suppression control has been equipped to inhibit machine stand vibration even in fully-closed control. These efforts have successfully expanded the applicable range of the high-speed positioning function which follows the ideal model.

3.3 Real-time switchover function for model following control and feedback control

On machine tools, sometimes it is necessary to switch between positioning control and trajectory control, such as in situations where machining is performed after positioning. To achieve higher speeds in applications such as these, Sanyo Denki has added a real-time switchover function to change between model following (vibration suppression) control and feedback control at high speed. This has made it possible to perform trajectory control immediately after high-speed positioning with suppressed machine stand vibration, thus significantly reduce machine tool cycle timing. Fig. 3 shows the control block diagram of the real-time switchover function for model following control and feedback control.

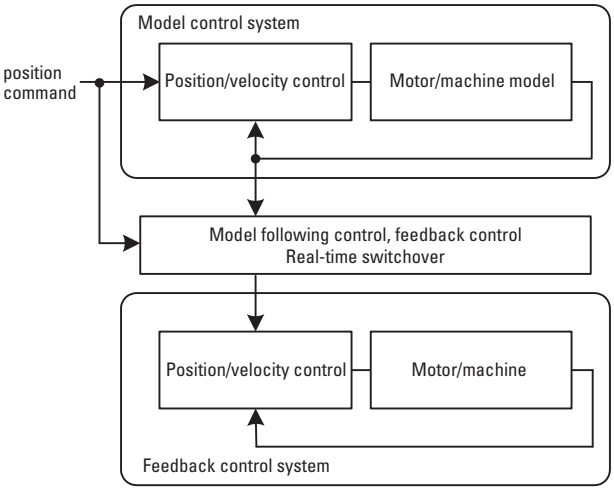

Fig. 3: Real-time switchover function for model following control and feedback control

3.4 Suppression of machine resonance and vibrations

On the new models, not only has torque command notch filter depth adjustment and frequency resolution segmentation been made possible, but notch filter stages have also been added, improving the ability to suppress machine resonance. Moreover, an adaptive notch filter was added which can adaptively adjust notch filter frequency, making it possible to support any fluctuation in machine resonance frequency. This adaptive notch filter estimates machine resonance and applies the estimated frequency to the notch filter actually in the control system to achieve adaptive resonance suppression against the fluctuation in machine resonance frequency. Fig. 4 shows the effect on resonance suppression in a machine system with 790 Hz of resonance when the adaptive notch filter is enabled midway through drive. This result shows that enabling the notch filter effectively suppresses machine resonance.

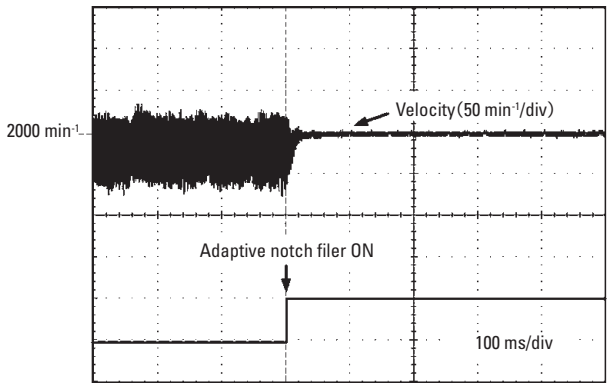

Fig. 4: Suppression of machine resonance with an adaptive notch filter

In addition to model following vibration suppression control, CP (Continuous Path) vibration suppression control has been added as a vibration suppression function, making it possible to suppress machine stand vibration in trajectory control. Moreover, the applicable range of FF vibration suppression control has been expanded and it has become possible to suppress low-frequency vibration of large machines and suppress ball-screw vibration with minimal delay.

Moreover, minor vibration suppression function has been added to suppress vibration created by minor elastic deformation of the machine. This function detects motor speed and in the case of speed reversal, compensates the encoder pulse as well as prevents amplification due to the effect of minor vibration. This suppresses the resonance at motor stoppage and enables high gain to be achieved.

3.5 Real-time auto-tuning

The real-time auto-tuning responsive range of the new models is 1.3 times wider than that of the conventional models, so auto-tuning operation speed increases the further.

4. Actions for Better Energy Efficiency

4.1 Reduced power consumption

The new models have reduced loss by as much as 7% at the time of rated operation by adopting a next-generation power device.

Moreover, most power loss results in heat generation, raising the internal temperature of the servo amplifier which can cause part malfunction and affect life, therefore requiring forced air cooling using a cooling fan. Conventionally, cooling fan RPM was constant regardless

of servo amplifier internal temperature therefore if motor output was small, energy would be consumed unnecessarily.

Due to this, the new models control cooling fan RPM appropriately to suit the internal temperature of the servo amplifier and inhibit unnecessary energy consumption. In particular, standby power can be reduced to a maximum of 10% when the servo motor is stopped and the machine is not operating.

4.2 Power consumption monitor function

The new models have a function to monitor the power consumption of the servo motor and servo amplifier. This function calculates power consumption by adding servo motor and servo amplifier loss based on the servo motor RPM and current.

This makes it possible to easily monitor the amount of power used by the equipment.

5. User Support Functions Pursuing Easy Use

5.1 Virtual motor operation function

Virtual motor operation is a function which simulates movements of the servo motor and servo amplifier based on commands from upper server equipment without actually needing to operate the motor. As well as naturally confirming interface signals (input commands, general inputs/outputs, etc.) between the upper server equipment and servo amplifier, it is also possible to use the machine model configured within the servo amplifier internally and quasi-confirm motor operation. By utilizing this function, verification of wiring and control systems is possible without requiring machine operation thereby enabling reduction of equipment development time.

5.2 Servo adjustment support function

A servo adjustment support function has been equipped on “SANMOTION motor setup software” in order to make servo adjustment even easier.

This function automatically determines the appropriate adjustment mode by simply setting machine and load conditions using a dialog-style human interface as shown in Fig. 5. This means that servo adjustment is possible with only a maximum of 2 parameters. If higher performance is demanded, finer adjustment can be performed easily with parameters prepared for specific purposes such as “stabilization time reduction” and “vibration suppression” .

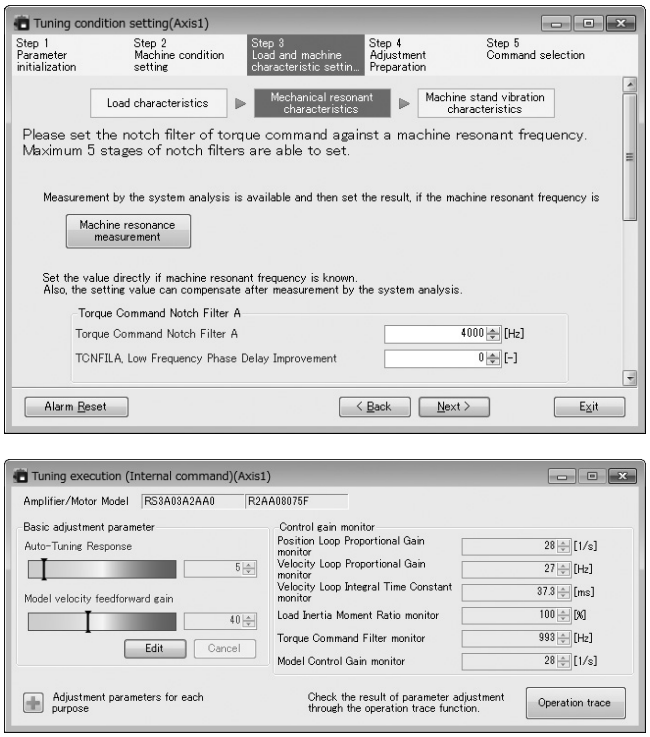

Fig. 5: Servo adjustment support function screen

5.3 Drive recorder function

To support troubleshooting, the new models have been equipped with a drive recorder function which records servo motor and amplifier operational data such as motor RPM at fault occurrence, torque and main circuit bus voltage for a set period of time.

This function makes it possible to record up to 10 types of operational data at once and store record data from the previous 16 occasions in a non-volatile memory. As such, it is possible to display recorded data in a wave graph using setup software and analyze operation and status leading up to fault occurrence.

This makes it possible to swiftly identify or narrow down fault causes and take the appropriate remedial measures, making troubleshooting easy and contributing to the improvement of system reliability.

6. Conclusion

This paper introduced the features of the new AC servo amplifier "SANMOTION R 3E Model" which was developed based on the concepts of "Evolved", "Eco-efficient", "Easy to use".

In comparison with the conventional "SANMOTION R ADVANCED MODEL" the new servo amplifiers feature the following.

(1) Reduced positioning settle time of machinery through advancements in servo basic performance (roughly doubled speed frequency response) and model following control. Reduced tact time with the real-time changeover function for model following control and feedback control.

(2) Enhanced functions to suppress vibration such as CP vibration suppression control supporting machining applications of machine tools, etc., 2-stage FF vibration suppression control and minor vibration suppression.

(3) Improved automation of servo adjustment through expanding real-time auto-tuning response (by 1.3 times) and equipping an adaptive notch filter.

(4) The safety performance level of the Safe Torque Off has been raised to "SIL3/IEC61508, PL=e/ISO13849-1".

(5) Loss reduction of up to 7% and 10% at rated operation and standby respectively. Easy visualization of machinery power consumption through a power consumption monitor function.

(6) Improved user-friendliness through enhancement of user support functions such as a virtual motor operation function, servo adjustment support function and drive recorder function.

It is believed that these servo amplifiers will greatly contribute to improvements in machinery performance, safety, energy efficiency and reliability.

Moving forward, Sanyo Denki plans to enhance the network product lineup with a focus on the 2.0-15 kW medium motor output capacity type and industrial real-time EtherNet.

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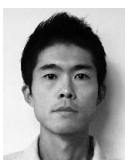

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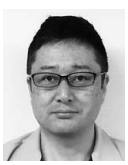

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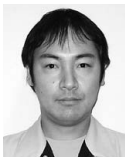

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