SANYO DENKI

Technical Report

Feature | Technologies for Helping Make New Dreams Come True

1971
Ueda Works

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November
2020

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Cover image:

Ueda Works

1971

In the 1950s, demand for stepping motors was very limited in Japan. At that time, our company's main products were DC servo motors and AC servo motors. However, we were sure that stepping motor demand would definitely grow in the near future, and had been advancing stepping motor development.

Under these circumstances, we received a stepping motor sample order from IBM Corporation of the United States, which was leading the world in the field of computers at the time. We found it a great opportunity to prove our high technical expertise. We devoted all our efforts and successfully developed a stepping motor that satisfied customer expectations, leading to a mass production order.

At Ueda Works, young engineers established a mass production system, and all our employees worked together to complete the project. This was the moment when our next major product StepSyn was born, following San Ace cooling fans. This achievement boosted our company's business even further.

In stepping motor windings, thin wires are used. Since this work required fine dexterity, a winding workplace consisting entirely of women was added to Ueda Works. The stepping motor that was born in this way is still playing an active role as one of our main products.

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November 2020

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Technologies for Helping Make New Dreams Come True

Tatsuya Hirata Operating Officer

This fiscal year is the final year of our 8th Mid-term Management Plan. We have been aiming to become a global company that is recognized as one of the top brands in the world.

Although we have accomplished many of our initiatives, there are still some goals that we will carry over to our 9th Mid-term Management Plan. In this respect, we still have many things we want to accomplish.

Looking back at our history, SANYO DENKI has overcome many major challenges, such as the Great Depression of 1929, the Great Recession of 1945 following World War II, the oil crisis of 1974, and the financial crisis of 2008. The current fiscal year has been dominated by an unprecedented change. Needless to say, we are referring to COVID-19. COVID-19 has caused a lot of damage worldwide and has created unexpected environmental changes. Turning this serious state of affairs into an opportunity is truly a daunting task.

It is against this backdrop that SANYO DENKI aims "to establish a corporate culture capable of transforming environmental changes into business opportunities." To this end, each of our divisions is developing businesses in new fields such as those that pertain to the 5th generation mobile communications system (5G), business continuity planning (BCP), artificial intelligence (AI), and electric vehicles (EV). In addition, the medical field is changing significantly, and measures are being taken to combat COVID-19 infections. As part of this trend, many of our products are being used in PCR testing equipment to detect people infected with COVID-19 and in testing equipment used in the development of vaccines.

In today's world of accelerated social change, we are developing products with a view toward the needs of future market environments.

As mentioned previously, each of our divisions is developing new products for the global market. For example, our Cooling Systems Division has developed the *San Ace C70* 9TD type Centrifugal Fan, *San Ace 40* 9HVA type High Static Pressure Fan, and *San Ace 60W, 80W, 92W* 9WPA type high-performance Splash Proof Fans. Our Power Systems Division has developed the *SANUPS W75A* rectifier unit for wind power and hydro power generation systems and *SANUPS N11B-Li* equipped with lithium-ion batteries for outdoor use that can be used with disaster-management ICT equipment. Our Servo Systems Division has developed a *SANMOTION R 3E Model* AC servo amplifier with built-in positioning functionality and the *SANMOTION C* 3A wireless adapter for motion controllers.

The major theme of our 9th Mid-term Management Plan is to "break out of our shells." There are various types of shells, such as small ones, big ones, and very difficult ones. Specifically, we must use the measures we have cultivated over the years in combination with future initiatives to accomplish our goal of "leveraging our expertise to face the challenges of a changing global market."

This means that we are going to continue to advance the "new product development," "borderless," "real-time," and "factory automation" themes of our 8th Mid-term Management Plan so that we can establish a corporate pillar of "world-leading products." Moving forward, we must strengthen our marketing strategies, sales strategies, and technical innovation, while cherishing our relationships with customers to gain their trust. This will enable us to build new pillars (i.e., new customers) and fortify existing pillars (i.e., existing customers). To help achieve this, we will work hard to understand the issues and challenges of our customers so that we can offer them products that meet their needs. We are committed to contribute to society by identifying customer needs, strengthening our product development accordingly, and ensuring that our manufacturing and sales divisions work in unison. By doing this, we will be able to continue providing the world with "technologies for helping make new dreams come true."

Technologies for Helping Make New Dreams Come True

Honami Osawa

1. Introduction

The market has been demanding a variety of cooling fan features, including those that provide high airflow, high static pressure, low noise, and low power consumption. Market changes have further intensified these demands, and we have always developed new products aiming to meet them. To continue to meet the market demand, which is expected to continue to grow in the future, we will need to incorporate new technologies into our products.

Furthermore, there has also been demand for preventive maintenance of equipment by remotely controlling and monitoring the status of cooling fans, and for a system that enables efficient cooling and ventilation of equipment using a combination of various sensors. To meet these needs, we have developed San Ace Controller as the industry's first IoT-ready fan controller that can connect to a network environment and remotely operate and monitor fans using an external device. We developed this San Ace Controller considering ventilation and pressure/humidity control applications for new markets such as residential and housing equipment, industrial equipment, and agricultural equipment. Nevertheless, we have received some requests to add new features to the controller.

In this article, we will describe new techniques for achieving higher cooling fan performance and new fan controller technologies required in the future.

2. Enhance Cooling Fan Performance

2.1 Foreword

Before describing the performance improvements of each fan component, we would like to introduce the airflow vs. static pressure characteristics and flow vs. pressure characteristics of our cooling fans that can be determined from their structure and properties.

Figure 1 shows an example of the airflow vs. static pressure characteristics of our cooling fans. This graph shows the airflow vs. static pressure characteristics of the highest-airflow models of our old and new fans of the same size. The order of product release was Fan A, B, C, D, then E. It can be seen that newer products have better airflow vs. static pressure characteristics.

Figure 2 shows these models in a non-dimensional manner. The impeller and frame characteristics (such as being a high airflow type or high static pressure type) can be determined by this process.

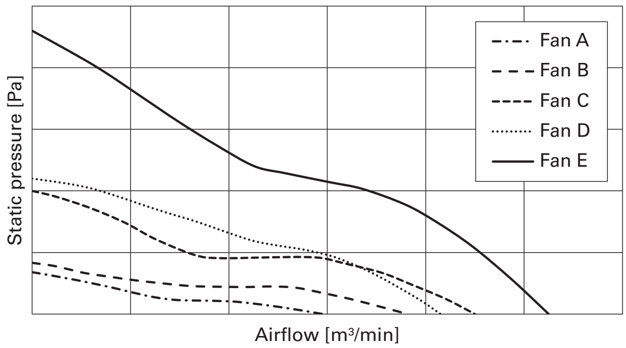

Fig. 1 Airflow vs. static pressure characteristics

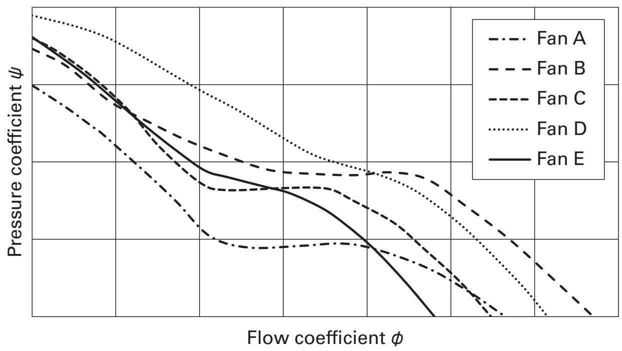

Fig. 2 Flow vs. pressure characteristic

Flow vs. pressure characteristics show the aerodynamic characteristics of fan impellers and frames. Put simply, the aerodynamic characteristics improve as the value increases (i.e., as the curve moves toward the upper right corner of the graph).

By comparing these two graphs, it can be seen that the latest model has the highest airflow vs. static pressure characteristics by far, but this is not the case with respect to the aerodynamic characteristics of its impeller and frame. This means that it is the motor and circuit combination of the latest model that achieves the highest airflow vs. static pressure characteristics.

Therefore, to improve cooling fan performance, it is important to appropriately improve the following:

(1) Aerodynamic performance
(2) Motor performance
(3) Drive circuit performance

It should also be noted that the fans in Figures 1 and 2 are all the same size. It can be said, then, that the graph in Figure 2 is a comparison of aerodynamic characteristics at the same rotational speed. Accordingly, technologies that achieve high airflow vs. high static pressure characteristics are highly dependent on improvements in the rotational speed of the motor.

We will now describe the techniques for enhancing performance by improving fan components.

2.2 Improve aerodynamic performance

The design of impellers and frames conventionally required repeated trial and error. This approach was very time-consuming and tedious.

In recent years, improvements in computer speed and simulation technologies have made it possible to automate the design process. "Simulation-based design optimization" is an approach in which a computer designs the optimal shape through trial and error based on required performance conditions. This type of approach is becoming more and more realistic, and we have also been using it in our company.

Figure 3 provides an example of simulation-based design optimization.

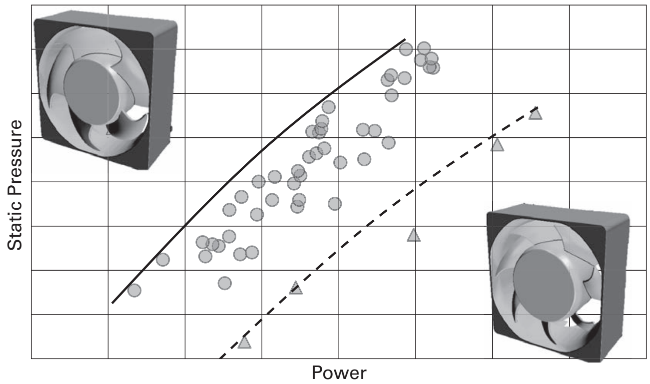

Fig. 3 Example of simulation-based design optimization

In this example, electric power is on the horizontal axis and static pressure on the vertical axis. Impeller and frame efficiency improves as the curve moves toward the upper left corner of the graph. The triangular plots (△) were obtained through conventional trial and error approach, while the circular plots (○) were obtained using recent simulation technology. This shows that the new approach enables the design of lower-power cooling fans with the same static pressure values.

With simulation-based design optimization, we can use parameters that inherit the expertise incorporated into our previous products, and then add new parameters to realize completely new types of impeller and frame designs. With this approach, we aim to achieve the industry's highest cooling fan performance.

2.3 Enhance motor performance

As mentioned in Section 2.1, newer models do not necessarily have better aerodynamic performance. Impeller and frame combinations that achieve high aerodynamic performance require a motor with high torque. To achieve this, the diameter of the motor will usually need to be increased. A larger motor diameter can result in a smaller ventilation area, which in turn can create the differences in aerodynamic performance shown in Figure 2.

However, if the diameter of the motor can be reduced while maintaining its torque and reliability, this would enable the combination with an impeller and a frame that realizes high aerodynamic characteristics.

In the following sections, we will describe the miniaturization and efficiency enhancement of motors.

Higher motor efficiency means less loss. Motors are susceptible to the following types of loss:

(1) Copper loss
(2) Iron loss
(3) Mechanical loss

A large proportion of the loss is occupied by (1) and (2).

In the next section, we will introduce some techniques for reducing each type of loss.

2.3.1 Reduction of copper loss

The following techniques are used to reduce copper loss:

(1) Use of magnets with strong magnetic force

The use of magnets with strong magnetic force is necessary to generate a sufficient amount of torque using low currents. In this regard, the use of rare-earth magnets, such as neodymium, alnico, and samarium cobalt, instead of current mainstream ferrite magnets, can facilitate the reduction of copper loss.

(2) Improvement in the winding fill factor

Improvement in the winding fill factor is necessary to reduce the Joule loss caused by the current and winding resistance of the motor. This can be accomplished by increasing the conductor's cross-sectional area and improving the winding technique.

Specifically, flat wire can be used to increase the conductor's cross-sectional area while techniques such as aligned winding can be used to realize a higher fill factor; both help reduce copper loss.

2.3.2 Reduction of iron loss

Iron loss can be reduced by improving the magnetic material and the shape and structure of the stator (iron core).

We will now mainly describe some technical measures for stators.

(1) Use of electromagnetic steel sheets with low iron loss and high magnetic flux density

In recent years, silicon steel sheets have been used for stators, but the following materials have been attracting attention:

- Fe-based amorphous
- Nanocrystalline soft magnetic materials
- Fe magnetic powder cores

These materials are all characterized by their low iron loss and low eddy current loss, making them worthy for future consideration as stator materials.

(2) Thickness optimization for electromagnetic steel sheets

Currently, electromagnetic steel sheets with a thickness of 0.35 mm are widely used. However, due to the increased drive frequency of today's high-speed motors, eddy current loss has also been increasing. A solution to this problem is to laminate thinner steel sheets in a manner that reduces eddy current loss.

(3) Magnetic circuit design for motors

To develop a motor that meets the required specifications by incorporating the above-mentioned copper and iron loss reduction measures, it is necessary to optimally use the space inside the motor.

Electromagnetic field analysis is currently indispensable for designing motors. By using analysis techniques to optimize the structure and magnetic circuit, we have been designing highly efficient and reliable motors.

2.4 Improve circuit performance

Improvements in cooling fan performance have been accompanied by increased power consumption, requiring the use of devices that drive high currents. In general, these types of devices are large in size and generate a lot of heat. Also, designs that prioritize the optimization of aerodynamics limit the space (diameter) available for the PCB and decrease the area available for mounting electronic components.

For these reasons, the following two measures are needed when designing circuits:

(1) Compact component mounting
(2) Heat dissipation measures for electronic components and the PCB

In the following sections, we will describe some solutions to these challenges.

2.4.1 Compact component mounting

As mentioned previously, designs that optimize aerodynamics limit the space available for the PCB and decrease the area available for mounting electronic components. The following two approaches can be taken to solve these challenges:

(1) Reduce the number of components
(2) Use BGA (ball grid array) and LGA (land grid array) package components

Modules such as intelligent power modules (IPMs) can be used to reduce the number of components. Since IPMs integrate power devices and the drive circuit into a single module, they can reduce the number of components, contributing to space-saving mounting and smaller PCB designs.

Figure 4 shows an example of a conventional circuit and Figure 5 shows a circuit using an IPM.

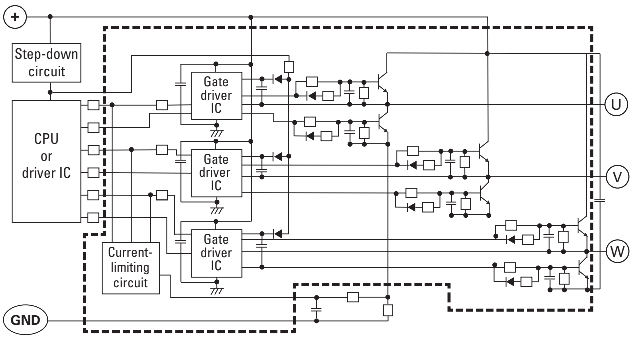

Fig. 4 Conventional circuit example

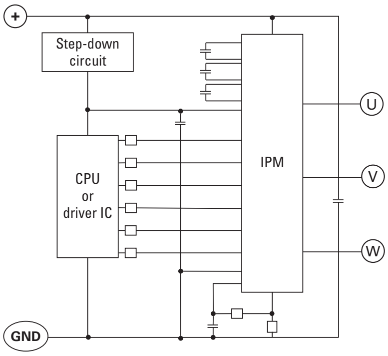

Fig 5 Example of circuit with IPM

In this example, the components inside the dotted line in Figure 4 are integrated into an IPM. This contributes to reducing the number of components and the mounting area.

The use of BGA and LGA packages ensures that the leads of electronic components do not protrude outside of their package. This helps reduce the mounting area.

These techniques have already been applied to some of our cooling fans and are expected to be used more in the future.

2.4.2 Heat dissipation measures for electronic components and the PCB

The motor and circuitry of cooling fans are generally not sealed. As a result, we have taken measures to promote heat dissipation due to convection and radiation caused by the flow of air from the rotating impeller.

As power consumption and mounting density increase in circuits, we expect that cooling through conventional approaches alone will become difficult. The circuit designs of cooling fans in the future will, in addition to conventional approaches, need to make use of conduction-based heat dissipation.

In recent years, conduction-based heat dissipation has been used in compact sealed devices, such as smartphones, digital cameras, and engine control units (ECUs), and we believe that this method should be considered when designing cooling fan circuits.

The following five methods are used to improve heat dissipation in sealed devices:

(1) Reduction of thermal resistance between components and the PCB
(2) Improvement of the PCB's thermal conductivity
(3) Reduction of contact thermal resistance
(4) Use of a heat spreader
(5) Improvement of the housing's thermal conductivity performance

Figure 6 provides a reference example.

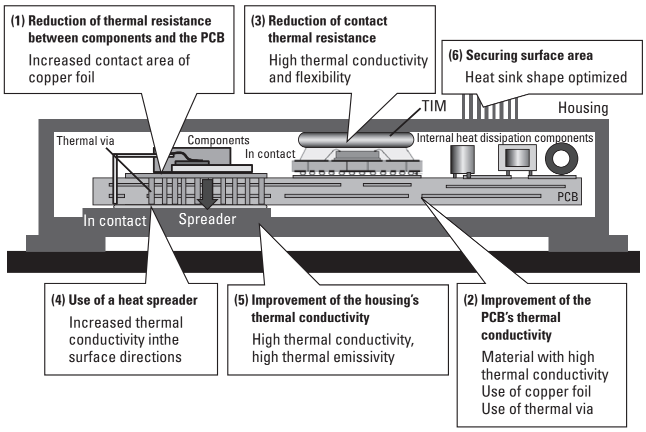

Fig. 6 Improving heat dissipation in sealed devices

We believe that these methods can be used with cooling fans to dissipate the heat generated by electronic components, and will help further improve their reliability.

3. New Technologies for Fan Controllers

3.1 Foreword

There has been market demand for preventive maintenance of equipment by remotely controlling and monitoring the status of cooling fans, and also for a system that enables efficient cooling and ventilation of equipment using a combination of various sensors. To meet these needs, we have developed San Ace Controller.

After releasing the controller, we started receiving the following requests from the market:

(1) Enhancement of sensor-based monitoring and control
(2) Open network support

We will now discuss these feature requests.

3.2 Enhancement of sensor-based monitoring and control

The current San Ace Controller supports the following dedicated sensors:

- Temperature sensor
- Humidity sensor
- Barometer
- Accelerometer

In addition to these, the market is requesting support for the following sensors:

- Dust sensor
- Odor sensor
- Presence sensor

To meet customer requirements, we plan to develop these dedicated sensors to enhance the functionality of San Ace Controller.

3.3 Open network support

The wired communication that the current San Ace Controller supports is Ethernet. However, there is increasing market demand for communication with slaves (sensors and external devices) that use open networks, such as EtherCAT and OPC UA (open platform communications unified architecture).

Figure 7 shows a configuration example for the current model, and Figure 8 shows a configuration example for a model with open network support.

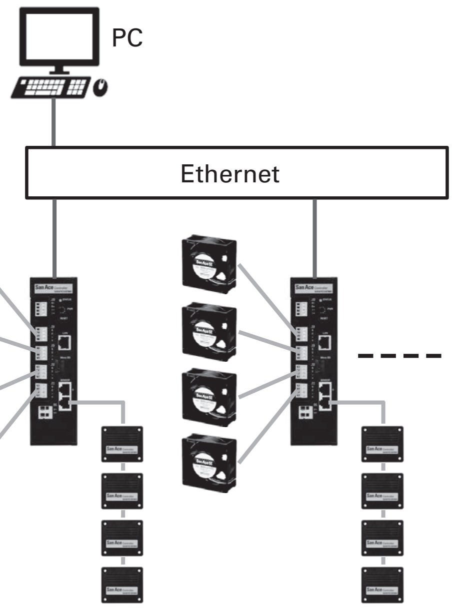

Fig. 7 Configuration example for the current model

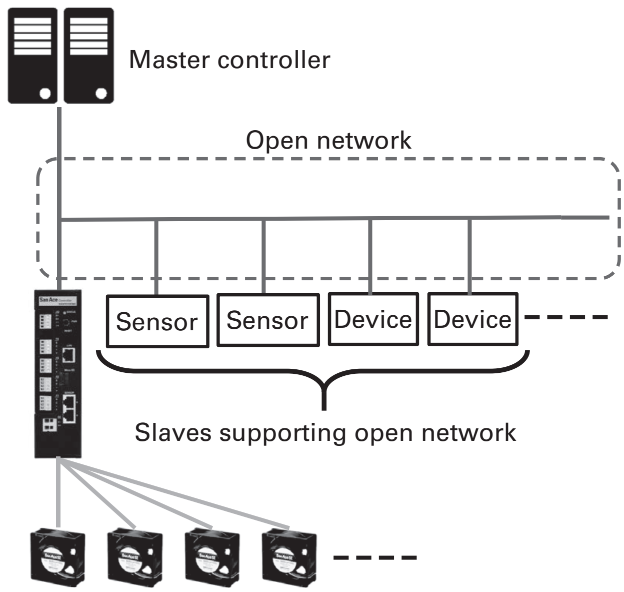

Fig. 8 Configuration example for an open network supported model

We currently do not offer a fan controller that supports open networks, so we need to develop one. Such a controller can control commercially available slaves. We are willing to develop one in the future because such a product can expand the scope of application for customers.

4. Conclusion

In this article, we described techniques for achieving higher airflow and static pressure for cooling fans, and also the new fan controller features and specifications.

The market is demanding not only higher airflow and static pressure, but also decreased noise, power consumption, and cost. We are working to meet these demands by employing new technologies and approaches.

Our current fan controller is the first in the industry to provide IoT features, and more requests will be expected in the future. We plan to meet these requests through feature enhancement and new fan controller development.

The Design Department in our Cooling Systems Division will continue to constantly develop new products. We are committed to always developing the industry's best products. Furthermore, we plan to continue developing and providing products that help our customers realize their dreams by identifying market changes and demands and by offering the best products and timely customizations.

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Splash Proof Fans *San Ace 60W, San Ace 80W, San Ace 92W*

Akira Nakayama Jane Oliva Rogen Molino Grace Rico Jovelyn Villar

Tetsuya Yamazaki Shigekazu Mitomo Takashi Kaise Yukihiro Nagatsuka Yoshihisa Yamazaki

1. Introduction

Due to their enhanced performance and smaller sizes, today's outdoor base stations, photovoltaic inverters, and digital signage are generating more heat. As a result, the splash proof fans used in these applications must provide greater cooling performance than ever before.

To meet this demand, we developed and released three high-performance Splash Proof Fans that provide greater cooling performance (high airflow and high static pressure) than our current models. These are the *San Ace 60W*, *San Ace 80W*, and *San Ace 92W* 9WPA types (hereinafter, "new models"). This article introduces the features and performance of the new models.

2. Product Features

Figures 1 through 3 show the appearance of the new models.

The new models maintain compatibility with the current models in sizes and mounting hole positions, while achieving higher airflow and static pressure.

The new models' structural features are as follows.

(1) Figure 4 shows the coating on the live parts. Live parts (windings and circuits) are coated with a protective material with excellent waterproof performance.

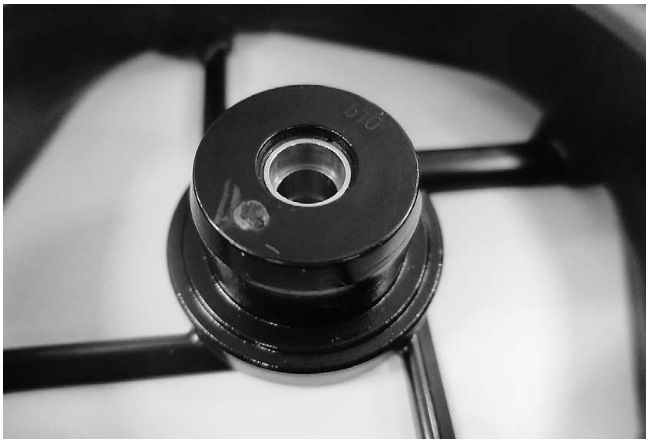

Fig. 4 Coating of electrical component

Fig. 1 60 × 60 × 25 mm
San Ace 60W 9WPA type

Fig. 2 80 × 80 × 25 mm
San Ace 80W 9WPA type

Fig. 3 92 × 92 × 25 mm
San Ace 92W 9WPA type

(2) Figure 5 provides a comparison of the frame shapes of the new models and the 9WL type fans. The frame is made of plastic (rasin), but maintains compatibility in shape with our current 9WL type fans with aluminum frames.

	Current models Aluminum (9WL type)	New models Plastic (9WPA type)
60 × 60 mm		
80 × 80 mm		
92 × 92 mm		

Fig. 5 Frame shape comparison with the current 9WL type fans

3. Product Outline

3.1 Dimensions

Figures 6 through 8 show the dimensions of the new models.

The fans' external dimensions and mounting hole dimensions are unchanged and compatible with our current models.

3.2 Specifications

Tables 1 shows the general specifications for the new models.

Rated voltages of 12 V and 24 V are available to support operation in a wide range of applications.

The models are equipped with a PWM control function to regulate fan speed according to equipment internal temperatures, to facilitate the reduction of equipment power consumption.

The new models have an expected life of 40,000 hours at 60˚C (survival rate of 90%, run continuously at rated voltage and normal humidity in free air).

The airflow vs. static pressure characteristics in figures 9 through 11 show the respective rated voltages and upper and lower limits of their operating voltage ranges.

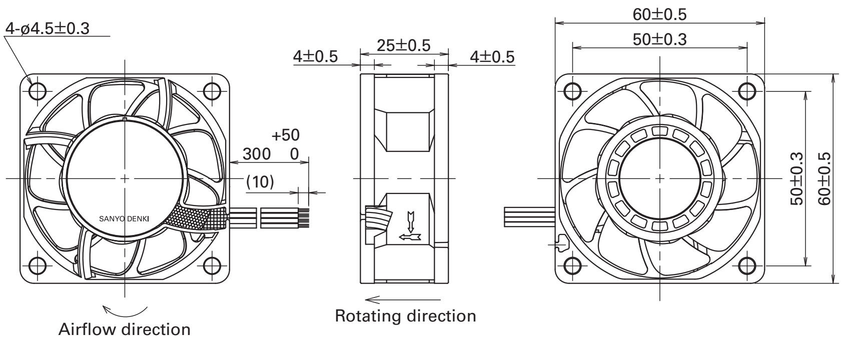

Fig. 6 Dimensions of *San Ace 60W* (Unit: mm)

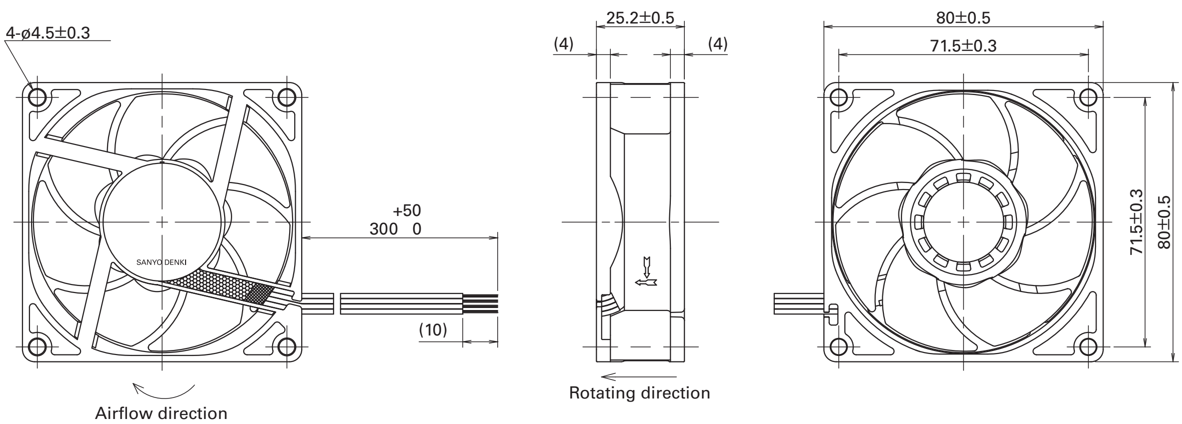

Fig. 7 Dimensions of *San Ace 80W* (Unit: mm)

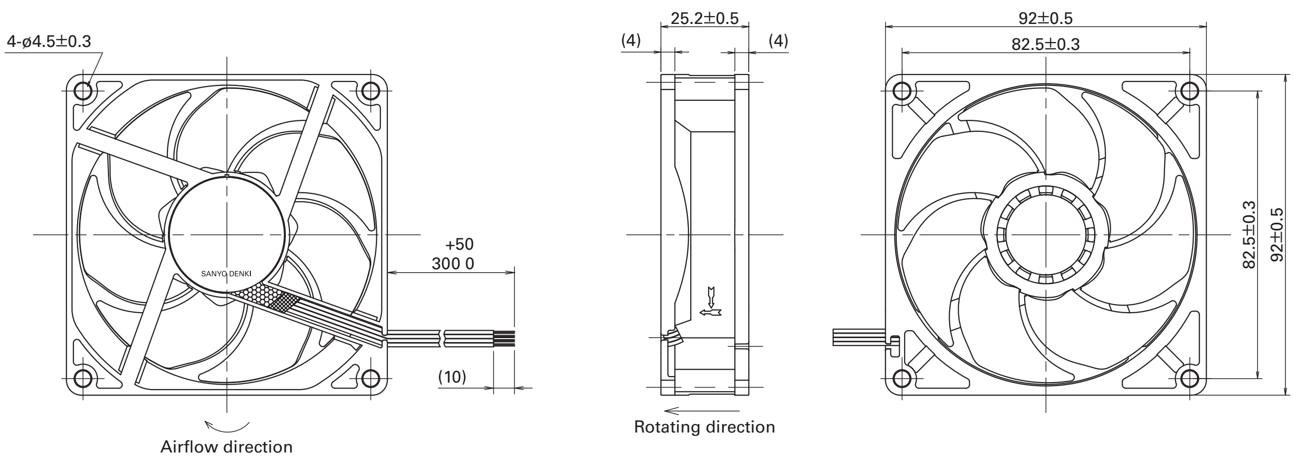

Fig. 8 Dimensions of *San Ace 92W* (Unit: mm)

Table 1 General specifications for the new models

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min⁻¹]	Max. airflow [m³/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH₂O]	Sound pressure level [dB(A)]	Operating temperature range [°C]	Expected service life [h]
9WPA0612P4G001	12	10.8 to 13.2	100	0.93	11.16	12000	1.52	53.7	357	1.44	56	-20 to +70	40000 at 60°C (70000 at 40°C)
			20	0.09	1.08	3500	0.41	14.5	31	0.13	22		
9WPA0624P4G001	24	21.6 to 26.4	100	0.46	11.04	12000	1.52	53.7	357	1.44	56		
			20	0.05	1.2	3500	0.41	14.5	31	0.13	22		
9WPA0812P4G001	12	10.8 to 13.2	100	0.71	8.52	8250	2.32	81.9	210	0.84	54		
			20	0.07	0.84	2400	0.67	23.6	18.2	0.073	21		
9WPA0824P4G001	24	21.6 to 26.4	100	0.36	8.64	8250	2.32	81.9	210	0.84	54		
			20	0.05	1.2	2400	0.67	23.6	18.2	0.073	21		
9WPA0912P4G001	12	10.8 to 13.2	100	0.5	6	5700	2.45	86.5	126	0.51	47		
			20	0.04	0.5	1200	0.52	18.4	6	0.02	11		
9WPA0924P4G001	24	21.6 to 26.4	100	0.25	6	5700	2.45	86.5	126	0.51	47		
			20	0.03	0.7	1200	0.52	18.4	6	0.02	11		

* Input PWM frequency: 25 kHz; speed is 0 min⁻¹ at 0% PWM duty cycle.
Note: The expected life at an ambient temperature of 40°C is for reference purpose only.

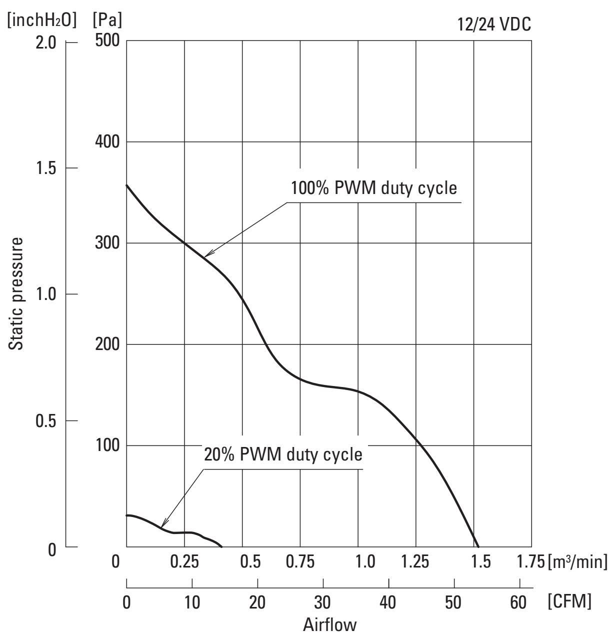

Fig. 9 Airflow vs. static pressure characteristics of *San Ace 60W*

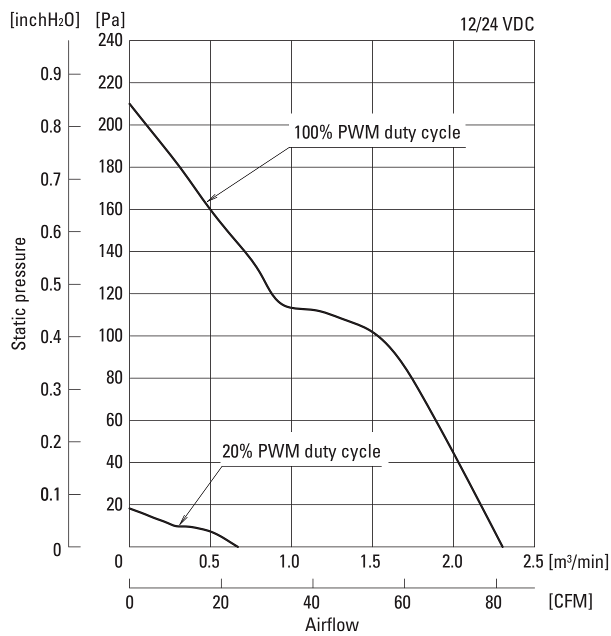

Fig. 10 Airflow vs. static pressure characteristics of *San Ace 80W*

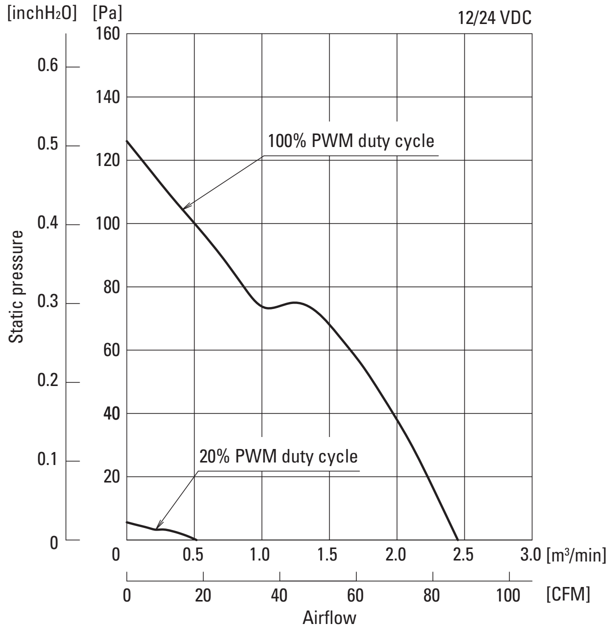

Fig. 11 Airflow vs. static pressure characteristics of *San Ace 92W*

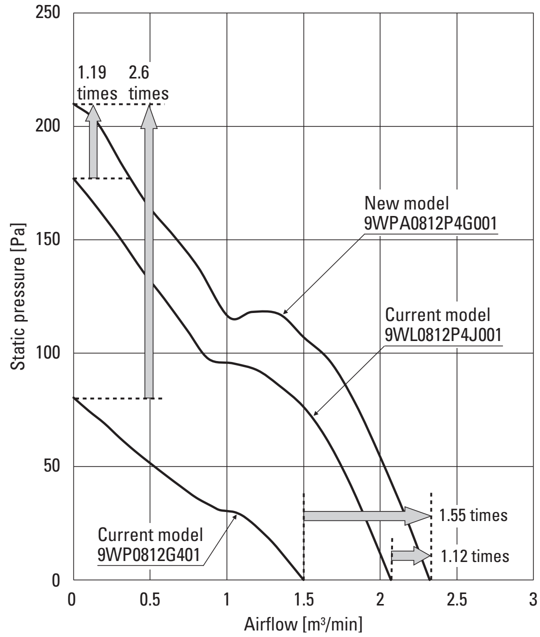

Fig. 13 Comparison of the airflow vs. static pressure characteristics for the new and current *San Ace 80W* models

4. Comparison with Current Models

4.1 Comparison of airflow vs. static pressure characteristics

Figures 12 through 14 compare the airflow vs. static pressure characteristics of the new and current models. Compared to the current models, the new models have greater maximum airflow and maximum static pressure.

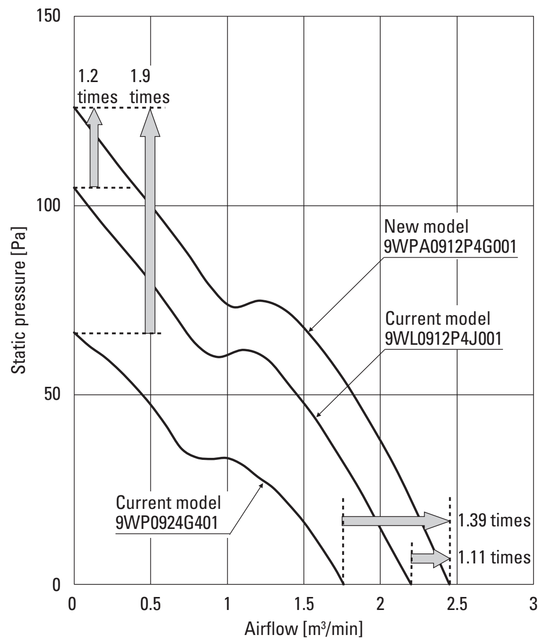

Fig. 14 Comparison of the airflow vs. static pressure characteristics for the new and current *San Ace 92W* models

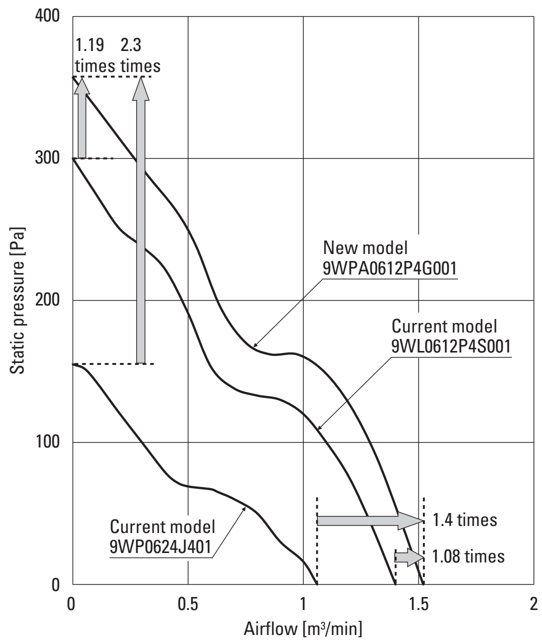

Fig. 12 Comparison of the airflow vs. static pressure characteristics for the new and current *San Ace 60W* models

5. Key Points of Development

The new models offer higher airflow and static pressure than the current models while featuring good waterproof performance.

We designed the new models to have higher speeds to achieve higher performance than the current models. Furthermore, they have a high-efficiency motor and drive method to achieve lower power consumption.

The key points of development are explained below.

5.1 Structural design

To achieve an IP68-rated water protection,* we ensured that all live parts are coated with plastic that is highly waterproof and resistant to temperature changes. Reliability and productivity have been improved by optimizing the coating shape.

The frame is made of plastic to help achieve the desired performance of the product. It is designed to support the higher speeds of the fans.

* Protection rating The degree of protection (IP code) is defined by IEC (International Electrotechnical Commission) 60529 as "Degrees of Protection Provided by Enclosures (IP Code)" (IEC: 60529:2001)

5.2 Motor and circuit

The new models have a new circuit design to realize higher performance. By adopting a high-efficiency motor and drive system, the new models are able to suppress the amount of motor heat generation. This made it possible to attain higher speeds.

In addition, the new models achieve lower power consumption than that of the current 9WP type fans at the same airflow. Figure 15 compares the power consumption and the airflow vs. static pressure characteristics between the new *San Ace 80W* model and a current model at the same maximum airflow.

The new model has higher static pressure and lower power consumption than the current model in all operating regions.

Moreover, we were able to reduce the number of components by using new components.

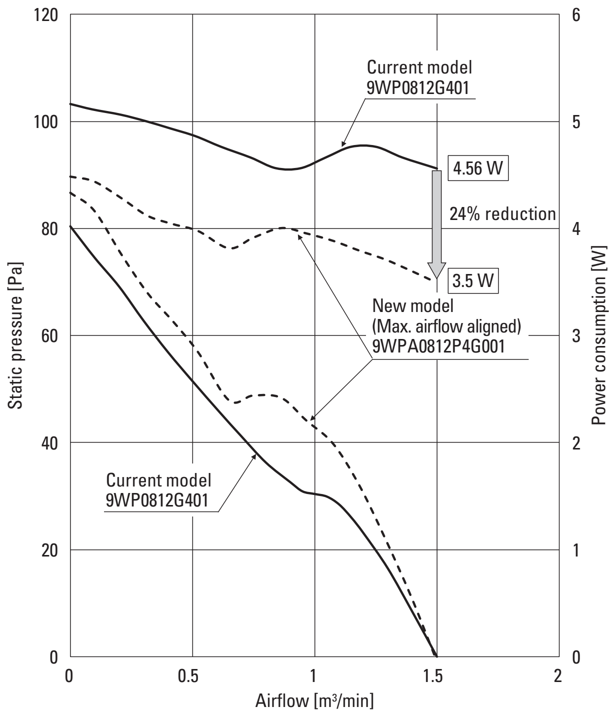

Fig. 15 Power consumption comparison with the current model

6. Conclusion

This article introduced the features and performance of our *San Ace 60W*, *San Ace 80W*, and *San Ace 92W* 9WPA type high-performance Splash Proof Fans.

Compared with current models, the three new models provide higher airflow and static pressure. We expect that the new models will make a significant contribution to sophisticated applications that require higher cooling performance such as base stations, photovoltaic inverters, and digital signage.

We will continue developing products in response to various market needs. In particular, we plan to continue offering products in a timely manner which contribute to the creation of new value for our customers to help make their dreams come true.

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40×40×28 mm High Static Pressure Fan *San Ace 40* 9HVA Type

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1. Introduction

In the 1U server and ICT equipment market, there is increasing demand for high-performance compact cooling fans capable of supporting equipment with enhanced functionality and denser component mounting conditions. Furthermore, in recent years, many customers have emphasized the need to reduce power consumption. To do this, it is important to achieve high static pressure and energy savings.

To meet these requirements, we have developed and released the *San Ace 40* 9HVA type High Static Pressure Fan (hereinafter, "new model") which features a newly designed impeller, frame, motor, and circuit.

This article will introduce some of the features and performance of the new model.

2. Product Features

Figure 1 shows the appearance of the new model.

The features of the new model are:

(1) High static pressure
(2) Low power consumption

High performance has been achieved while maintaining the size of the current model.

Fig. 1 40 × 40 × 28 mm *San Ace* 40 9HVA type

3. Product Outline

3.1 Dimensions

Figure 2 shows the dimensions of the new model. The fan's external dimensions and mounting hole dimensions are unchanged and compatible with our current model.

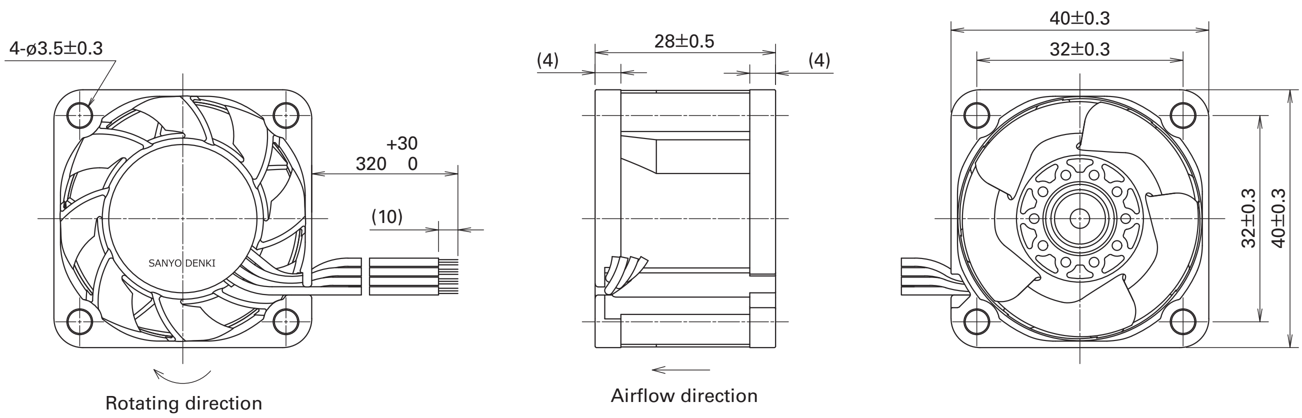

Fig. 2 Dimensions of the new model (Unit: mm)

3.2 Specifications

3.2.1 General specifications

Table 1 shows the general specifications for the new model. The rated voltage is 12 VDC and the rated speed is 38,000 min^{-1} (J speed), making it suitable for the 1U server market.

Table 1 General specifications for the new model

Model no.	Rated voltage [V]	Operating voltage range [V]	PWM duty cycle* [%]	Rated current [A]	Rated input [W]	Rated speed [min^{-1}]	Max. airflow [m^3/min]	Max. airflow [CFM]	Max. static pressure [Pa]	Max. static pressure [inchH₂O]	SPL [dB(A)]	Operating temperature range [°C]	Expected service life [h]
9HVA0412P3J001	12	10.2 to 13.8	100	2.60	31	38000	1.05	37.1	2300	9.24	71	-20 to +70	30000 at 60°C (53000 at 40°C)
			20	0.12	1.4	8000	0.22	7.8	101	0.41	34		

* Input PWM frequency: 25 kHz; speed is 0 min^{-1} at 0% PWM duty cycle.
Note: The expected life at an ambient temperature of 40°C is for reference purpose only.

3.2.2 Airflow vs. static pressure characteristics

Figure 3 shows the airflow vs. static pressure characteristics for the new model. It shows the characteristics at 100% and 20% PWM duty cycles at a rated voltage of 12 V.

3.2.3 PWM control function

The new model has a PWM control function that enables external control of fan speed.

See Figure 3 for the airflow vs. static pressure characteristics at different PWM duty cycles.

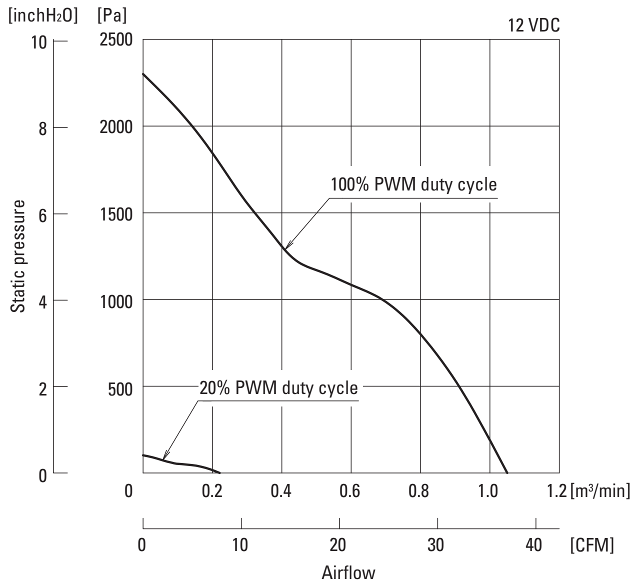

Fig. 3 Airflow vs. static pressure characteristics of the new model

3.3 Expected life

The new model has an expected life of 30,000 hours at 60°C (survival rate of 90%, run continuously at rated voltage and normal humidity in free air).

4. Key Points of Development

The new model achieves a significant improvement in static pressure compared to our current 40 × 40 mm fans. To achieve the target static pressure performance, it was necessary to increase the speed of the motor, while also optimizing the shape of the impeller and frame.

The impeller, frame, motor, and circuit were all newly designed to achieve these goals.

In the following sections, we will describe the main features of the new model as well as the differences between it and the *San Ace 40* 9HV type (hereinafter, "current model").

4.1 Impeller and frame design

To achieve a significantly higher static pressure performance than the current model, the fan speed of the new model had to be increased to 38,000 min^{-1}, while also optimizing the shape of the impeller and frame. Since this is the fastest speed among all of our fans, we designed the impeller to withstand it.

In addition, the current model used aluminum as the frame material, but the new model uses resin to reduce weight. Resin has lower heat dissipation performance than aluminum, and this makes cooling down the motor more difficult. However, we improved its cooling performance by adjusting the number and size of the impeller's vent holes.

Figure 4 shows an impeller shape comparison for the current model and new model.

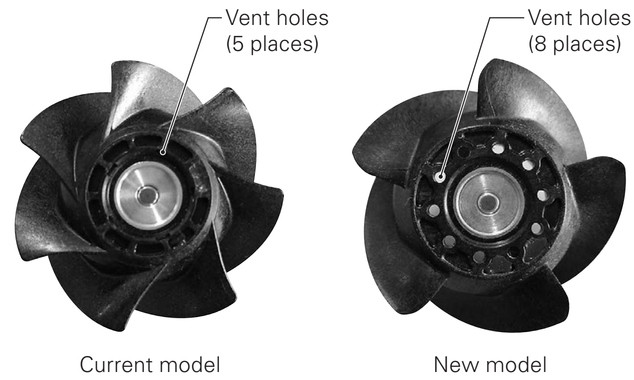

Fig. 4 Impeller shape comparison between current and new models

4.2 Motor and circuit design

Figure 5 shows the motors of the current model and new model. To achieve a higher fan speed, it was necessary to develop a circuit that would provide current to the motor through high-frequency switching, while also reducing motor vibration. To accomplish these, we designed a new circuit and motor; the new circuit suppresses peak current values even at high switching speeds and the new 3-phase motor provides low cogging torque and vibration.

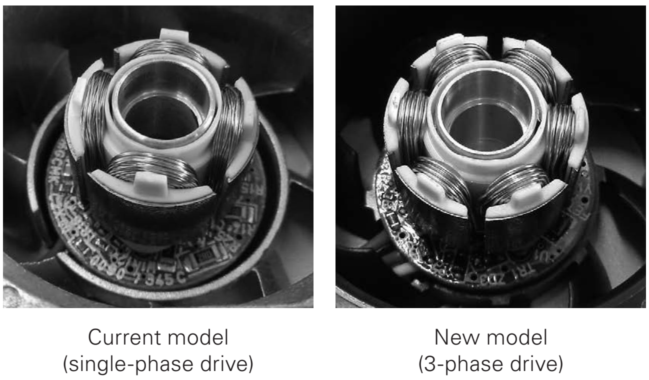

Fig. 5 Motors of the current and new models

The higher speed has increased power consumption to 31 W. As a result, the new model consumes the most power among all of our 40 × 40 mm fans. This 1.7 times higher power consumption than the current model raised an issue of heat generated by electronic components. If a larger fan size could be used, the size of the PCB could also be enlarged. This would enable the use of large components with high current-carrying capacities or the use of multiple electronic components to facilitate heat dissipation. However, 40 × 40 mm fans do not support larger PCBs because the larger board size would reduce the ventilation area and degrade aerodynamic performance. It was against this backdrop that we decided to optimize the component layout so as to maximize the internal cooling effect of the impeller's ventilation holes, as mentioned above. As a result, we achieved a high-speed fan circuit design that uses the same PCB size as the current model.

5. Comparison with Current Model

5.1 Comparison of airflow vs. static pressure characteristics

Figure 6 compares the airflow vs. static pressure characteristics of the new model and the current model. Airflow and static pressure have been improved 1.26 times and 2.1 times that of the current model, respectively. According to the estimated system impedance curves in the figure, the new model's operating airflow is 28% higher than the current model when used in a device with low system impedance. Furthermore, its operating airflow is 33% higher than the current model when used in a device with high system impedance.

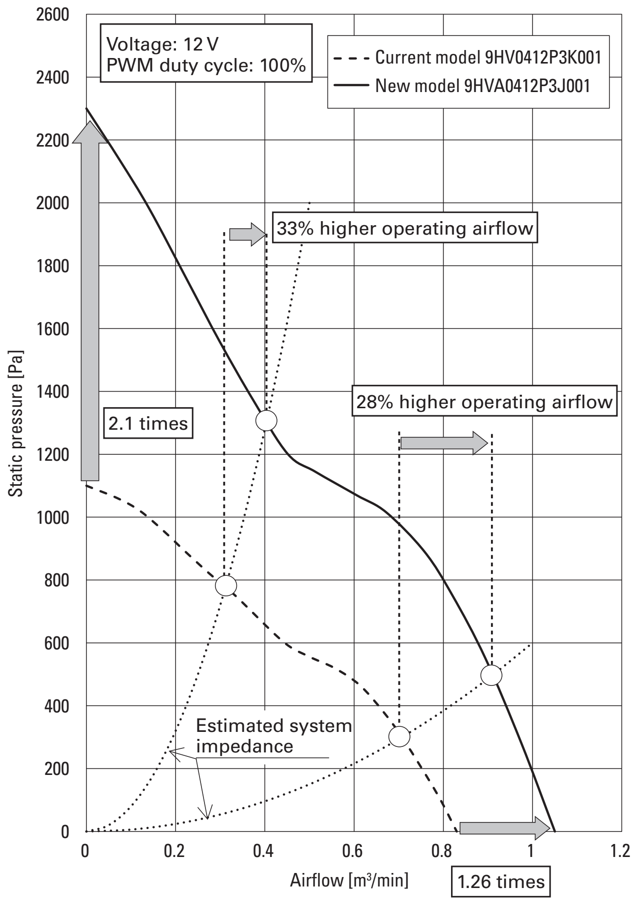

Fig. 6 Airflow vs. static pressure characteristics of the new and current models

5.2 Comparison of power consumption at an equivalent performance level as the current model

Figure 7 provides a comparison of power consumption for the current and new models at equivalent cooling performance. When the fan speed of the new model is reduced with PWM control to obtain the same cooling performance as that of the current model, power consumption is lower across all operating ranges. In particular, it is 20% lower near the maximum airflow and 10% lower in the high static pressure range. This reduces running costs for the new model.

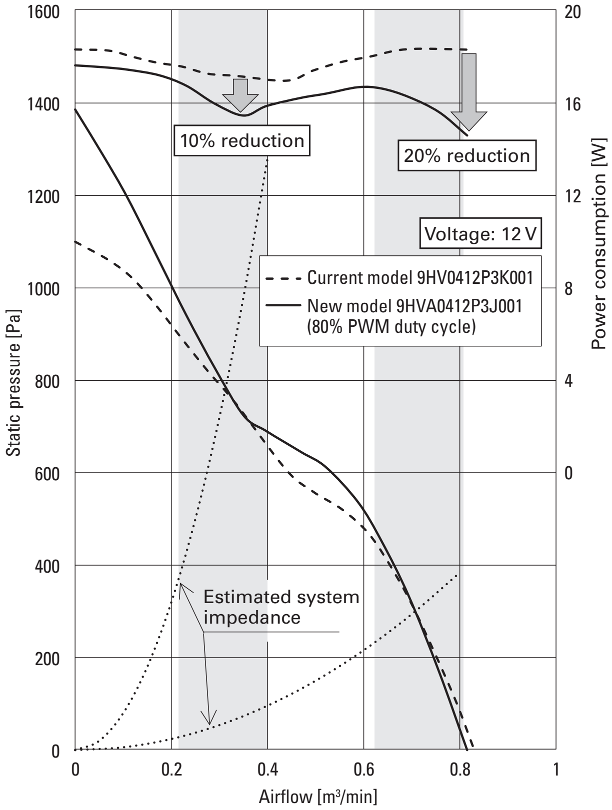

Fig. 7 Airflow vs. static pressure characteristics (Compared with the current model)

5.3 Comparison with a 40 × 40 × 56 mm product

The cooling performance of the new model even exceeds that of a 40 × 40 × 56 mm Counter Rotating Fan, whose thickness is twice that of the new model.

Figure 8 provides a comparison of the airflow vs. static pressure characteristics with a 40 × 40 × 56 mm 9CRV0412P5J201 Counter Rotating Fan.

The maximum static pressure of the new model is 2.2 times higher than that of the even thicker Counter Rotating Fan, and its cooling performance is greater across all operating ranges. As a result, the new model will be effective in space saving.

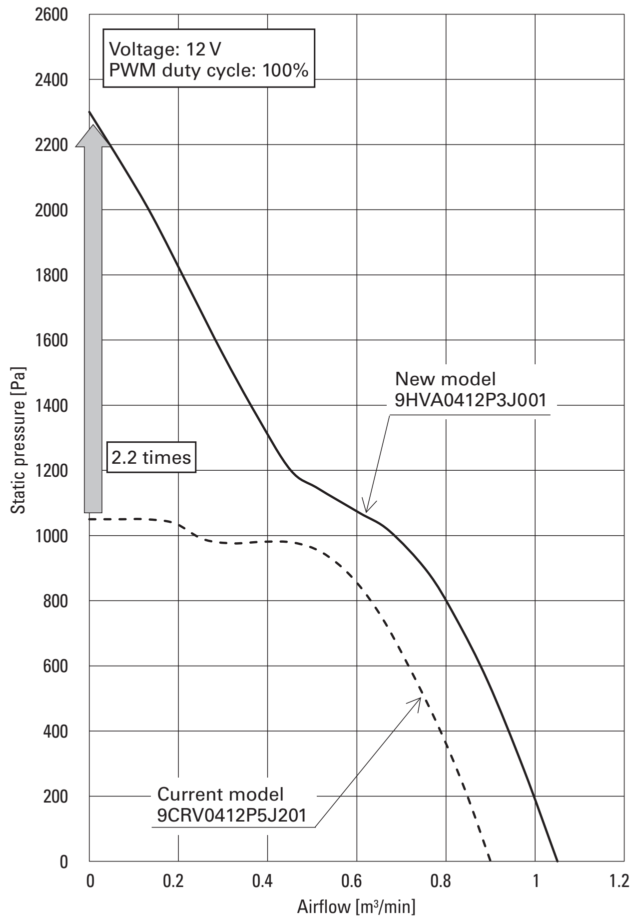

Fig. 8 Airflow vs. static pressure characteristics (Compared with a 40 × 40 × 56 mm Counter Rotating Fan)

6. Conclusion

In this article, we introduced some of the features and performance of the 40 × 40 × 28 mm *San Ace 40* 9HVA type High Static Pressure Fan.

Compared to our current model, the new model offers significantly higher static pressure. Furthermore, when cooling performance is equivalent to that of the current model, the new model greatly reduces power consumption.

We expect that the high static pressure and low power consumption features of the new model will make a significant contribution to the market by facilitating energy savings and cooling in high-density devices.

We plan to continue developing cooling fans that make use of the most advanced technologies so that we can quickly adapt to customer needs.

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Power Technologies for Helping Make New Dreams Come True

Chiaki Seki

1. Introduction

In recent years, damage to social infrastructure has become a major topic of news as many areas in Japan have suffered large-scale power outages caused by natural disasters. Due to these circumstances, uninterruptible power supplies (UPSs), which have conventionally been installed indoors for power backup of ICT equipment and plant facilities, will be expected to play a new role in society by providing long-term and stable power backup of outdoor equipment in the future.

In addition, renewable energy sources are also attracting more attention around the world as potential candidates to help realize a low-carbon society. For photovoltaic generation systems that have been promoted by the feed-in tariff scheme, there is a growing need for power conditioners (i.e., renewable energy inverters) with isolated output capability that can make use of generated power during power outages caused by natural disasters. In addition to photovoltaic power generation, wind and hydro power generation are also attracting more attention as viable renewable energy sources. Wind and hydro power generation systems require the use of rectifiers to convert the AC power generated by the generation system into DC power for use with power conditioners. We expect that the combination of our power conditioners and a dedicated rectifier can be used in not only wind and hydro power generation, but also in fields new to us such as biomass and geothermal power generation.

Since all of these devices are installed outdoors, they need to be able to withstand environmental changes and have a high level of water and dust protection. They also need to provide maintenance-free operation for long periods of time. In the following sections, we will introduce technologies that are necessary for our products to be used in outdoor applications in new markets to meet these needs.

2. UPS Technologies

Conventionally, our UPSs have mainly been installed indoors and used to back up servers, ICT equipment, and office equipment. They have also been incorporated into industrial equipment. However, due to the proliferation of mobile devices today and the lessons learned from natural disasters including the Great East Japan Earthquake, it is anticipated that there will be increasing demand for power backup solutions for distributed outdoor facilities such as paid parking lots, traffic lights, base stations, outdoor surveillance cameras, and emergency equipment, as shown in Figure 1.

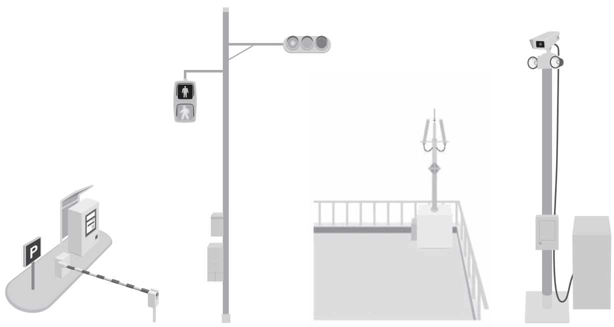

Fig. 1 Examples of equipment used outdoors

The *SANUPS N11B-Li* series, shown in Figure 2, has been designed for outdoor use. It features a wide temperature range (-20°C to +50°C) for safe use in extremely cold and hot regions.

Furthermore, since outdoor installation is usually not conducive to regular maintenance and battery replacement, we designed this product to feature water and dust protection (protection rating of IP65[1]) and lithium-ion batteries that provide long backup time in a small size.

These features enable it to achieve maintenance-free operation. Through the development of this UPS, we have acquired the technical expertise for installing power supply products outdoors.

Fig. 2 *SANUPS N11B-Li* series

(1) IP65 is a protection class defined in "JIS C 0920: Degrees of Protection Provided by Enclosures (IP Code)." It stipulates complete protection from dust and against water spray from all directions.

To install electronic equipment outdoors and operate it safely over a long period of time, it is necessary to improve the equipment's temperature resistance and housing performance.

In the development of this UPS, we used some of the design techniques that we acquired through our previous power conditioner developments and designed it to have a sealed structure with an IP65 protection rating to enable it to be installed outdoors. To that end, we used thermal fluid analysis to simulate internal heat flow and optimized the structure and layout design to effectively circulate and discharge heat to the outside by using the entire housing.

Figure 3 shows one example of thermal fluid analysis.

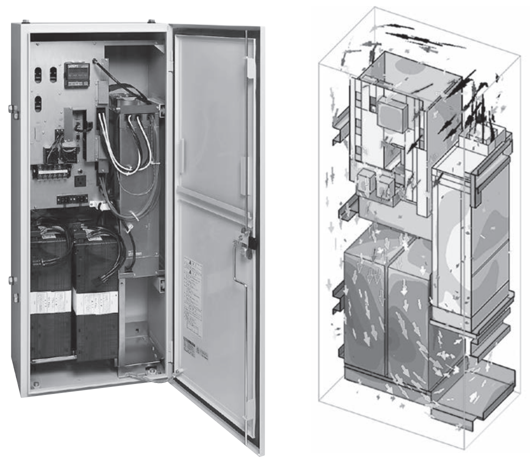

Fig. 3 Thermal fluid analysis model of the *SANUPS N11B-Li* series

The analysis helped us create a sealed structure that prevents heat from building up in particular spots and does not hinder UPS performance and reliability. As a result, we were able to successfully develop a highly reliable outdoor UPS that has an IP65-rated sealed structure.

When installing equipment outdoors, consideration also needs to be given to ensure that the effects of direct sunlight does not impact the equipment. To achieve this, we attached heat shields to the outside of the housing as shown in Figure 4, and optimized the spacing and ventilation structure of the housing and heat shield by conducting exposure tests under hot midsummer sun.

As a result, the surface temperature of the heat shield rose about 15 to 20°C above the ambient temperature due to the direct sunlight, but the effect of the temperature rise on the inside of the housing was limited to about 5°C.

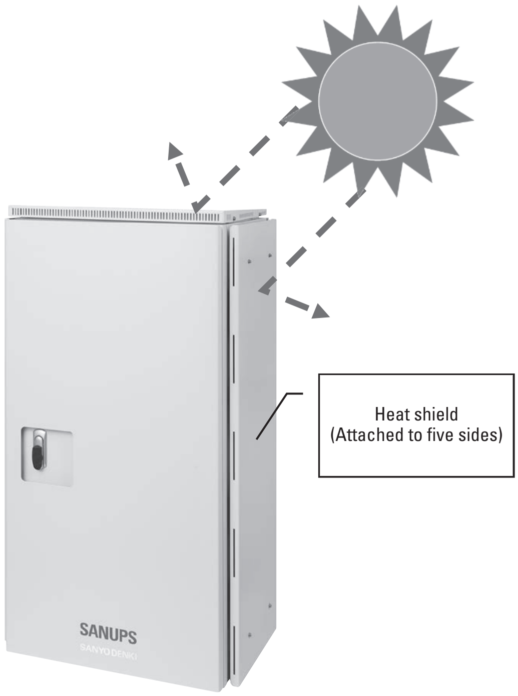

Fig. 4 Heat shield of the *SANUPS N11B-Li* series

3. Renewable Energy Inverter Technologies

In addition to our conventional *SANUPS P73H* and *SANUPS P73J* power conditioners (i.e., renewable energy inverters) for photovoltaic generation systems, we developed the *SANUPS W73A* for wind power and hydro power generation systems. This product comes in two types: a grid-connected type and a grid-connected isolated type that features isolated operation capability.

The grid-connected type power conditioner is unable to supply power in the event of a power grid failure, but the grid-connected isolated type can continue supplying power during times of emergency thanks to its isolated operation capability. This grid-connected isolated type is also expected to be used as an independent power supply in non-electrified areas such as remote islands.

Wind and hydro power generation systems require the use of high-efficiency rectifiers to convert the AC power generated by the generation system into DC power for use with power conditioners.

Therefore, we newly developed the *SANUPS W75A* as a rectifier dedicated for use with 10 kW or lower output wind and hydro power generation systems.

Since the *SANUPS W75A* was designed to be installed outdoors with a power conditioner, it needed to have the same water and dust protection (IP65) as the combined power conditioner to build a robust environmentally durable system.

To this end, the unit makes use of a fanless passive air cooling system. We decided to use large cooling fins for this product based on the results of heat dissipation simulations performed while taking the temperature rise of the diodes used in the rectification circuit into account. By making the cooling fins a part of the housing, this product satisfied the required cooling performance even with a sealed structure and also achieved quiet operation.

We expect that the combined use of our *SANUPS W73A* power conditioner and *SANUPS W75A* rectifier unit will be further introduced in renewable energy power generation systems, including wind and hydro power generation systems, that use AC generators.

From the development of our previous power conditioners and this rectifier unit, we have now acquired the technical expertise for converting the power generated by almost all types of renewable energy generation systems into AC power, as shown in Figure 5.

Moving forward, our products can convert not only photovoltaic, wind, and hydro power, but also various other types of renewable energy sources, such as biomass and geothermal power, into AC power. We also expect that customizing customers' equipment tailored to their needs will further help expand new markets.

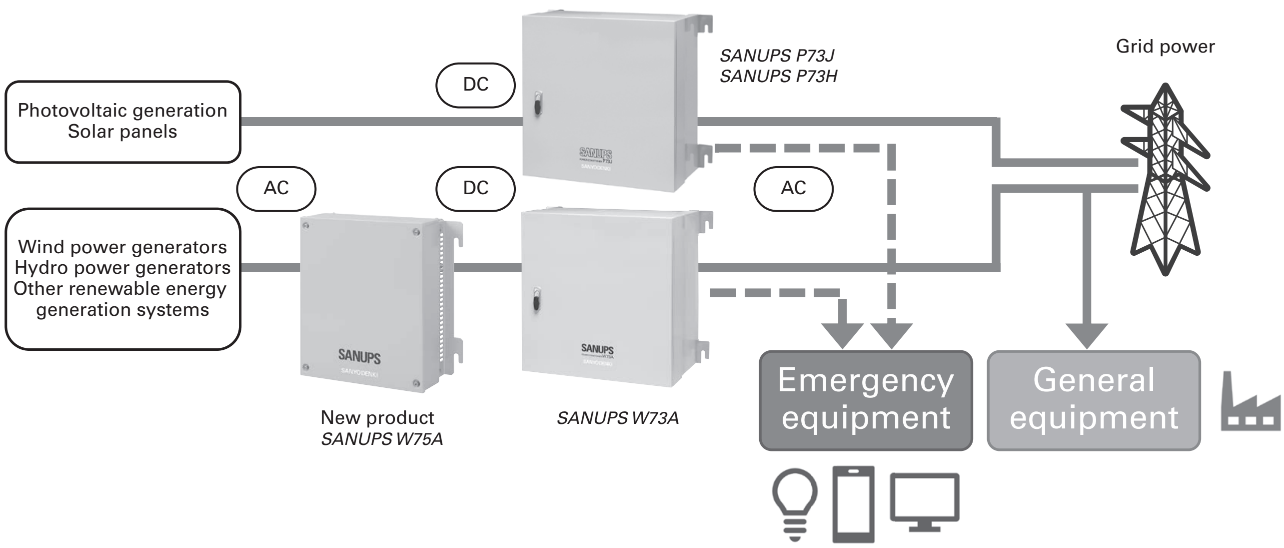

Fig. 5 Power generation system overview

4. Conclusion

We plan to continue to offer UPSs and power conditioners that can safely be used in harsh outdoors environments, so as to meet the expectations of our customers with the aim to contribute to the realization of a low-carbon society.

In addition, we will endeavor to develop new technologies to introduce higher quality power supplies into new fields that require operations in unusually severe environments.

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Development of the *SANUPS W75A* Rectifier Unit for Wind Power and Hydro Power Generation Systems

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1. Introduction

In recent years, renewable energy sources such as photovoltaic, wind, hydro, and biomass have been attracting worldwide attention as potential candidates to help achieve decarbonization. At the end of 2015, the Paris Agreement was decided as a common goal for the world. Moreover, in 2018, Japan established its 5th Strategic Energy Plan.[1] The plan aims to make renewable energy "an economically self-supporting, decarbonized main source of electricity" by 2050. Moving forward, it is expected that the introduction of renewable energy will be promoted further.

In addition to widespread photovoltaic power generation, wind and hydro power generation are two other renewable energy sources that are attracting increasing attention in Japan. Compared to other renewable energy sources, the introduction of wind power generation is expected to expand due to its relatively low cost and applicability under the feed-in tariff scheme. As for hydro power generation, it has a higher energy conversion efficiency than other sources, and also facilitates long-term operation and stable supply. As a result, micro hydro power generation is attracting attention for its use in agricultural water and waterworks applications.

We have newly developed the *SANUPS W75A* rectifier unit that can be used in wind power and hydro power generation systems with output capacities of 10 kW or less. This article introduces the features of this new product.

2. Development Background

Figure 1 illustrates a simplified power generation system. Wind and hydro power generation systems require the use of a rectifier to convert the AC power generated by the generation system into DC power for use with its power conditioners (i.e., renewable energy inverters).

However, there had been no standard rectifiers on the market for generation systems with an output capacity of 10 kW or less. Therefore, we have developed the *SANUPS W75A* as a rectifier that can be used in such power generation systems.

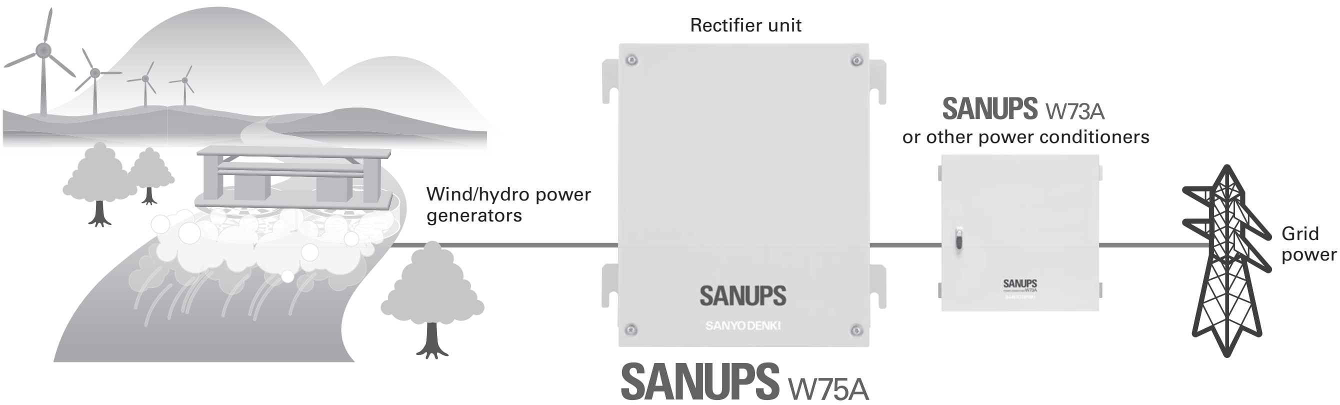

Fig. 1 Power generation system overview

3. Outline and Specifications of the *SANUPS W75A*

The *SANUPS W75A* has a rated output capacity of 11 kW. Table 1 shows its specifications and Figure 2 its appearance.

The main circuit uses a full-wave rectification method. It converts the AC power generated by the system's generators into DC power for use with the power conditioners. Its conversion efficiency is 99%[1], the highest level in the industry.

Table 1 Specifications of the *SANUPS W75A*

Items \ Model no.		W75A113	Remarks
Main circuit type		Full-wave rectification	
Cooling system		Passive air cooling	
Rated Output		11 kW	The generator output should be 11 kW or less. If exceeding this, contact us.
AC input	**No. of phases/wires**	3-phase 3-wire	
	Rated voltage	300 VAC	
	Maximum allowable voltage	420 VAC	Take necessary measures at the generator side to ensure that a voltage higher than the maximum allowable input voltage will not be applied.
	Input operating voltage range	106 to 420 VAC	Rated output range is 176 to 420 VAC.
	Input frequency range	0 to 400 Hz	
	Rated input current	30 AAC	At a power factor of 0.7
	Number of circuits	1 circuit	
DC output	**Current type**	Direct current	
	Rated voltage	420 VDC	
	Maximum current	45 ADC	
	Rated current	26 ADC	
	Voltage range	0 to 600 VDC	
Brake	**Operating voltage**	530 VDC	Release voltage: 400 VDC
	Current	Mean: 25 A max.	
Efficiency		99%	Efficiency measurement method in accordance with JIS C 8961: 2008
Acoustic noise		25 dBA or less	At 1 m height, 1 m from the front of the unit
Operating environment	**Operating temperature range**	-25 to +60˚C	When using in combination with a SANUPS W73A power conditioner in the same environment
	Relative humidity	90% or less (non-condensing)	
	Altitude	2000 m max.	
Protection rating		IP65	
Housing material		SUS430	Thickness 1.2 mm

Fig. 2 *SANUPS W75A*

The *SANUPS W75A* was designed to be used in combination with our *SANUPS W73A* series power conditioners for three-phase 10 kW wind power and hydro power generation systems. This rectifier unit can be combined with power conditioners other than the *SANUPS W73A* series products if their ratings such as DC output voltage range are within the specifications shown in Table 1.

(1) Efficiency measurement is according to JIS C 8961. Our *SANUPS W73A* power conditioner was used as the load.

4. Features of the *SANUPS W75A*

4.1 DC voltage rise control function (Brake function)

The *SANUPS W75A* is equipped with a DC voltage rise control function (brake function) to prevent damage to the power conditioner in the event that the generator generates power in excess of the power conditioner's input voltage range. This function can be enabled by connecting an external shunt resistor. Figure 3 shows the circuit block diagram of the *SANUPS W75A*.

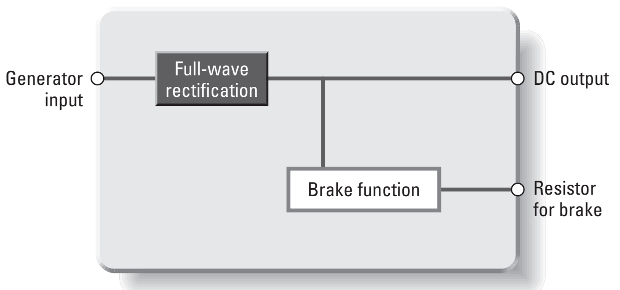

Fig. 3 Circuit block diagram of the *SANUPS W75A*

This function constantly monitors the DC output voltage. When the output voltage exceeds the specified value, the brake function is activated to send current to the resistor for brake. This prevents the input voltage of the power conditioner from rising too high. In addition, the product has a potential difference between the brake activation and release voltages to ensure that the control function is not activated too often.

4.2 Generator speed contact output

In wind power and hydro power generation systems, it is necessary at times to collect generator speed data.

The *SANUPS W75A* comes with a contact output terminal that outputs the generator's output voltage frequency. Generator speed can be measured using the output voltage frequency. Moreover, generator speed can be monitored by connecting a signal transducer to the contact output terminal.

In addition, by using the *SANUPS W73A* series and the *SANUPS PV Monitor* remote monitoring device in combination, remote monitoring and data collection of generator speed can be done via a network, helping build smart grid systems.

4.3 Temperature rise alarm contact output

The *SANUPS W75A* continuously monitors the temperature of its full-wave rectification circuit. The rectifier unit comes with a contact output terminal that turns off the full-wave rectification circuit by opening the circuit when the temperature of the circuit exceeds its specified value. Furthermore, the safety of the system can be enhanced by using the contact output to incorporate controls such as safe shutdown of the generator and power conditioner.

4.4 Quiet operation

The *SANUPS W75A* uses a fanless passive air cooling system to improve its quietness. The rectifier uses large cooling fins that take into account the temperature rise of the diodes used in the full-wave rectification circuit. By making the cooling fins a part of the housing, this product satisfied the required cooling performance even with a sealed structure and also achieved quiet operation.

Figure 4 shows the rear surface of the *SANUPS W75A*.

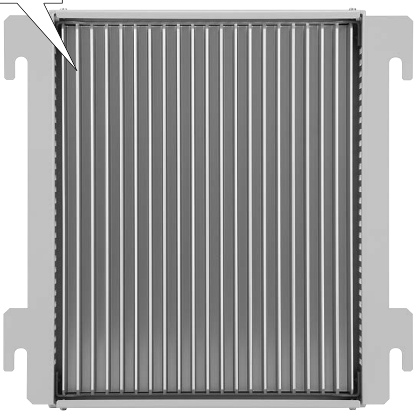

Fig. 4 Rear structure of the *SANUPS W75A*

4.5 Waterproof and dustproof

With a sealed structure and fanless passive air cooling system, the *SANUPS W75A* achieves an IP65(2) water and dust protection rating. The structure completely protects the unit from dust and water sprayed from all directions.

This means that the unit is protected from rainwater, dust, small insects, and animals. This enables the construction of an environmentally durable system that can be safely used outdoors for long periods of time.

4.6 Use in other power generation systems

The *SANUPS W75A* has a wide range of voltages. Specifically, it covers an AC input voltage range of 106 to 420 VAC and DC output voltage range of 0 to 600 VDC. Use of this rectifier is not limited to wind and hydro power generation systems. It can be used in a variety of renewable energy generation systems that use 3-phase generators, including biomass and geothermal power generation systems.

5. Conclusion

This article introduced the *SANUPS W75A* rectifier unit for wind and hydro power generation systems. In addition to the rectifier's basic functions for converting the AC power generated by generators into DC power, it also comes with contact output and environmental durability.

We believe that this product will contribute to the promotion of renewable energy generation systems such as those for wind and hydro power generation.

We will continue to develop products in related fields in a timely manner so that we can meet the needs of our customers. By doing this, we expect that our products will contribute to the spread of renewable energy and the realization of a low-carbon society.

(2) Classifications defined in "JIS C 0920: Degrees of Protection Provided by Enclosures (IP Code)"
IP65: Complete protection from dust and against water spray from all directions. (Based on the protection performance test defined by Japan Ship Machinery Quality Control Association Research Institute of Marine Engineering)

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Technologies for Helping Make New Dreams Come True

—Servo technologies that contribute to medical, welfare, and food fields—

Hideaki Kodama　Hidetoshi Hayashi

1. Introduction

There has been a heightened interest in human health of late in light of the impact of infectious diseases and the changes they have wrought on our ways of life. Medical and welfare equipment has therefore also been advancing greatly to meet these new challenges. Automation of food production lines which sustain our lives has also been accelerating in consideration of food safety, leading to greater expectations for servo systems products.

We have applied servo systems technologies that we have cultivated over many years in the industrial machinery market to the advanced medical, welfare, and food fields with the aim of developing servo technology which can help people and machines work together harmoniously.

Staying healthy to continue contributing to society is the dream and desire of both people and society.

This article introduces our products and technologies which contribute to human health and food safety. It will highlight four examples in the medical, welfare, and food fields where our servo products and technologies help make new dreams come true.

2. Contributing to a Long, Healthy Life (medical): Radiation Therapy Equipment

Technology for cancer radiation therapy is advancing daily. Dedicated stereotactic radiotherapy (SRT) for intracranial therapy these days is capable of delivering submillimeter (0.1 mm units) level irradiation precision, and is equipped with a function for correcting the position of the patient by providing image guidance during therapy.

This chapter introduces actuator (linear servo motor) development technology that has contributed to the development of new radiation therapy equipment that is capable of generating radiation beams from a number of directions, including non-coplanar beams, by combining rotary axes, and does not require a large shield.

2.1 Overview of equipment

Figure 1 shows the appearance of the radiation therapy equipment. The main features of this equipment are:

(1) There is no need for a large scale shielded room.Because self-shielded design.

(2) Radiation beams can be directed at the target area from all directions using multiple rotary axes.

(3) Innovative safety function: real-time dose verification system.

(4) This new equipment achieves submillimeter level irradiation precision, and is equipped with a function for correcting the patient position by providing image guidance during therapy.

Fig. 1 Radiation therapy equipment appearance

The θ-axis used to rotate the irradiating part of the equipment consists of multiple axes, allowing the affected area to be irradiated from a wider angle. Accurate positioning of the irradiation area is realized by these rotary axes together with the treatment bed used to convey the patient. The treatment bed has three axes, and is capable of three-dimensional motion. This allows the patient to be treated by accurately directing radiation at the affected area of the head.

We developed linear servo motors used in the rotary axes for the irradiating part of the equipment, and the driving axes which move the treatment bed.

2.2 Product specifications (linear servo motors)

This section provides an outline of the linear motors used for the θ-axis. Figure 2 shows where our linear motors are used in the unit.

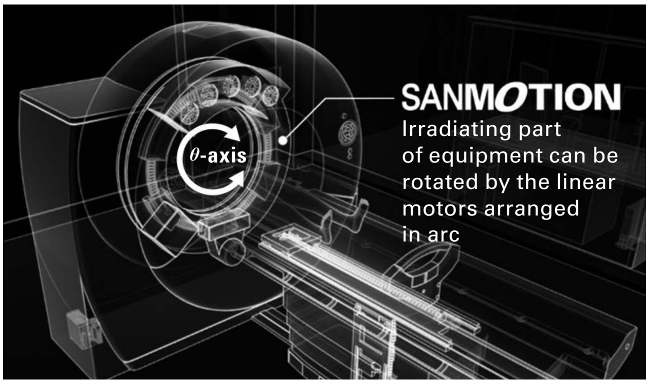

Fig. 2 Where our linear motors are used

The θ-axis is a key axis which determines the irradiation angle, and load inertia to rotate the entire shielded structure about this axis is large. Therefore, positioning operation is required to be accurate.

To achieve this, we developed a linear motor with magnets arranged in the circumferential direction, and linear motor coils arranged in an arc. Conventional rotary motors require conversion mechanisms such as belt mechanisms, and factors such as backlash and drops in rigidity hinder control. However, high-accuracy control can be achieved using direct drive with arc linear motors.

Figure 3 shows the appearance of the arc linear motor armature.

Using direct drive offers a greater movement radius, and allows the required number of coils to be arranged, thereby generating sufficient torque for rotation.

Cogging thrust generally increases by arranging magnets in an arc, but a low level of cogging similar to that when arranging magnets linearly has been realized by devising a system which cancels cogging thrust inside the coils.

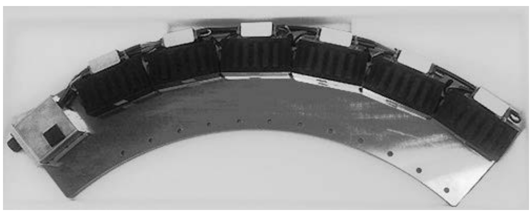

Fig. 3 Arc linear motor armature

The technology enabling low cogging thrust developed here is being used in the development of a new need for dedicated intracranial radiation therapy equipment.

3. Contributing to a Long, Healthy Life (medical): Mammography Units (breast cancer screening units)

Mammography is a dedicated radiographic technique for imaging the breast. It is one of the most effective methods of diagnostic imaging indispensable for the early detection of breast cancer. This chapter introduces the actuator technology used in mammography units. This technology makes it possible to detect changes at an early stage that would not normally be noticed by patients during their daily lives.

3.1 Overview of equipment

Figure 4 shows the mammography unit appearance, and Figure 5 shows where our DC servo motors are used in the unit.

Our DC servo motors are used to rotate and move the compression plate vertically. Mammograms are carried out by first placing the area to be examined between the unit's two plates. The compression plate gradually applies pressure to the area and holds at a level appropriate for the examination, and the area is then irradiated with radiation and ultrasonic waves.

Fig. 4 Mammography unit appearance

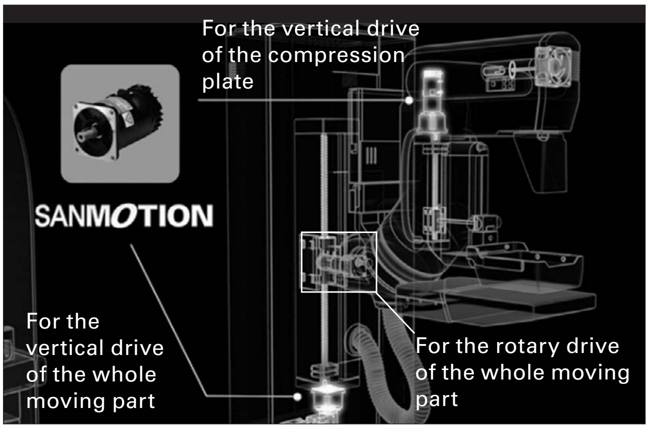

Fig. 5 Mammography unit motor arrangement

3.2 Human body-friendly control

The breasts of those undergoing examination differ in many ways in terms of size, shape, and firmness, and thus delicate pressure control of the compression plate is required. The control can be easily done with DC servo motors. By simply monitoring the current flowing to DC servo motors, the subtle pressure applied to the plate can easily be controlled, minimizing physical strain such as pain in the area being examined.

3.3 Safety ensured by low-voltage motors

Since mammography involves the compression plate coming into direct contact with the human body, safety against electrical shock had to be ensured for electric actuators. To this end, it is necessary to use servo motors that support 40 VDC or lower voltages. Our *SANMOTION K* series DC servo motors meet this requirement, and we have a standard lineup of low-voltage models.[1]

3.4 Reliability in high-radiation environments

The structure of DC servo motors is such that control is relatively easy when compared with AC servo motors, and commutation sensors are not required unlike AC servo motors. There is no need for electronic components such as hall sensors, ensuring highly reliable control even in environments exposed to high levels of radiation.

3.5 Equipment noise reduction

Mammography often involves placing electric actuators in locations relatively close to the patient body. Consequently, noise produced by actuators and harmonic noise generated by inverters can sometimes cause the patient discomfort or stress. The structure of DC servo motors is such that the harmonic noise-producing windings are located in the rotating part of the motor, reducing the harmonic noise emitted from the motor. Furthermore, our *SANMOTION K* DC servo motors have a revised structure that achieved reduced noise[1]. This allows patients to be examined without having to worry about stressful motor noise.

4. Contributing to Living Independently (welfare): Wearable Robots for Active Living Support[2]

With its super-aging society, Japan is seeking ways to allow the elderly to continue to enjoy healthy lives without assistance. This chapter introduces “human-friendly wearable robot” development technology involving actuators and servo amplifiers we have developed. This robot has been designed to assist those who have become physically impaired due to diminished physical ability, or who have been injured in the course of their work.

4.1 Overview of equipment

The “human-friendly wearable robots,” in which we were involved in the development, have been designed to be lightweight and easy and comfortable to wear. The purpose of this robot is to help the elderly or patients walk independently, to assist with nursing care of them, and for the rehabilitation of those with disabilities.

The two main features of this robot are:

(1) Coordinated control (control technology)

· User’s movement can be improved more naturally not by forcibly improving their movement through robot movements, but by its human-like cooperative motion assistance. That is, despite being a robot, this robot can assist the user’s movement just as a human being does.

(2) Non exoskeleton type exterior mechanisms

· These wearable robots have a plastic, non-exoskeleton structure that mimics the human skeletal structure rather than the rigid metallic exoskeleton structure often seen in conventional assistance robots, making it both lightweight and easy-to-wear, ensuring maximum freedom of movement.

Figure 6 shows the configuration of a wearable robot This wearable robot consists mainly of a jointed frame, which forms the external mechanism worn by the user, an actuator unit (4 axes) that assists the user’s motion, and a controller that controls the actuator. We developed the linear servo motors in the actuator unit and the servo amplifier in the controller.

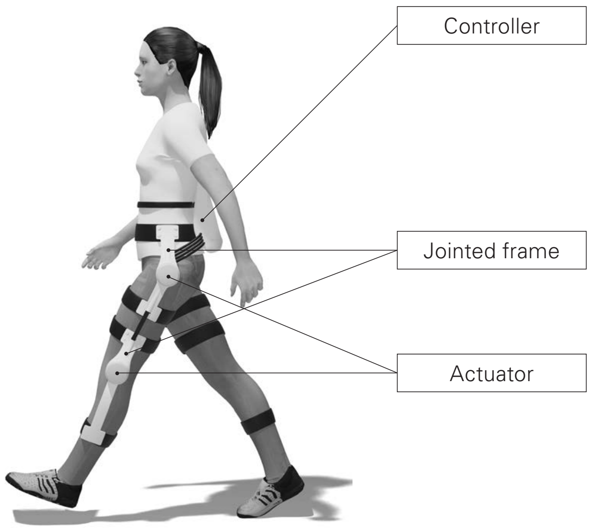

Fig. 6 Wearable robot equipment configuration

4.2 Actuator configuration and motor specifications

The actuator consists of a gear, motor, encoder, and torque sensor. A palm-sized flat motor is used.

With wearable robots, the wearer must bear an extra load determined by the weight and size of the actual device, and this demands stricter conditions than those required by other robots in terms of size and weight reduction. To achieve the first aim of miniaturization, we developed a flat structure with bearings and the encoder arranged on the inside of the electromagnetic part of the motor. To keep weight to a minimum, we developed a mechanism which exerts minimal restrictions on the user with a lightweight design achieved through such means as making the frame thinner.

4.3 Development of servo amplifier for wearable robots

We have also been striving to reduce the size and weight of the servo amplifier used to drive the motors to realize the concept of “can be worn just like clothes” for a robotic suit worn on the body to support the independence of those requiring care.

4.3.1 Miniaturization and weight reduction

The entire servo system, including the drive unit, is worn on the body; heat dissipation and safety have been assured while employing an open frame configuration with a control board and power board so as not to compromise comfort.

For increased wearability, we designed the servo system to be lightweight and compact so that it can fit in the controller box on the back.

Our standard servo amplifiers control motors with multiple LSI components such as CPUs, ASICs, and memory. To reduce the number of components used in the servo amplifier, we employed the CPU-based current detection function and encoder interface function, created software to control the current that had previously been done by a ASIC, and developed a control circuit capable of controlling two motor axes with a single CPU. Also, by developing a compact, lightweight 4-axis integrated servo amplifier capable of being stored in the controller on the back, we have succeeded in realizing the product concept of “a robot that can be worn just like clothes.”

5. Contributing to Improving Food Environments: Development of Robots for Food Packaging Lines

In line with changes in food culture and life style, new food supply methods are being established involving the use of convenience stores and courier services. Greater emphasis has been placed on safety and hygiene in food processing and packaging plants, but the aging population in Japan has made it difficult to secure the labor required for such work. To meet this challenge, the use of production site automation and unmanned operation is accelerating.

The use of high-speed parallel link robots for food production facilities with high production volumes has been attracting much attention.

This chapter introduces parallel link robot development technology that uses our motion controllers for use in handling robots for food production lines.

5.1 Overview of equipment

The equipment we were involved in developing was a post-packaging box filling line process using a parallel link robot. An image-processing unit detects products being carried on a belt conveyor. A robot then follows the products, picks them up, and finally packs them into boxes. This equipment is collectively known as a conveyor tracking system. Figure 7 shows an overview of the system.

The box filling process requirements can be met with a robot and belt conveyor coordinated with upstream processes. However, our motion controller has been revised to add capabilities to allow installed robots to be changed, moved, and expanded freely.

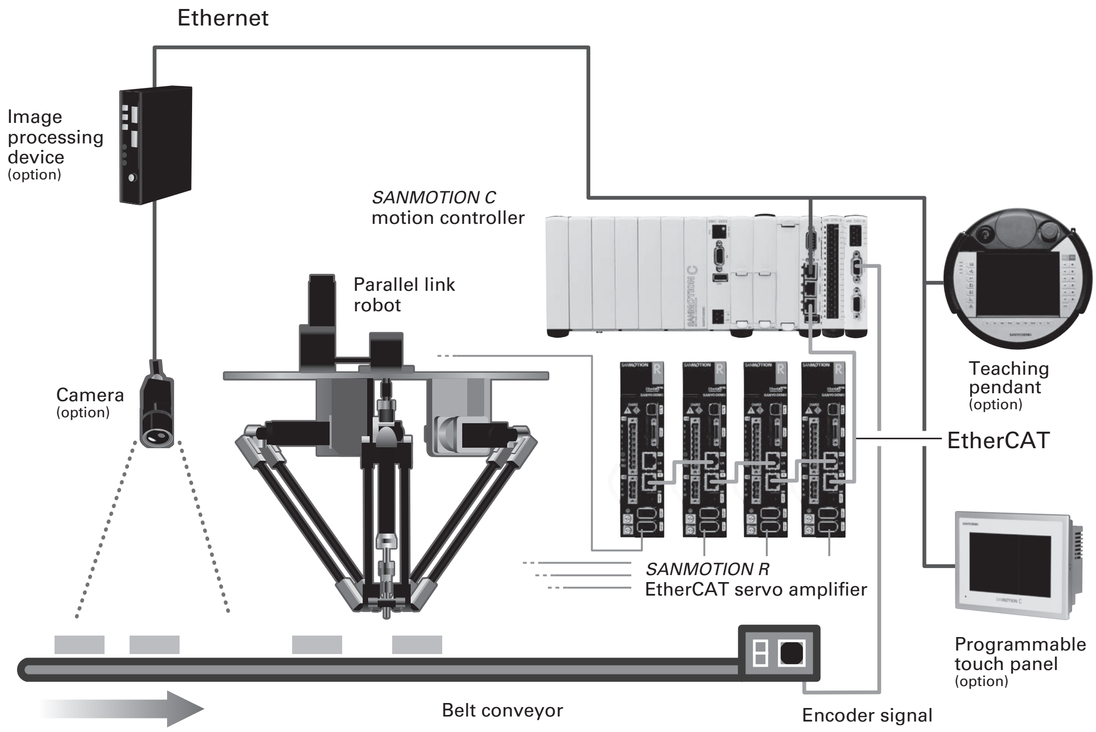

Fig. 7 Conveyor tracking system configuration

5.2 Robot control technology

There are a number of issues involved in developing a production system that uses robots, such as training personnel to have robot expertise and prolonged development periods.

To solve such issues, our *SANMOTION C* motion controller features technologies and functions to support robot development, which are introduced below.

5.2.1 Parallel link robot posture control

As shown in Figure 8, the *SANMOTION C* motion controller has a mechanism setting tool, which makes it possible to control robot posture easily.

Robot posture can be controlled simply by setting the type of robot to be developed, arm length, and gear ratio. Posture control does not require complicated calculations, therefore the burden of program development placed on customers is reduced.

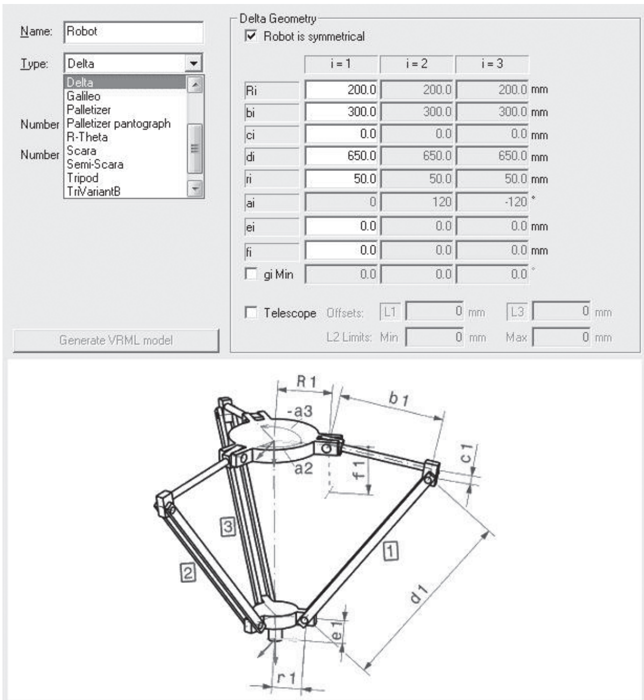

Fig. 8 Robot mechanism setting tool

Food production lines are expected to use multiple robots, therefore flexibility is required in terms of expanding robot processes and making installation changes. Figure 9 shows the construction and installation method of the special parallel link robot with which our motion controller was combined to save space in the production line.

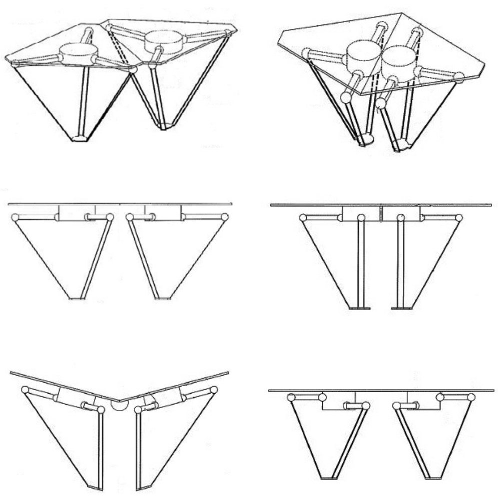

Fig. 9 Parallel link robot specialized mechanisms and construction methods

5.2.2 Teaching/programming function

We provide a dedicated teaching pendant for *SANMOTION C* shown in Figure 10 to allow robot motion to be programmed easily. The wizard navigation, shown in Figure 11, makes it easy to make complex belt conveyor and camera installation adjustments. Robot operation commands shown in Table 1 can be used to operate robots easily. These functions allow robot motion to be programmed quickly.

Front view　　Side view

Fig. 10 Teaching pendant appearance

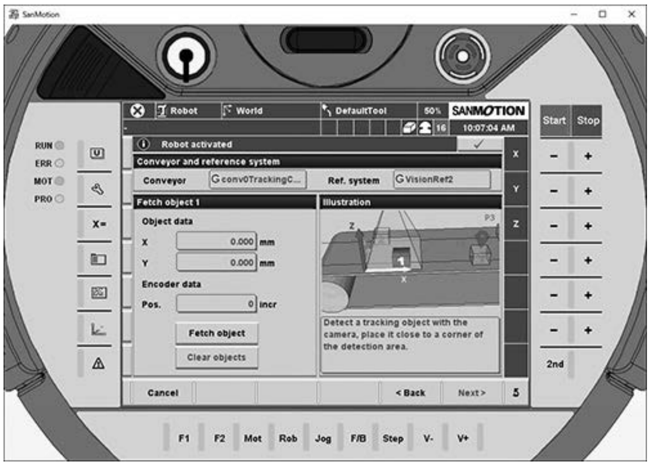

Fig. 11 Belt conveyor and camera setting screen

Table 1 Example of main robot language commands

Command name	Description
PTP	Point-to-point motion
LIN	Linear interpolation motion
CIRC	Circular interpolation motion
PTPRel	Distance-specified PTP motion
LINRel	Distance-specified linear interpolation motion
StopRobot	Robot stop
WaitFinished	Wait for robot command to process
RefRobotAxis	Homing operation
TOOL	Tool coordinates setting
Ovl	Overlap setting (Path)
Ramp	Acceleration/deceleration curve setting
WaitTime	Wait time (timer)
DIN.Wait	Wait for digital input
Dout. Set	Digital output setting (BOOL)
WHILE ... DO	Iterative control
IF ... THEN	Branch instruction

Using the robot development support technology of *SANMOTION C*, even users with no robot expertise can develop robot motion programs quickly. By providing total support with robot installation, development, and programming, we contribute to the realization of unmanned operation and automation.

6. Conclusion

This article introduced the following four cases where our products and technology are used to help make new dreams for people's lives come true.

(1) Linear servo motor technology for radiation therapy equipment
(2) DC servo motor technology used in mammography
(3) Servo technology for wearable robots
(4) Motion control technology for food packaging parallel robots

These servo technologies support medical treatment and food environments. Servo technologies tend to be thought of as technologies used in industrial machinery only, but as this article has highlighted, servo technology also has a significant role to play in medical and welfare equipment, as well as equipment for the food production industry. We will continue to develop servo technology that allows people and medical and welfare equipment to work together, and provide products and services that can contribute to good health and making people happy.

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Development of *SANMOTION C Wireless Adapter 3A*

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1. Introduction

In the manufacturing industry, production equipment that uses wireless communication technology has been developed to improve production efficiency and facilitate timely responses to customer needs and market changes. As one example, notifications of production equipment abnormalities can be sent remotely through wireless communication so that problems can be quickly resolved. As such, production equipment is required to support such functionality to effectively use wireless communication for improved maintainability. In addition, there is also demand for add-on products that can easily add wireless communication features to make existing production equipment IoT-ready.

To meet this demand, we developed the *Wireless Adapter 3A* as an add-on product that can provide the *SANMOTION C S100* motion controller (hereinafter, *S100*) with wireless capabilities. The "3A" in the product name stands for: Anytime (can check information whenever it is needed), Anywhere (can be used no matter in which country it is installed), and Anything (can connect to a PC or smart device).

This article will introduce the features of this new product.

2. Product Overview

2.1 Appearance and dimensions

Figure 1 shows the appearance of the *Wireless Adapter 3A* and Figure 2 shows its dimensional drawing.

The new product comes with a USB interface and can be used by connecting it to the USB connector on the front of the *S100*. When mounted to the *S100*, it fits within the cable wiring space so as not to interfere with other equipment (see Figure 3). In addition, the adapter has an easy-to-grasp grip on its side to prevent it from slipping. This design makes it easy to be connected to and disconnected from the *S100* (see Figure 4).

Fig. 1 *Wireless Adapter 3A*

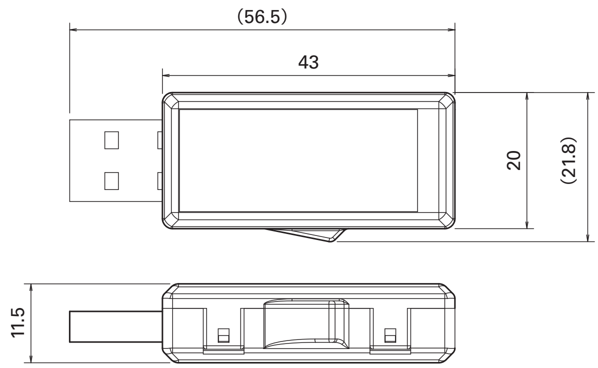

Fig. 2 Dimensional drawing of *Wireless Adapter 3A* (Unit: mm)

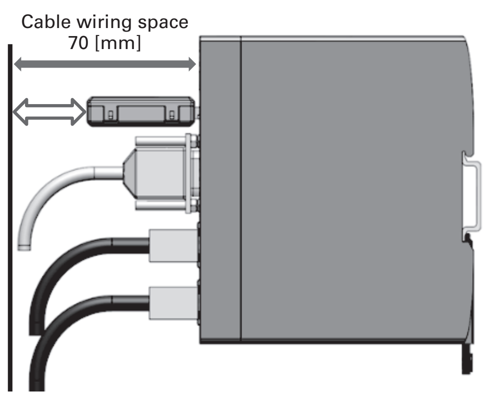

Fig. 3 Illustration of spacing when mounted to the *S100*

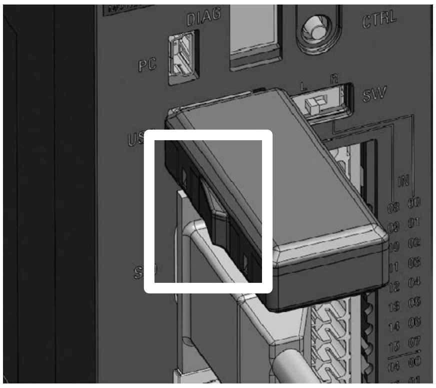

Fig. 4 Side grip

Table 1 shows the basic specifications of the *Wireless Adapter 3A*.

Table 1 Basic specifications

Interface	USB 2.0 Type A
Wireless standard	Compliant with IEEE 802.11 b/g/n
Frequency band	2.4 GHz
Data rate	IEEE 802.11b: Up to 11 Mbps IEEE 802.11g: Up to 54 Mbps IEEE 802.11n: Up to 72.2 Mbps
Maximum number of connectable units	3
Operation mode	Access point mode Station mode
Security	WPA2-PSK (AES)
Operating temperature	0 to +55°C
Storage temperature	-40 to +70°C
Humidity	10 to 95% (non-condensing)
Dimensions (W×H×D)	21.8 × 11.5 × 56.5 mm
Mass	Approx. 10 g
Wireless standard	TELEC (Japan) FCC (USA) ISED (Canada) CE (Europe) SRRC (China) NCC (Taiwan) NBTC (Thailand)

3. Features

3.1 Helps build wireless networks easily

Wireless features can be used by simply connecting the new product to the USB interface of the *S100*. Wireless settings can be configured using the *SANMOTION C Software Tool*, an integrated development tool (see Figure 5). It does not require any advanced knowledge of networks and its setting parameters have been kept to a minimum.

The new product has two operation modes: an access point mode (acting as a master network station) and a station mode (acting as a slave network station). In the access point mode, wireless devices can be easily connected to each other even in environments without wireless networks. When a wireless network is available, in the station mode, the product can be used as a slave network station.

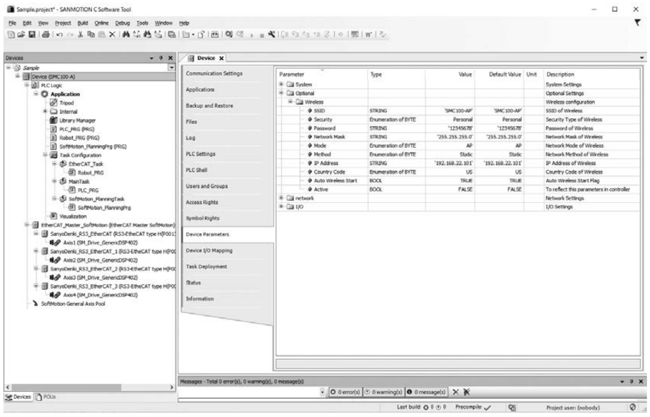

Fig. 5 Wireless LAN setting screen

3.2 Complies with IEEE 802.11b/g/n (2.4 GHz) wireless standards

Table 2 shows major wireless standards. The new product uses the IEEE 802.11b/g/n wireless standards that provide fast and long-distance communication, and supports the 2.4 GHz frequency band that provides greater penetration through obstructions such as walls.

The 2.4 GHz band is susceptible to inter-channel interference because it is used by a large number of devices. However, the new product comes with a function for checking ambient signal conditions. It automatically selects the best channel based on signal conditions, providing stable communications.

3.3 Compliant with radio laws of many countries

When exporting production equipment that comes equipped with wireless devices, it is necessary to meet the requirements of the radio communication regulations of importing countries. This means that the wireless devices of the production equipment would need to be replaced with devices compatible with the regulations of the importing country. However, the new product doesn't have to be replaced. By simply reconfiguring the setting parameters, it can be made compliant with the laws of many countries, including Japan, the United States, Canada, countries in Europe, China, Taiwan, and Thailand.

Table 2 Wireless standards

Items	Frequency [MHz]	Communication speed [Mbps]	Communication range [m]	Number of connectable units [Qty]	Radio wave interference	Power consumption	Versatility
Wireless LAN IEEE 802.11n	2400	65 to 300	100	32	Poor	Poor	Good
Bluetooth	2400	1 to 24	20	7	Average	Average	Average
ZigBee	2400 920	0.02 to 0.25	50	65,536	Good	Good	Poor

3.4 Shortens production facility downtime

By combining the new product with the web-based data visualization function of the *S100*, operators can view the status of production equipment in real time using smart devices (see Figure 6). In the event of an abnormality, operators are instantly notified of the circumstances so that they can quickly investigate the cause and perform recovery work. This minimizes equipment downtime.

Fig. 6 Visualization of production equipment conditions

In addition, it is often the case in manufacturing sites that communication of information between devices is performed using wired connections. Therefore, changing the layout of a manufacturing line will require time-consuming wiring work. In the event that a cable is damaged during wiring, this could result in a significant amount of manufacturing downtime. By using the new product to make communication wireless, wiring work becomes unnecessary and the layout of manufacturing lines can be flexibly changed with no risk of damaging cables (see Figure 7).

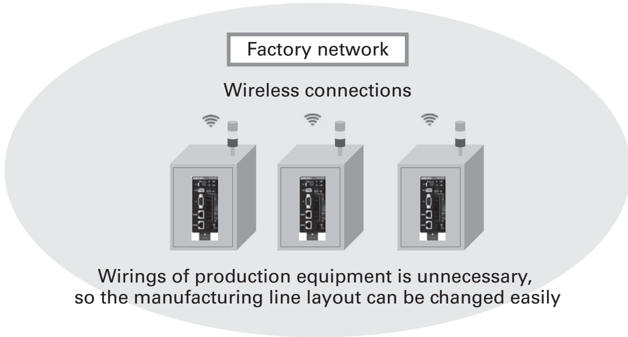

Fig. 7 Easy layout change

3.5 Improved maintainability

Figure 8 compares wired and wireless environments. Production equipment may sometimes be installed in locations where maintenance is difficult or even dangerous. The new product is especially useful in these environments. It enables operators to remotely diagnose failures in production equipment, perform program maintenance, configure servo systems, and update firmware from a safe location, greatly improving maintainability.

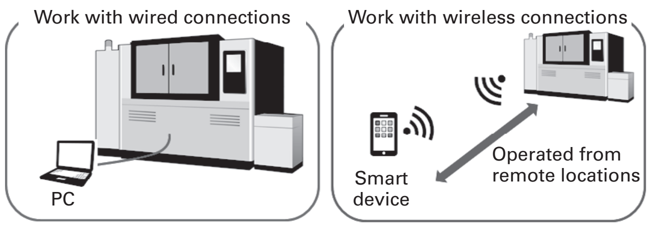

Fig. 8 Comparison of maintenance

4. Conclusion

This article introduced the features of the *Wireless Adapter 3A*. To recap, it can do the following:

(1) It can connect to the USB interface of the *S100* to provide the *S100* with wireless capabilities that simplify the construction of a wireless environment.

(2) It complies with the radio communication regulations of various countries, and doesn't have to be replaced when imported.

(3) It provides wireless capabilities that shorten production equipment downtime and improve maintainability.

The new product makes it easy to add wireless capabilities to the *SANMOTION C S100* motion controller. We expect that it will improve maintainability and contribute to the easy construction of manufacturing lines. We will continue to develop products that meet market needs and help create new value for our customers' manufacturing.

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