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# Overview



Author: *Kazuaki Iwata\**

## Thoughts on Monozukuri in the 21st Century

In the worsening global environment and the worldwide recession that emerged in 2008, Japanese monozukuri (manufacturing) companies are struggling under unprofitable conditions and uncertain prospects. Looking at the future of value-added monozukuri, I would like to focus on at least three viewpoints: (1) consideration of strategic risk, (2) paradigm shift to sustainable development, and (3) development of a new science of science and technology.

The first point considers various risks resulting from the increasingly complex monozukuri environment, globalization, and growing uncertainty; specific risks include the changing behavior of customers and competitors, the maturing and shrinking market, and the fluctuating exchange rate and price of natural resources. The second point requires explicit consideration of the global environment, natural resources and the like, which used to be an assumed external environmental condition. This new situation calls for the sustainable development of a total system incorporating external systems. Third, while conventional monozukuri relies solely on physical rule-based science and technology, we began to see the limits of this problem-solving approach. It is now important to have new viewpoints – a new science of science – integrated with the biological and social rules.

With a view to “Monozukuri as a civilization and culture” that encompasses those viewpoints, we look forward to the new monozukuri created by fostering the wisdom of humans, and utilizing both explicit and implicit knowledge.

# Servo Gain Self-Adjustment Function in MELSERVO

Author: Takayuki Wakana\*

## 1. Introduction

For the purposes of improving performance, eliminating the need for special skills, and reducing work time, we have developed "Advanced Gain Search", a new servo automatic adjustment function.

## 2. Features of Advanced Gain Search (AGS)

AGS provides the following:

- (1) Easy adjustment: Optimum adjustment is available without requiring special knowledge about the servo. → Eliminates the need for special skills and improves performance
- (2) Quick adjustment: Adjustment can be made in a short time by reducing the repetition of actual machine checks. → Reduces the work time
- (3) Stable adjustment: Enables adjustment with appropriate margins considering variable elements of the machine. → Improves quality
- (4) Secure adjustment: Enables adjustment that suppresses oscillation and prevents machine stress during adjustment → Improves work safety and prevents machine degradation
- (5) Visual adjustment: Easy-to-understand adjustment is available by using the display format that provides intuitive understanding of the adjustment results → Improves operability

## 3. Operation Flow

### 3.1 Adjustment parameter settings

Figure 1 shows the adjustment parameter setting screen.

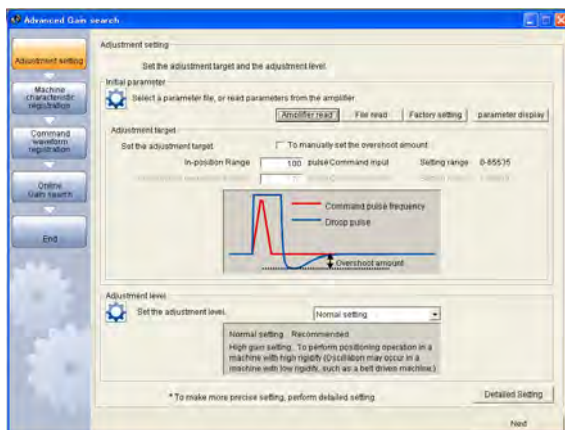


Fig. 1 Adjustment parameter setting screen

On the adjustment parameter setting screen, various parameters are read in and adjustment levels are set. On the left side of the screen, the AGS function displays a list of adjustment processes, highlighting the current process to help users easily understand the work processes.

### 3.2 Registration of machine characteristics

Machine characteristics data measured by using the machine analyzer function are registered on the machine characteristics registration screen.

- Adjustment considering variable elements of the machine characteristics

In the case of a machine as shown in Fig. 2, the distance between the servo motor and the work varies and thus the machine characteristics may change depending on the stop position of the machine. In such a case, the conventional process requires a set of adjustments at each stop position and this adjustment cycle is repeated until the adjustment is balanced and the target value is satisfied at all stop positions, resulting in a significant amount of work time due to the increased number of adjustment cycles. On the contrary, the AGS function enables a one-step adjustment dealing with the changes in machine characteristics thanks to the ability to register the machine characteristics for each stop position (up to nine points). In addition, by registering the characteristics of multiple machines, it is also possible to make an adjustment that considers the variance in mass-produced machines.

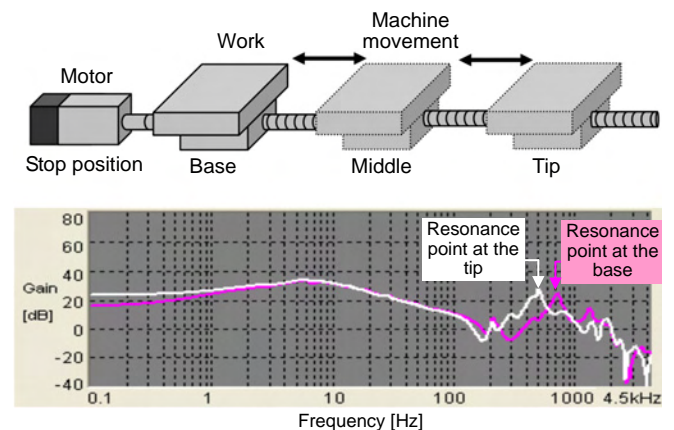


Fig. 2 Positional dependence of machine characteristics

### 3.3 Registration of command waveform

On the command waveform registration screen, a series of control data entered from the controller is measured and then registered by using the waveform measuring function.

- Adjustment considering multiple commands

Similar to the machine characteristics, command patterns also affect the adjustment process. Therefore, multiple sets of operation speed and traveling distance can be registered for up to nine points.

### 3.4 Online gain search

This process actually carries out an adjustment. Automated adjustment eliminates the need for special skills and making judgments. Consideration is also given to improved performance, reduced adjustment time, suppression of oscillation, and intuitive operation.

- Adjustment that maximizes performance

A machine resonance suppression filter is effective for improving machine responsiveness when there is a resonance frequency. Since the end-user's machine usually consists of many parts and thus has a resonance frequency, adjustment of the filter is an essential part of the servo adjustment to improve performance. The AGS function provides an automatic search on a personal computer for optimum filter settings that give the best responsiveness corresponding to the registered machine characteristics.

- Reduced adjustment time

During the adjustment work, the sequence of parameter change and results measurement is repeated. Of the total adjustment time, the percentage of actual machine operation time required for the measurement is greater than that for the parameter change. Therefore, prior to the actual machine operation, the parameters are narrowed down (coarse search) by carrying out a simulation on a personal computer. Based on the results, fine tuning (detailed search) is carried out by actual machine operation. Consequently, as shown in Fig. 3, the number of repetitions of actual machine operation cycle and hence the adjustment time are significantly reduced.

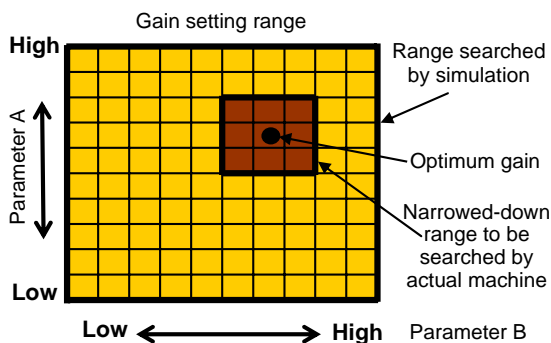


Fig. 3 Conceptual diagram of narrowed-down search

- Intuitive operability

As shown in Fig. 4, the adjustment results for various parameter combinations are indicated on a scatter chart, ranging from settling-time adjustment for reducing the takt time to overshoot adjustment (overrun distance beyond the target position) such as that required in the case of limited traveling range. The user is able to select any combination ratio between the two extremes by intuitively selecting an adjustment result that is close to the user's needs. (The default setting uses the recommended values calculated by Mitsubishi's proprietary evaluation function.)

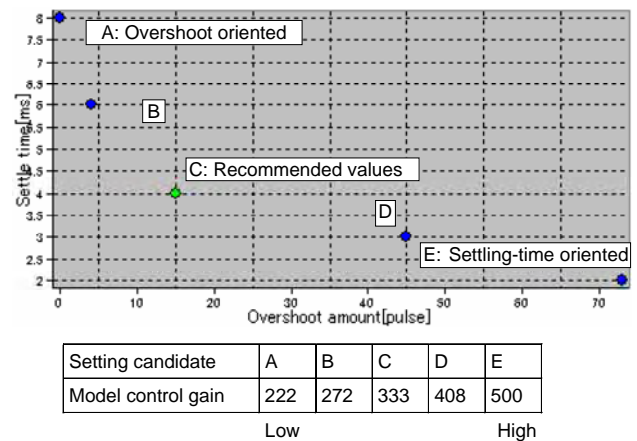


Fig. 4 Graphics display of adjustment results

- Suppression of oscillation during adjustment

During adjustment to search for the upper limit of the servo gain, oscillation is likely to be induced and the machine may be stressed. Therefore, prior to the actual machine verification, a computer simulation is carried out to confirm that no oscillation is induced; and, if necessary, the servo gain is lowered at the time of actual machine verification. In addition, during verification, if an overshoot distance exceeds the specified value as the responsiveness is being raised, the search is suspended to prevent oscillation. These preventive measures avoid any trouble due to oscillation during the adjustment work, allowing the user to securely perform the adjustment.

### 3.5 Completion

To help intuitively recognize the parameters altered by the adjustment, parameter values before and after the adjustment are displayed on the same screen, and the altered parameters are colored blue for easy recognition. Finally, the altered parameter values are written into the servo amplifier to complete the adjustment work.

#### 4. AGS Application Example

Figure 5 shows an example of an adjustment made by using the AGS function.

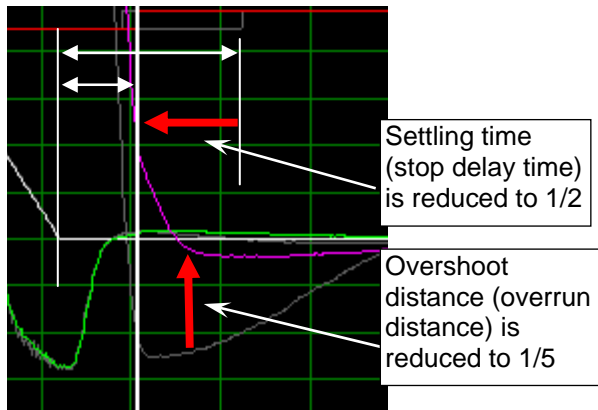


Fig. 5 Adjustment example

In comparison to the conditions before adjustment, significantly improved results were obtained including:

- Settling time (time from the stop command to the actual machine stop) was reduced to 1/2
- Overshoot distance was reduced to 1/5
- Adjustment time was reduced to 1/5 (from 20 minutes to 4 minutes)

We will continue product development to help users reduce their work time through enhanced adjustment functions.

# Easy-to-Operate and Compact Inverter, the *FREQROL-D700 Series*

Authors: *Manabu Yoshimura\** and *Masanori Kato\**

## 1. Introduction

Until now, the use of compact inverters has been limited to low-end applications. However, demand is increasing for cost reduction and downsizing of equipment, and the low-end product market also requires enhanced functionality, performance and reliability. In response, we are expected to provide not only low price and simple operability, that is, advantages of compact models, but also high performance, functionality and reliability.

In addition to the simple operability that has always been required in the low-end market, the newly developed compact inverter FREQROL-D700 provides the highest level of reliability, and improved drive performance equivalent to or better than the level of the previous model, FREQROL-E500, which has long been a leading product in the field of high-performance and high-functionality compact inverters.

## 2. Improved Reliability

### 2.1 Improved reliability in the control wiring

As the systems equipped with inverters obtain higher performance and functionality, they require an increased number of controller terminals, simpler wiring, and improved wiring reliability for compact inverters.

To ensure sufficient space for the required number of terminals on a compact product, the conventional approach was to use a screw-type terminal block with small-sized screws. However, this type provides only a low tightening torque, and thus the applicable wire gauges are limited to 0.75 mm<sup>2</sup>. In addition, when the equipment is operated or transported, vibration may loosen the screws and lead to poor electrical contact, necessitating frequent maintenance work such as screw re-tightening.

The FREQROL-D700 employs a spring clamp terminal. The spring structure prevents loosening of screws due to vibration, and eliminates the need for re-tightening maintenance. It also provides a simple wiring feature where special rod terminals are used and end-treated electrical wires are simply inserted to complete the wiring. In addition, the shape of the wire insertion opening and the structure of the internal spring are optimized to accept greater wire gauges up to 1.5 mm<sup>2</sup>, resulting in improved reliability.

This spring clamp terminal solves the problems related to the control wiring of conventional models, and the FREQROL-D700 has achieved both the highest level of wiring reliability and simplicity of wiring.

### 2.2 Safety stop function

For the first time with Mitsubishi general-purpose inverters, the FREQROL-D700 is equipped with a shutoff circuit conforming to the following safety standards, facilitating compliance with the European Machinery Directive.

- EN954-1 Category 3
- IEC60204-1 Stop Category 0

We also plan to obtain ISO 13849-1 certification.

The hardware for the shutoff circuit has a double redundant configuration. It monitors any failure in the shutoff circuit, and if detected, triggers an external alarm (Fig. 1). This built-in circuit enables emergency output shutoff, having reliability equivalent to a configuration with two external magnetic contactors (Fig. 2).

## 3. Expanded Application Range with Improved Drive Performance

### 3.1 Performance of 150%/1 Hz achieved with general-purpose magnetic flux control

General-purpose inverters are often driven by constant voltage/frequency (V/F) control, which takes advantage of the characteristics of induction motors. However, with V/F control operation, a motor is unable to generate its maximum torque, particularly in a low rotating speed range. To solve this problem, the

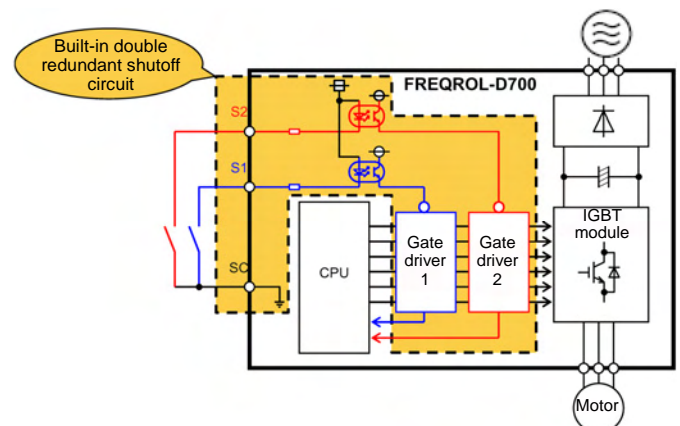


Fig. 1 Shutoff circuit

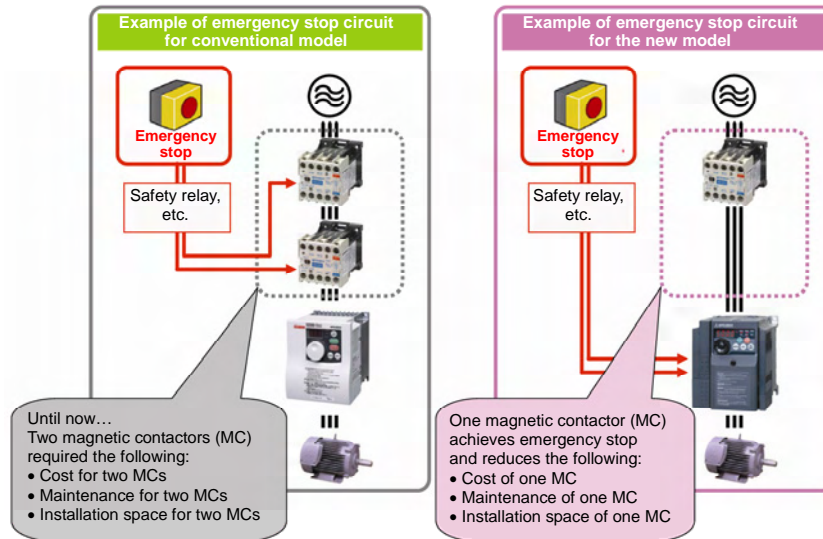


Fig. 2 Safety standards compliance

FREQROL-D700 employs the same type of current detection circuit as the FREQROL-E700 for enhanced current detection accuracy, as well as the general-purpose magnetic flux control found on high-end models of the previous FREQROL-E500 series. Consequently, the FREQROL-D700 has achieved top-level drive performance of its class at 150%/1 Hz, making it ideal for equipment that needs a high starting torque (Fig. 3).

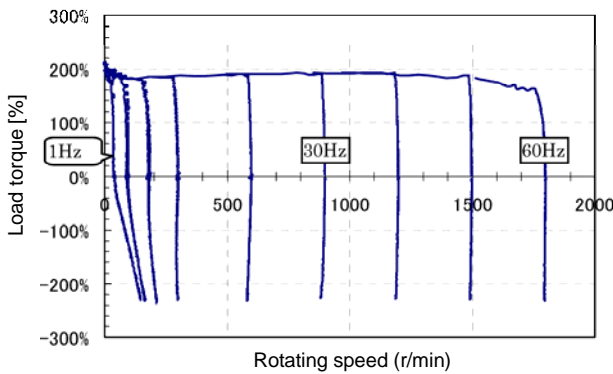


Fig. 3 Speed-torque characteristics of D700

### 3.2 Integrated easy startup function

If the power is lost, the motor decelerates to a stop, and automatically restarts when the power is restored; such drive continuation capability is required in the event of a brief power failure. While conventional models are already equipped with a power failure stop function, the FREQROL-D700 now automatically controls the output frequency to maintain the internal voltage that normally drops when the power is lost. As a result, parameter adjustment needed with conventional models is no longer required, and operation can be continued easily and securely at the time of power failure. (Fig. 4)

## 4. Easy Operation and Maintenance

### 4.1 Easy setup with the FR Configurator

Inverter operation mode is set up by setting the parameters. When a conventional model is replaced with a new model, the user is asked to set up the parameters so that the same operation mode is maintained. Since some of the parameter numbers of the FREQROL-D700 differ from those of the conventional FREQROL-S500 model, parameter setting for the new model may take a long time.

Therefore, the FR Configurator, an engineering tool executable on a personal computer, has been developed to provide easy conversion from the conventional model parameters to those for the new model.

### 4.2 Long service life and service-life diagnostics

The FREQROL-D700 takes over the common concept of the 700 series products, that is, improved maintainability and reliability provided by the long service life of parts and the service-life diagnostics function.

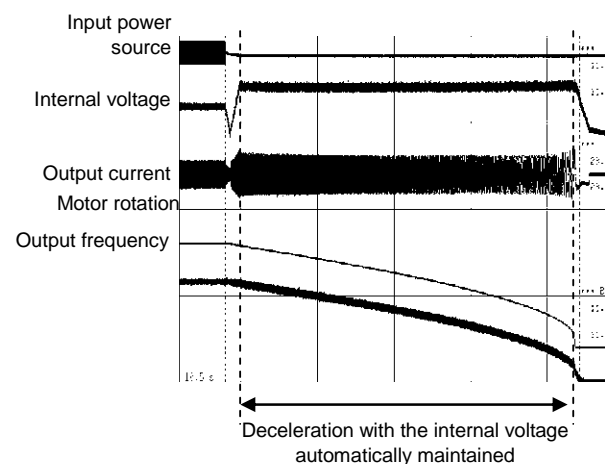


Fig. 4 Deceleration to stop sequence at a power failure



These features along with the previously described maintainability of the control wiring provided by the spring clamp terminal have achieved the highest level of maintainability for Mitsubishi inverters.

## 5. Conclusion

The new compact FREQROL-D700 inverter was developed focusing on high reliability and simple operability. We will continue to develop easy-to-operate, high-value-added products.

## References

- (1) Yasuhiro Shiraishi, Katsushi Ikeda, Shizuri Tamura, and Yoshihiko Kinpara: "Next Generation Energy Saving Inverter 'FREQROL-F700 Series'", Mitsubishi Denki Giho, Vol. 79, No. 3, pp. 189–192.
- (2) Katsushi Ikeda, Yasuhiro Shiraishi, Akira Imanaka, and Yoshihiko Kinpara: "The Next Generation High Performance Inverter for General Purpose 'FREQROL-A700 Series'", Mitsubishi Denki Giho, Vol. 79, No. 11, pp. 735–738.
- (3) Goichi Kajiura, Kiyoshi Eguchi, and Masaki Kono: "Easy to Operate, Powerful and Small-size Inverter 'FREQROL-E700 Series'", Mitsubishi Denki Giho, Vol. 81, No. 4, pp. 289–292.

# Standalone Type Motion Controller

Author: Hiroshi Mihara\*

## 1. Introduction

The Q17nDCPU motion controller series is compatible with the Mitsubishi FA integrated concept “iQ Platform”, and has achieved improved performance as well as high-speed coordination control with the sequencer CPUs. To enhance the lineup of motion controllers, we developed a standalone-type motion controller for the market that requires a product optimized for small-scale systems (wrapping machine, winding machine, etc.) (Fig. 1).

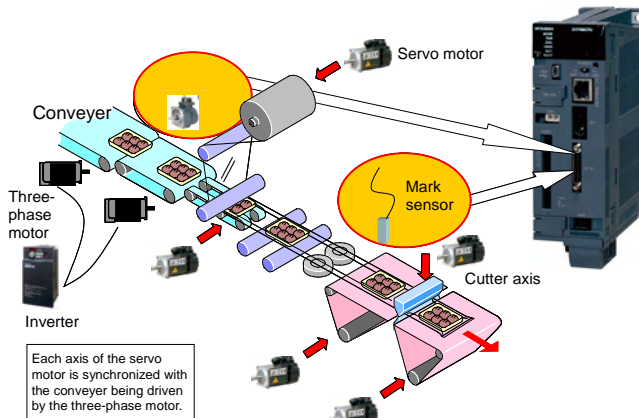


Fig. 1 Application example for food wrapping machine

## 2. Overview and Key Features of Q170MCPU

### 2.1 Integration of synchronization control functions into single unit

The Q Series multi-CPU motion system consists of a base unit, power supply unit, programmable controller CPU, motion CPU, and other I/O units. Applications for the Q170MCPU are confined to small-scale systems, and thus only those functions required for synchronization control are integrated into the single unit.

### 2.2 High-speed motion processing

The hardware and software architecture of the new controller follow those of the Q17nDCPU to maintain the same performance. The cycle time for motion calculation is 0.44 ms for controlling one to six axes, and 0.88 ms for seven to 16 axes. A cyclically performed task, the Motion Sequential Function Chart (Motion SFC), is executed at an interval of 0.44 ms to achieve consistent, high-speed motion control.

### 2.3 SSCNET III compatible servo interface

The servo interface is compatible with the high-speed synchronous servo network SSCNET III with an optical communication system, and enables the control of daisy-chain-connected servo amplifiers (MR-J3-B/MR-J3W-B) up to 16 axes.

External servo signals (limit switch, near-point DOG signal, and speed-position switching signal) are accepted via servo amplifier, eliminating the need for an external input unit.

### 2.4 Optimization of bus load

The Q Series motion controllers execute control via external units, and their input and output signals are connected over the system bus. However, in addition to the I/O control of external units, this system bus is also used for various data communications such as exchanging system control information between CPUs. As a result, the response time varies depending on the bus load, and the variation may affect highly real-time operations that require data input in every motion processing period, such as for a synchronous encoder.

In the Q170MCPU, highly real-time signals such as synchronous encoder signals and mark sensor signals are fed directly to the ASIC on the motion CPU side. Consequently, stable control can be provided independent of the variation in the system bus load (Fig. 2).

### 2.5 Coordination between CPUs

A key point for improving overall system performance is appropriate distribution of the total load between the sequence control (information and overall system control) and the motion control (servo control), and thus it is important how data is transmitted and received between the programmable controller CPU and the motion CPU.

#### 2.5.1 High-speed data communication over the inter-CPU high-speed bus

The inter-CPU communication means implemented in the Q170MCPU is a high-speed serial bus, the same as in the Q17nDCPU. Data communication between the CPUs is performed via the shared CPU memory interconnected by this serial bus.

The high-speed serial bus is dedicated for cyclic communication of device data and other information between the CPUs. Data in the shared CPU memory, up to 16 k words (including system area), is refreshed

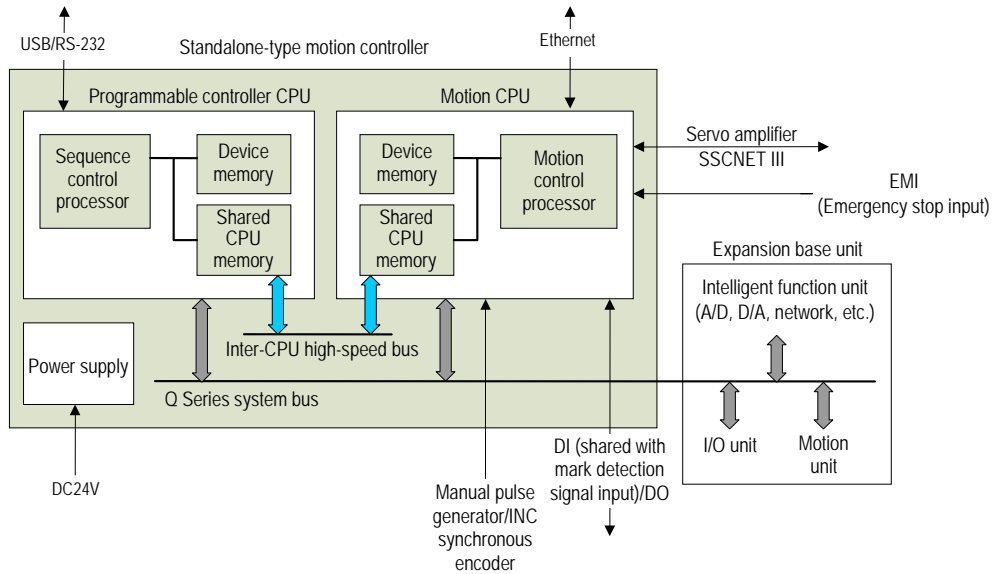


Fig. 2 Internal system configuration

at a high speed via the serial bus. The data is always refreshed at a constant interval (0.88 ms) synchronized with the motion control interval and independent of the user program load on each CPU. Therefore, servo control data can be efficiently transmitted.

In this way, sophisticated system control is realized by the close coordination between the sequence control and motion control, resulting in significant takt time reduction. A conceptual diagram of the shared CPU memory is shown in Fig. 3.

### 2.5.2 Synchronization between motion control and sequence control

In the processing steps on the programmable controller CPU, it is possible to describe an interrupt sequence in synchronization with the interval of this inter-CPU high-speed transmission. Since this interval is synchronized with the motion calculation interval as well, it is also possible to perform sequence processing in synchronization with the motion control. With these capabilities, the high-speed servo control is able to use information taken from the external units (high-speed counter module, analogue-digital converter module, etc.) mounted on an expansion base unit controlled by the programmable controller CPU, and thus a variety of sequence-oriented applications can be designed.

## 3. Engineering Environment

### 3.1 Engineering environment shared with the Q Series

To achieve improved customer efficiency from the development/design stage to the service stage, the engineering environment for the programming, debugging and maintenance of the new controller remains the same as that of the Q Series motion system

Programming for the controller CPU and the motion CPU also remains the same. User codes developed for the iQ Platform based system require little modification, thereby reducing the cost of the transition from the existing system.

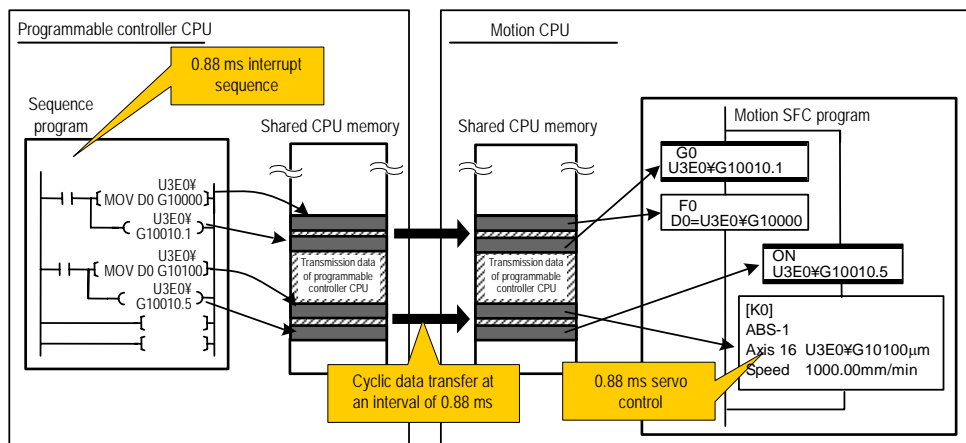


Fig. 3 Conceptual diagram of shared CPU memory

### 3.2 Improved debugging efficiency

For connection with personal computers (engineering tool), USB and RS-232C ports as well as an Ethernet port are provided. By using these ports, two individually operated personal computers can simultaneously perform sequence program debugging, and motion program debugging and servo gain adjustment, respectively. As a result, program debugging and machine adjustment tasks can be efficiently performed by multiple engineers (Fig. 4).

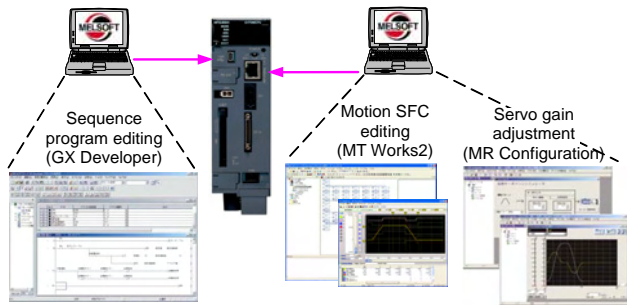


Fig. 4 Improved debugging efficiency using multiple personal computers

### 4. Conclusion

We have developed a standalone-type motion controller fully utilizing existing hardware and software resources. The new controller is suitable for small-scale systems that require synchronous control with servo drives. We will continue to expand the application area by introducing new motion controller products best suited for the market needs.

# Multi Hybrid Drive, the MDS-DM Series

Authors: Kazuyuki Nakamura\*, Yoji Tsutsumishita\* and Yoshitomo Hayashi\*

## 1. Introduction

Mitsubishi Electric offers converter/inverter separate-type drive units for CNC machine tools in response to the need for various machine configurations (number of axes). However, a configuration with a 1-axis spindle and 3-axis (or 2-axis) servo is the mainstream of CNC machine tools in the Asian market. In response, we developed and commercialized the multi hybrid drive, the MDS-DM Series, which integrates the spindle drive and servo drives into one unit and serves as a complete CNC drive unit specialized for the mainstream configuration (Table 1).

The features of the MDS-DM Series are:

- (1) All-in-one unit integrating the servo drive units, spindle drive unit, and power supply unit, achieving smaller size and better cost performance than conventional separate-type models
- (2) Enhanced power regeneration algorithm for higher-quality environmental power supply even under poor-quality main power supply

Table 1 MDS-DM Series product lineup

	MDS-DM-SPV2	MDS-DM-SPV3
Servo capacity	80A (3.5 kW) x 2	80A (3.5 kW) x 3
Spindle capacity	200A (15 kW) 160A (11 kW) 100A (7.5 kW)	200A (15 kW) 160A (11 kW) 100A (7.5 kW)
Power supply capacity	18.5 kW (Momentary 60 kW)	
External dimensions	H: 380 x W: 260 x D: 180+90 (mm)	

\* +90 mm in depth D is a cooler space outside the panel.

## 2. Optimum Design with Multi-axis Integration

To operate a machine having three servo axes and one spindle axis with the conventional system, 2-axis and 1-axis servo drive units, 1-axis spindle drive unit, and power supply unit must be combined. To integrate them into an optimum system (Fig. 1), we developed the following:

- (1) Software to enable one CPU to control three servo axes simultaneously, an increase from two axes in the conventional system
- (2) Unitized current sensing resistor for motor current sensing, by redesigning the previous electrical conductor as a structural element for accuracy-controlled resistance
- (3) Common design for the control power supply circuit

and structural members needed in each unit.

As a result of these developments, we realized a parts count reduction of 37%, smaller unit size<sup>Note 1</sup>, and improved cost performance.

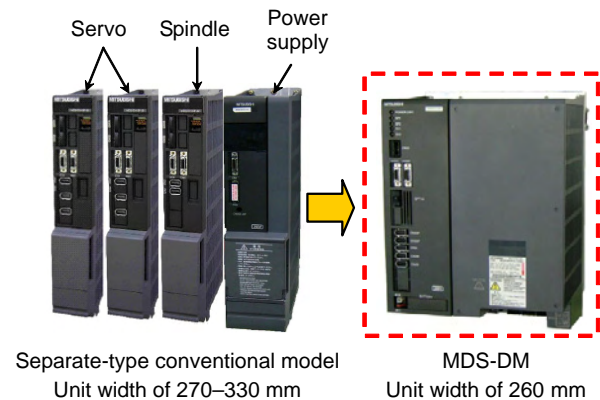


Fig. 1 Multi-axis integrated MDS-DM Series

## 3. Improvement of Environmental Power Supply Quality

The newly developed MDS-DM Series was evaluated in accordance with International Standard IEC61000 test methods regarding the environmental impact of power supplies, and achieved higher environmental quality than the conventional models.

Power supply phase detection during power regeneration is usually performed by monitoring the line-to-line voltage of the alternating current power supply to detect zero cross points. Based on these zero cross points, the switching timing is determined for the power regeneration switching element.

While this method has the advantage of easy system implementation, the power regeneration timing almost overlaps the zero cross points of the line-to-line voltage, resulting in the disadvantage of possible erroneous detection of power supply phase (Fig. 2).

The power supply phase detection method of the MDS-DM Series was improved to overcome this disadvantage and to ensure accurate power regeneration control.

Three phases of the alternating current power supply are star-connected to generate a phase-to-neutral-point voltage for each phase. Based on the zero cross points of these phase voltages, the

Note 1 In contrast to a total width of 270–330 mm for the separate-type conventional system, the MDS-DM Series has a unified width of 260 mm.

power supply phase is detected (Fig. 3). With this method, zero cross points of the phase voltages do not coincide with the power regeneration timing, thereby allowing power supply phase detection without any influence from the regeneration switching.

Since the international standard used for our evaluation is based on the European environment, we carried out testing beyond the limits of the standard, assuming a more global environment. Table 2 shows

the results of the power supply phase detection test.

#### 4. Conclusion

We developed the MDS-DM Series, CNC drive units for the Asian market, achieving smaller size, better cost performance, and improved environmental power supply quality. We will further refine the know-how acquired through these development efforts, and continue developing international products.

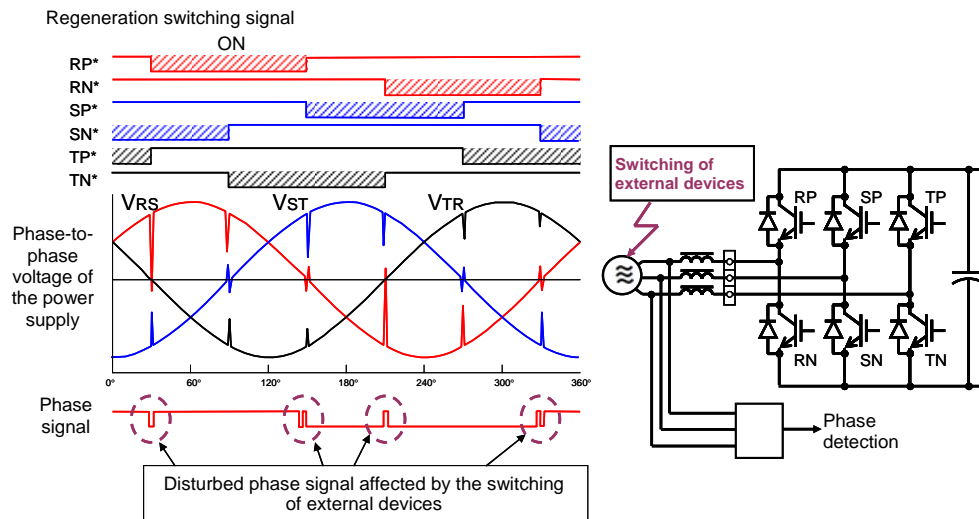


Fig. 2 Method of power supply phase detection (Conventional model)

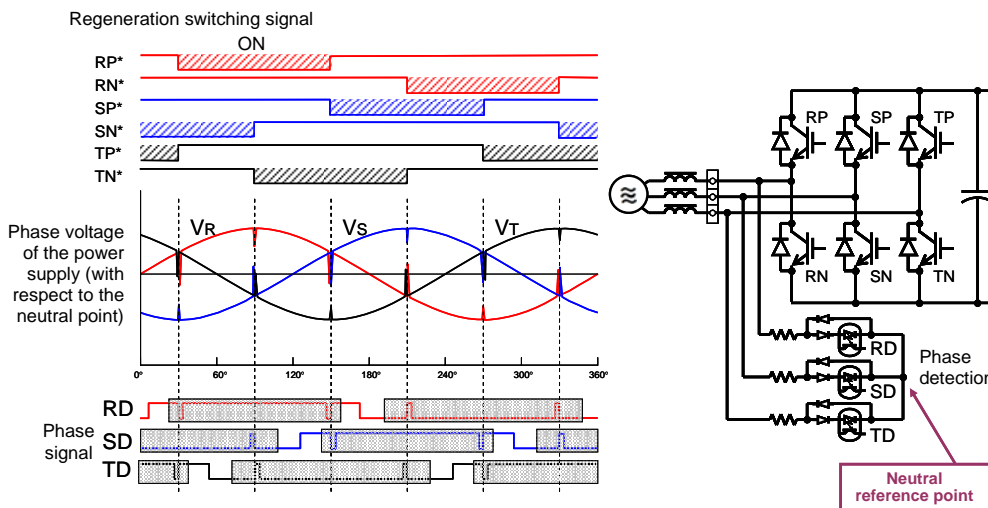


Fig. 3 Method of power supply phase detection (MDS-DM Series)

Table 2 Power supply distortion test results (comparison with conventional model)

Harmonic number (Specification)	Distortion (Specification)	Developed model (MDS-DM Series)	Conventional model (MDS-D-CV Series)
2nd	5%	⊙	○
3rd	9%	○	○
4th	2%	○	○
5th	12%	⊙	○
7th	10%	⊙	○

○: Comply with the specification

⊙: Quality beyond the specification was confirmed.

# New Mitsubishi CNC M700V Series

Author: Hirokatsu Miyatake\*

## 1. Introduction

We have developed the M700V Series, a higher-performance CNC (computerized numerical control) series with a newly developed LSI. It includes two sub-series, the M700VS Series with integrated control unit and display, and the M700VW Series with separate control unit and Windows<sup>(\*)</sup> display.

Here, we introduce the features of the new M700V Series and our latest control technologies for the series.



Fig. 1 Mitsubishi CNC M700V Series

## 2. M700V Series: Background of Development

We developed the widely used, highly regarded CNC M70 Series suitable for the Asian market. In contrast, markets such as Japan, America and Europe, which are advanced in high-function fields, demand CNCs that deliver higher productivity with reduced cycle time, faster and higher-accuracy nanocontrol and high-grade 5-axis machining.

In order to meet these market demands, we have commercialized the M700V Series by enhancing the

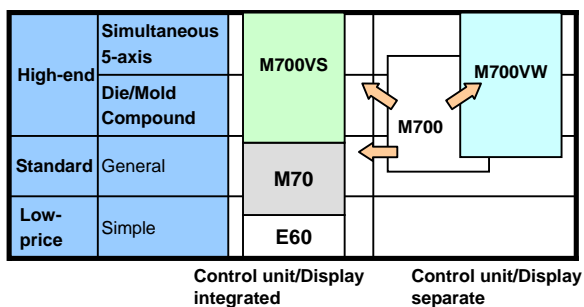


Fig. 2 Mitsubishi CNC product lines

performance and functions of the current high-end CNC M700 Series, and by adding a series with an integrated control unit and display. The newly developed LSI is mounted to strengthen the basic control performance, and it also provides a new SSS-3G function for high-grade 5-axis machining.

## 3. M700V: Features

### 3.1 A new architecture

The current high-end M700 Series enables high-grade precision machining by controlling all processing from numerical to servo in 1-nm units. With the M700V Series, for faster and higher-accuracy complete nanocontrol, we reexamined the architecture and developed the CNC-dedicated LSI. The LSI brings enhanced data processing performance with improved usability of the internal bus, as well as enhanced PLC processing performance. This has made the M700V Series realize 1.12 times greater machining program capacity and double the macro capacity compared to the M700. The basic instruction processing capacity of the PLC is 10 ns/instruction, which is the fastest in the CNC industry. As for PLC scan time, it is 1/5 that of the M700.

### 3.2 M700VW Series

An M700VW Series CNC consists of a control unit and a separate display with an embedded PC + Windows. This structure allows Japanese/American/European machine tool builders to conveniently carry out screen development and to add unique functions.

The installation dimensions and communication interface are completely compatible with the M700, which will ensure easy transfer from the M700. Cost performance has also been improved by widely upgrading the basic capacity as a CNC.

### 3.3 M700VS Series

In the M700VS Series, the control unit and display are integrated, targeting high-performance machine tools with less customizing required for Windows. Its dedicated graphic LSI accelerates operativity and response time such as the screen change speed, and the Mitsubishi standard M700 screen has been implemented without Windows.

For custom screen development, we have improved the NC Designer tool for the M700 to support a

(\*) Windows is a registered trademark of Microsoft Corporation.

Windows-less CNC.

The M700VS Series achieves a good balance between high basic performance, operativity, and cost performance, and at the same time, its installation, wiring, and peripheral units are compatible with the M70 Series, which enables easy transfer from a standard machine to a high-function machine. In response to the demand for higher performance received from machine tool builders, we offer measures to easily enhance performance with less development work.

In addition, considering heat generation, we have suppressed power consumption by setting the bus width and operation frequency according to the data size and by applying voltage reduction technology, achieving a 66% reduction in electric energy compared to the M700. Since this eliminates the need for a cooling fan that brings external air into the machine tool's operation board, a closed-structure operation board can be realized. This prevents cutting oil from entering the board, and reduces the risk of damage to various electrical parts. Furthermore, thermo-fluid analysis is actively utilized for the M720VS to eliminate the self-cooling fan, which reduces the maintenance duties.

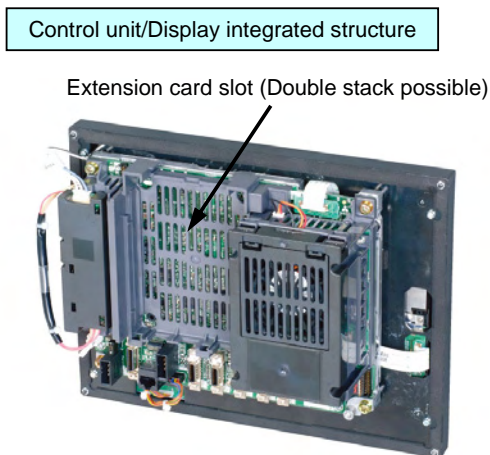


Fig. 3 Rear view of M700VS

#### 4. Control Technologies for High-grade 5-axis Die/mold Machining

Due to improved hardware performance, the fine segment processing capacity for die/mold machining has been enhanced from 135 kBPM (k block per minute) to 151 kBPM, and further reduced machining time for die/mold machining is expected. In addition, based on the recent growing need for simultaneous 5-axis machining, we enhanced SSS control for high-speed high-accuracy die/mold machining to develop SSS-3G control for simultaneous 5-axis machining.

SSS control improves the accuracy and efficiency of die/mold machining by judging a commanded shape in terms of a large area for the machining program to optimize the machining time according to the shape,

which helps to realize higher-grade machining in a shorter time. SSS-SG control is the enhanced version of the conventional SSS control, for higher-grade simultaneous 5-axis machining.

#### 4.1 SSS control applied to tool center point control

We have applied SSS control to tool center point control, which is a basic control for simultaneous 5-axis machining. As shown in Fig. 4, this is effective when a tool center point's program path has minute stepping. The tool center point is controlled to move smoothly by the optimized machining speed for a program path to avoid unnecessary deceleration.

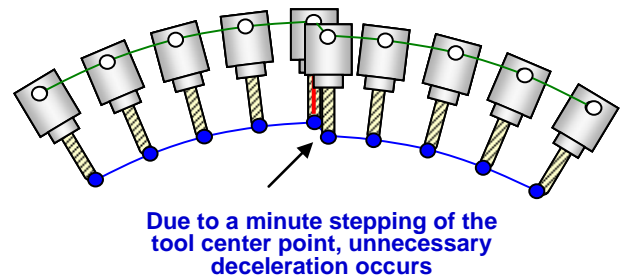


Fig. 4 Tool center point path with SSS control

#### 4.2 Introduction of rotary axis prefiltering

The linear axes and rotary axis move simultaneously in simultaneous 5-axis machining, so the varied movement of the rotary axis affects the tool angle, resulting in deteriorated machining quality. By prefiltering rotary axis commands to ensure smooth rotary axis movement, the tool angle shifts smoothly, as shown in Fig. 5, to suppress vibration at the tool center point.

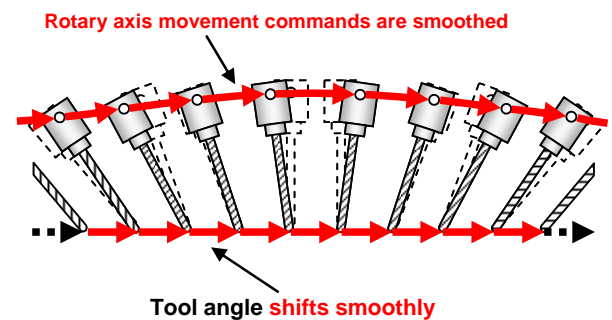


Fig. 5 Rotary axis prefiltering

Various unique technologies have been merged and refined in a new CNC. We are pleased to contribute to the global manufacturing industry by raising the level of our products for wider use by more customers.



# *New Frame-Type Spindle Motor, the SJ-D Series*

Author: Toru Ogawa\*

## 1. Introduction

Spindle motors for machine tools can be grouped into two main categories: frame-type spindle motors and built-in spindle motors. A frame-type spindle motor is generally configured into an assembled complete product (Fig. 1), whereas a built-in spindle motor is directly assembled inside the spindle unit of the machine tool.



Fig. 1 Frame-type spindle motors

The recent machine tool market is being polarized into high-end machines and affordable machines. A high-end machine is designed to have high added value such as a combination machine tool capable of machining complex shapes; and an affordable machine is devised for general machining. While high-end machines are generally equipped with built-in spindle motors, affordable machines usually have frame-type spindle motors that allow a simple structure for the spindle unit. Meanwhile, demand is rapidly increasing for spindle motors in China, Taiwan, India and other regions in Asia, where low-end machines have a higher market share with an emerging requirement for a frame-type spindle motor that provides energy and resource conservation, light weight, and high reliability.

This report provides an overview of our development of the new SJ-D Series frame-type spindle motor, which could provide an answer to these needs.

## 2. Features of the SJ-D Series

We fully utilized our design, analysis and manufacturing technologies to develop the SJ D Series leading to the future standard series of frame-type spindle motors. Their features include:

(1) Energy conservation through achievement of low-loss, high-efficiency operation

- (2) Resource conservation through reduction of raw materials used in manufacture  
 (3) Weight reduction, enhancing the rigidity during operation  
 (4) Low vibration, conforming to vibration level V3  
 (5) New industrial design that emphasizes uniformity

Among the technologies required to realize these features, the optimization of electrical design, and optimization of air draft cooling structure are detailed in the following sections.

## 3. Optimization of Electrical Design

### 3.1 Optimization of the electrical design of development model

In the electrical design of our development model, the highest priority was given to low-loss, high-efficiency operation to conserve energy, with a target of 20% reduction in electrical loss from the level of the conventional model.

In light of the analysis results of the conventional model, we applied the following two approaches to optimize the electrical design: (1) to achieve uniform magnetic flux density distribution, and (2) to optimize the slot combination. To this end, we performed a parameter study of optimum core dimensions by using electromagnetic field analysis.

### 3.2 Effect of optimized electrical design

We designed a development model using the optimum dimensions obtained through the parameter study. In this design, consideration was given to creating a uniform magnetic flux density distribution for reduced iron loss, and optimizing the stator and rotor slot combination for reduced harmonic secondary copper loss.

Reflecting these results of electrical design optimization, we built a development prototype, and measured the electrical characteristics during loaded operation (1500 [r/min], 5.5 [kW]) to analyze generated loss. The measurement results are shown in Fig. 2. In comparison with the conventional model, the development model significantly reduced loss mainly attributed to iron loss, ensuring higher efficiency, namely, 25% reduction of total electrical loss.

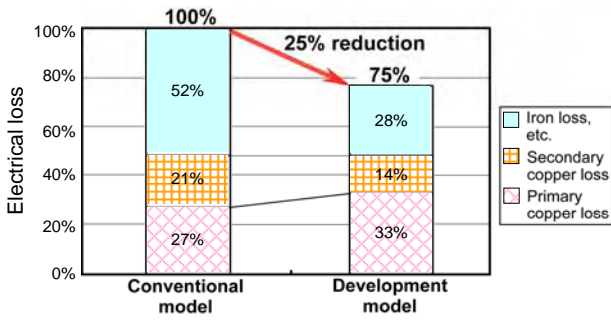


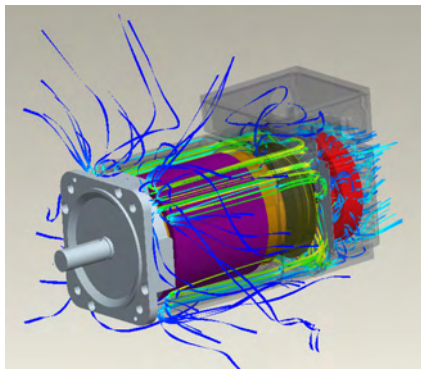
Fig. 2 Measurement results for electrical loss

#### 4. Optimization of Air Draft Cooling Structure

##### 4.1 Optimization of air draft cooling structure for development model

For the development model, in addition to the reduction in heat generation achieved by the reduced electrical loss as described in Section 3, we optimized the air draft cooling structure with a target of 30% reduction in temperature rise on the frame surface from the level of the conventional model. To achieve this, we did the following: (1) increased the heat radiation area, (2) improved the thermal conductivity, and (3) increased the cooling air flow rate.

To increase the cooling air flow rate, we performed fluid analysis to optimize the shape of the air draft passage and carried out a wind tunnel experiment to determine the optimum values. Figure 3 shows an example of the simulation results of fluid analysis. For optimizing the air draft cooling structure, we adopted a frame that is integrally molded with the air draft passage and optimized the position of the cooling fan and other parameters to reduce the pressure loss.



\* Strip-shaped lines indicate the trajectory (path line) of the cooling air flow, and the color levels indicate the difference in the flow speed.

Fig. 3 Simulation results of the fluid analysis

##### 4.2 Effect of optimized air draft cooling structure

The surface area of the frame of the development model was increased by 10% from the conventional model. Thermal conductivity was also improved by adopting an aluminum alloy frame integrally molded with the air draft passage. Through these outcomes, as well as through the reduction of electrical loss, temperature rise was reduced as shown in Fig. 4. After continuous operation at the rated output (1,500 [r/min], 5.5 [kW]) and after the motor reached completely saturated conditions, the reduction in temperature rise was 34% at the stator core, and 32% at the frame surface.

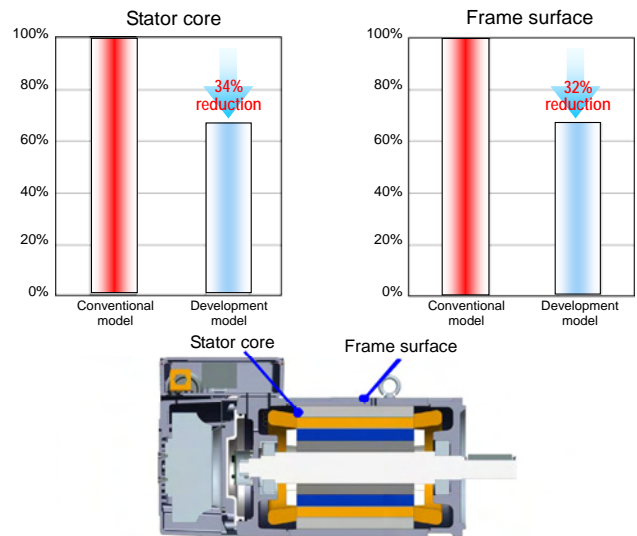


Fig. 4 Temperature rise reduction effect of each motor

#### 5. Conclusion

This report described some of the engineering efforts and key features of the newly developed SJ-D Series frame-type spindle motor, which has led to energy and resource conservation, light weight, and high reliability, and sets the standard for the frame-type spindle motors of the future. We will continue to work on energy and resource conservation to expand the lineup of environment-friendly spindle motors.

