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Latest Trend of Factory Automation (FA) Components and Industrial Machinery Systems in which Motion Control Technology and Other Control Technologies are Applied

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Changes for the Better

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Technical Reports

Precis

Under the slogan of "Mitsubishi FA Global No. 1," Mitsubishi Electric has been actively releasing new products to the FA market, particularly in Asian countries. This issue presents FA products that have been developed to meet global needs in order to strengthen the competitiveness of Mitsubishi's products.

Overview

Author: *Kenichi Tanaka**

Trend of Motion Control Technology for FA Components and Industrial Machinery Systems

All automatic machinery is equipped with motion control to ensure the optimum speed and accuracy of positioning, which determines the basic performance of mechanical systems. Thus, motion control is one of the most important technologies for the productivity of industrial components. Incorporated as a software program, motion control is a complex combination of various theories with the latest hardware technologies for mechanical and electric systems. For factory automation (FA) equipment and other industrial applications, such technologies are used extensively at the heart of machine tools, robots, semiconductor equipment, injection molding machines, and inspection equipment for digital appliances. Capital investment in motion control equipment in the global market is accelerating.

Furthermore, amid rising demand such as for safety measures and energy saving, it is now possible to construct intelligent control systems with higher added value. We will continue to improve the ease of use and performance of control systems by developing motion control technologies to meet the customer demand for more efficient, more accurate and faster mechanical systems.

**General Manager, Advanced Technology R&D Center*

Development of Next Generation Servo Amplifier "MR-J4 Series" and Servo Motor "HG Series"

Authors: *Kiyonari Kawajiri** and *Kazuyuki Enomoto**

1. Introduction

General-purpose AC servos used for the drive control of various mechanical devices must meet diverse market needs for high functionality, ease of use, and energy saving, as well as for high performance and accuracy.

We have developed the "MR-J4 Series" servo amplifier and "HG Series" servomotor under the concept of "harmony with man, machine, and environment," based on compatibility and the legacy of the conventional MR-J3 servo amplifier and HF servomotor. The features are described below (Fig. 1).

Man: Easy to use (pursuit of usability), automatic adjustment to maximize machine performance, and maintenance support function

Machine: Ultrafast speed, fast response, high accuracy, and low torque ripple

Environment: Space saving, wire saving, resource saving, and energy saving

2. Ultrafast Speed, Fast Response, High Accuracy, and Low Torque Ripple

The general-purpose MR-J4 AC servo amplifier and HG servomotor ensure industry-leading ultrafast speed, fast response, and high accuracy.

(1) In the MR-J4 series, the speed frequency response, which indicates the speed of response, has been improved from the conventional response of 0.9 to 2.5 kHz by using dedicated large-scale integrated (LSI) circuits, which is a unique high-speed servo architecture.

Moreover, in the SSCNET III/H, the advanced motion network communication of SSCNET III (Servo System Controller NETwork), full-duplex 150 Mbps – three times faster than the conventional speed – has been achieved to dramatically improve the system response.

(2) The HG series servomotor is equipped as standard with an absolute position encoder with four million pulses (4,194,304 p/r), 16 times higher than the conventional resolution. Additionally, torque ripple (distortion of torque) has been reduced by inclining the core tip in the axial direction. As a result, the torque ripple of the HG motor has been reduced by up to 75% (HF ratio).

3. Automatic Adjustment to Maximize Machine Performance

3.1 Advanced one-touch tuning

To maximize servo performance, it is necessary to

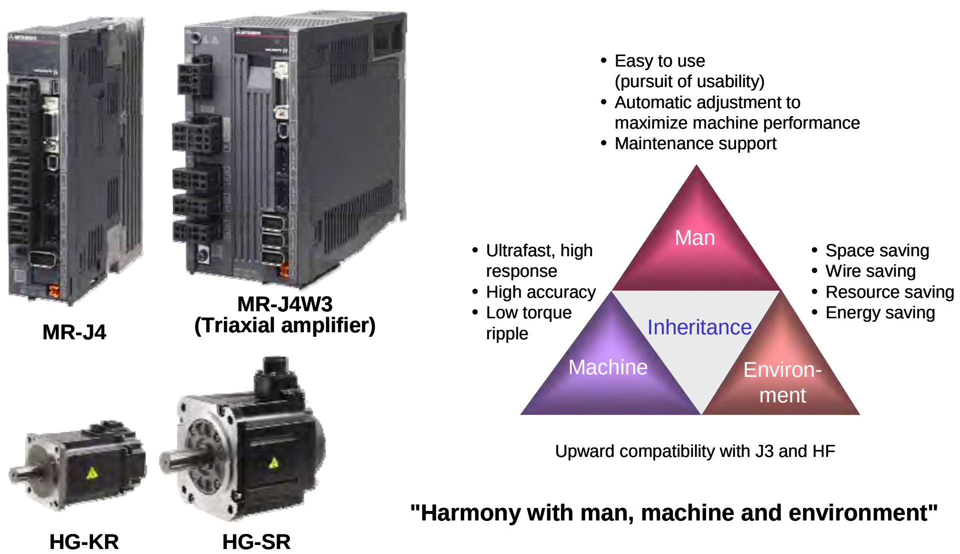


Fig. 1 Servo amplifier "MR-J4 series" and servo motor "HG series"

*Nagoya Works

adjust various control parameters according to the mechanical properties and operating specifications of the equipment. Among our servos, the MR-JN series is designed for ease of use, with a one-touch tuning function that automatically completes optimum adjustment just by pressing a switch during positioning – a highly acclaimed feature. This time, we have developed a function to increase performance by inheriting the ease of use, improving the adjustment rules, and extending the control methods.

This function optimally adjusts multiple machine resonance suppression filters, while automatically changing the control gain and checking the oscillation limits. Additionally, control to suppress residual vibration is automatically applied as needed, which shortens the settling time.

3.2 Advanced vibration suppression control II

In the positioning of chip mounters or semiconductor test equipment, residual vibration at the time of halt, which is caused by low machine rigidity, can be a major problem. As a countermeasure, vibration suppression control and automatic control adjustment, with which the MR-J3 series is already equipped, have become essential for positioning control. On the other hand, there is a growing demand for easier installation and lighter equipment, in addition to high-speed drive. For example, multiple vibrating parts can often become a problem, such as vibration in not only the machine stand on which the motor is mounted, but also in the moving part of the arm. If simple duplex vibration suppression control is used for these vibrating parts, other problem arise such as longer settling time.

Accordingly, we have developed a method to achieve fast settling while suppressing two vibrating parts, assuming that the elastic three-inertia system is a controlled object model (Fig. 2). In this method, a reference model of the three-inertia system that works to suppress vibrations in the servo amplifier control system is calculated, and a motor using the model torque and model position/speed is controlled. Furthermore, we have developed a method to automatically estimate the characteristics of two vibrations, which has enabled vibration of multiple frequencies to be suppressed by automatic adjustment.

Figure 3 shows the wave forms of an actual machine. The complex vibrations generated without vibration suppression control have been suppressed by automatic adjustment of the advanced vibration suppression control II, and settling can be done quickly.

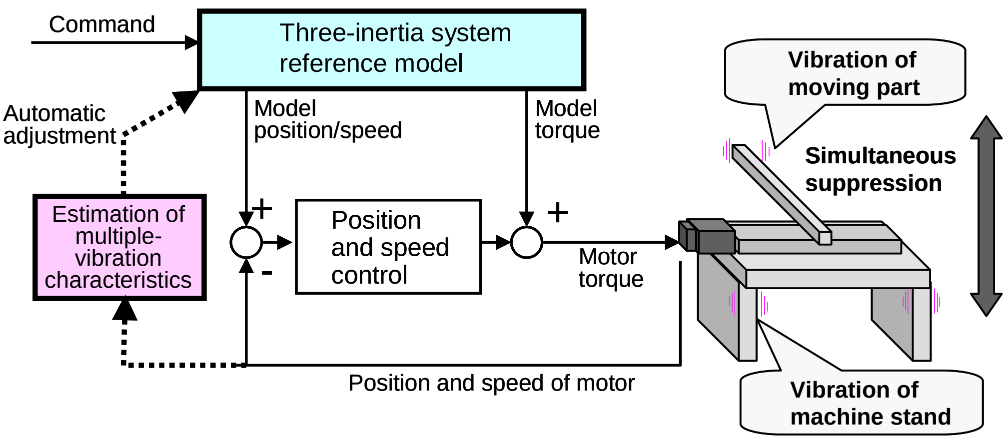


Fig. 2 Schematic of advanced vibration suppression control II

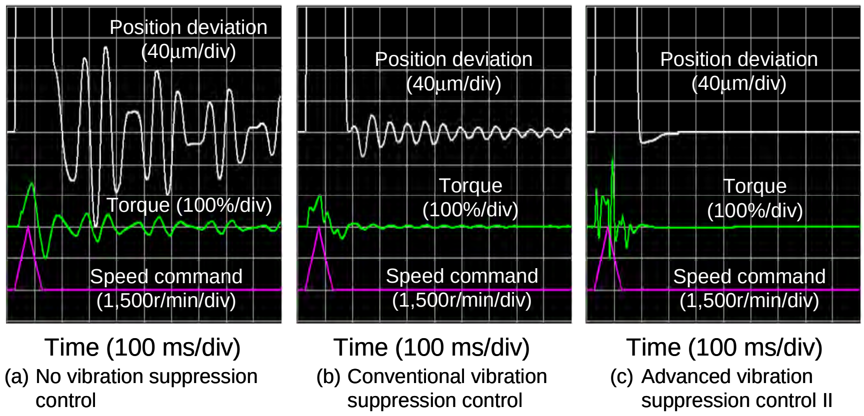
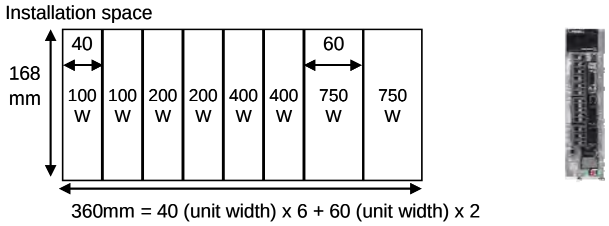


Fig. 3 Application example of advanced vibration suppression control II

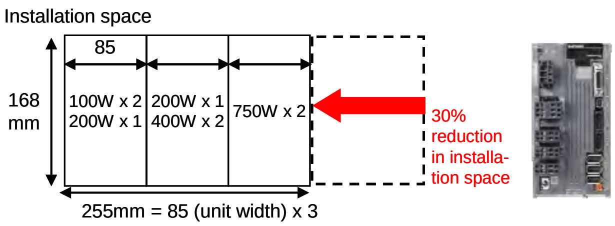
4. Space Saving, Resource Saving, Energy Saving

4.1 Biaxial, triaxial servo amplifiers

In the MR-J4 series, the product lineup includes multi-axis servo amplifiers (biaxial and triaxial). Since the amplifier controls multiple axes, processing time and heat dissipation characteristics must be addressed. We adopted a heat sink with an optimal shape in which the dedicated LSI and heat dissipation characteristics have been improved by approximately 20%, allowing the unit to be made substantially smaller. A comparison of the installation space when using the single-axis and multi-axis amplifier, respectively, is shown in Fig. 4 as an example. The multi-axis amplifier reduces the installation space by up to 30%, while the triaxial amplifier reduces the number of wires such as power cables by approximately 50% in comparison with using three single-axis amplifiers, thus saving space, wiring and equipment cost.



(a) MR-J4



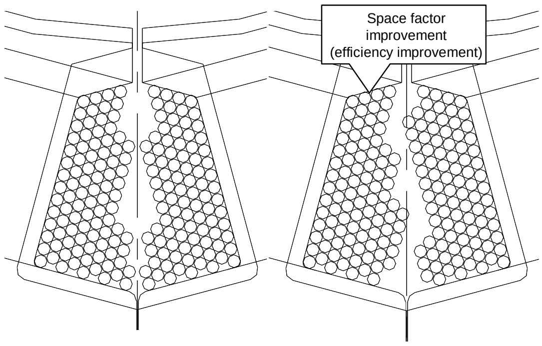
(b) MR-J4W (multi-axis)

Fig. 4 Space-saving with multi-axis servo amplifier

4.2 Small size, resource saving motor

To make the HG motor smaller, we adopted (1) an IPM (interior permanent magnet) structure and (2) an asymmetrical winding method, and the full length of the motor is up to 10% shorter. (1) The IPM structure improves the utilization ratio of the magnet compared to the conventional SPM (surface permanent magnet) structure by narrowing the air gap. (2) The asymmetrical winding method improves the coil space factor and raises efficiency by arranging different windings between adjacent teeth (Fig. 5).

Accordingly, usage of the magnet/core has been reduced by shortening the full length of the motor. In some models of 750 W or lower, magnet usage has been reduced by up to 30% by changing to a segment magnet structure from the ring type magnet of the conventional structure.



(a) Conventional winding (b) Asymmetrical winding

Fig. 5 Winding method

4.3 Energy saving and visualization

The multi-axis amplifier shares an electrolytic capacitor which temporarily stores regenerative energy using multiple axes, and saves energy because the reusable electric power is increased by two to three times that of the single-axis amplifier.

When power consumption is calculated without using a power meter to quantify energy saving, it is difficult to accurately estimate states that cannot be detected directly.

However, it is now possible to estimate the power consumption of the servo amplifier and the motor with an accuracy of about 10–20% by calculating the driving power energy and regenerative energy from the motor current and speed in the servo amplifier and correcting the temperature, etc.

To visualize the energy saving, information is transmitted to an upper controller through MR Configurator2, the new setup software, and SSCNET III/H, and power consumption can thus be analyzed and an indicator can be displayed. This enables us to change the operation pattern and save energy (Fig. 6).

5. Maintenance Support Function

5.1 High-capacity drive recorder

When an alarm occurs in the equipment, it is important to be able to identify the cause, but this can be particularly difficult if the error is not reproducible. By using this function, data such as the motor current of the servo amplifier, the command position and the speed is continuously stored in the memory, and is also recorded in the nonvolatile memory when an alarm occurs. Larger capacity, such as approximately twice the number of channels of the conventional MR-JN series is achieved. It is also easier to use and allows the cause of an alarm to be quickly investigated even immediately after the power is rebooted.

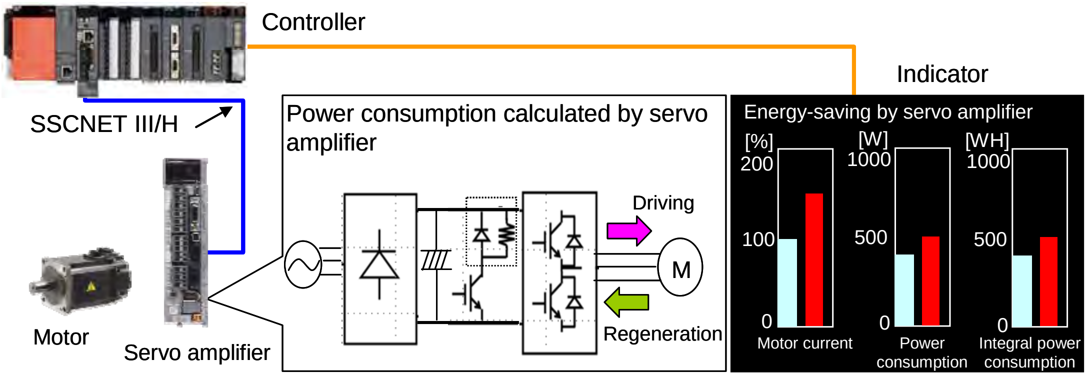


Fig. 6 Power consumption monitor function

5.2 Machine diagnosis

In recent years, the demand has grown for measures against aged deterioration of servo-driven machines and for a function to diagnose abnormalities. Therefore, we have developed several functions to continuously estimate the friction characteristics and torque vibration amplitude during normal operation of equipment. Among them, the friction estimation function estimates the disturbance applied to the drive shaft as a model consisting of Coulomb's friction and viscous friction, which can then be displayed and saved using a PC (MR Configurator 2) or used by the upper controller through SSCNET III/H. Comparing the data during normal operation and operation startup is useful for preventive maintenance of equipment.

6. Conclusion

We have introduced the MR-J4 next-generation servo, HG series based on the concept of "harmony with man, machine and environment," in addition to pursuing the high speed and performance required of servos. We will grasp the market needs in advance and strive to develop products that satisfy our customers.

Force Sense Control System for Industrial Robots

Author: *Kenji Murata**

1. Introduction

Industrial robots are increasingly being used in next-generation on-site manufacturing systems in response to global competition. The background to this progress includes: 1) Increased automation for securing a stable factory work force; 2) Shift to the cell production system to handle multi-product production to cope with the diversification of consumer tastes; 3) Demand for a manufacturing system that realizes low-cost design and operation in a short time; and 4) Demand for advanced work automation such as high-definition assembly, soft object conveyance, and high-speed handling.

However, this type of advanced work is difficult to automate, and so it is necessary to build an intelligent system that uses various sensors such as force sensors and vision sensors.

To meet these demands, we have developed a cell production system in which the assembly of thermal relays is automated by a robot equipped with an intelligent function (Fig. 1).

This report describes the function and control of an especially important force sensor system among intelligent systems, and an example of its application to robots.

2. Function and Control Methods of Force Sense System for Robots

2.1 Force sense function

The force sense function provides the sense of force to a robot by using the information from a 6-DOF (degrees of freedom) force sensor. This function can be used to perform advanced work that needs fine force adjustment/sensing and labor saving on teaching, which have not been possible by robots up to now. The main features are as follows.

(1) A robot can be softly controlled and moved while imitating an object workpiece, and as a result, it is easier to fit machine parts requiring accuracy.

(2) Since a robot can move while pressing an object with a constant force in any direction, polishing and buffing can be performed.

(3) The softness and contact sensing conditions of the robot movement can be changed during the movement of the robot, so when the softness is changed during pin insertion, the robot can be controlled so as not to damage the surface of the workpiece at the initial insertion, and then the pin can be inserted firmly by stiffly controlling the robot.

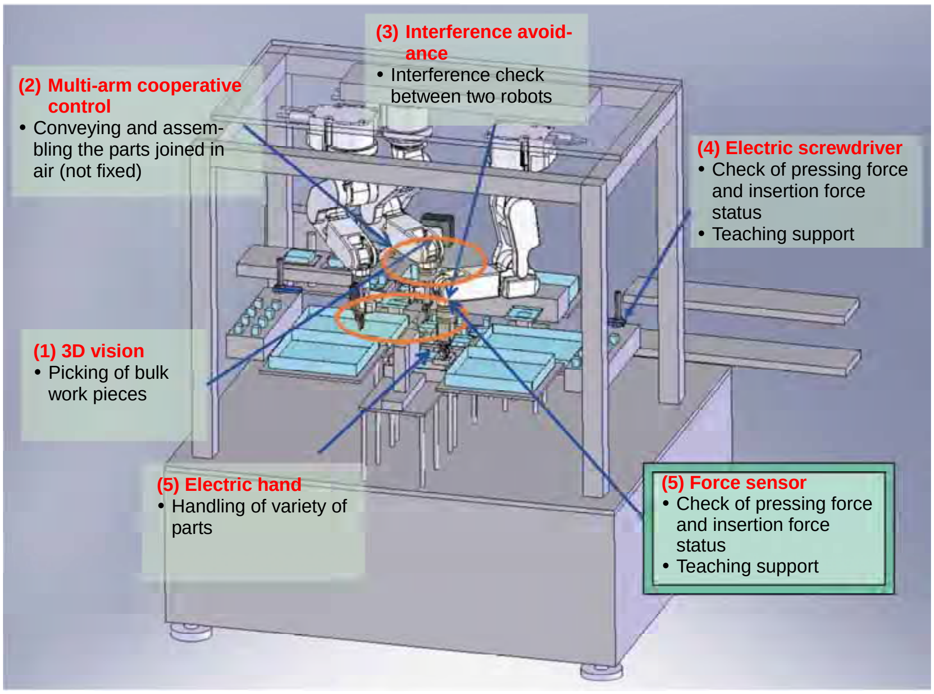


Fig. 1 Cell manufacturing system using a robot (2011 International Robot Exhibition)

*Nagoya Works

(4) The contact conditions can be sensed, interrupt signals can be produced, and the movement of the robot can be changed. Accordingly, when a force that may damage the workpiece is sensed, this feature is useful for error recovery such as changing the movement direction.
(5) Position and force information can be acquired at the time of contact, and therefore, position sensing can be performed with high accuracy by contact. In addition, the contact state of the workpiece and the robot hand, which are hard to view in the teaching work, can be checked. This reduces the teaching work.
(6) The force data in synchronization with the position data is stored as log data and can be easily displayed in a graph using PC S/W (RT ToolBox2) for a robot, which is useful for analysis when an error occurs.
(7) Log data can automatically be transmitted to a personal computer via FTP for storage in a database, making it possible to trace the assembly quality later on.
(8) If a sensor detects any force beyond the setting value, the robot can be stopped to protect the workpiece and the force sensor.

2.2 What is force sense control?

This function controls the robot so as to reach preset values of reaction force and softness when the robot contacts surrounding objects.

2.2.1 Force control (control of press force)

When a force command is set in the force sense control, the robot works autonomously while correcting the position so as to obtain the reaction force [N] set up in the force command beforehand when the force control is enabled. However, the robot works in the direction opposite to that of the force command value when an external force does not act on the robot (when not contacting). The working speed at this time is proportional to the force control gain (* refer to Section 2.3.1).

2.2.2 Stiffness control (control of softness)

The softness of the robot in the stiffness control is set using a stiffness coefficient. The larger the value, the stiffer the movement of the robot, and vice versa.

Figure 2 is an example of a case where stiffness control is applied only to the tool Z-axis. When the stiffness coefficient of the Z direction is 0.5 N/mm and the teaching position is 5 mm below the contact surface, the force F generated on the contact surface is as follows:

$$F = 0.5\ \text{N/mm} \times 5\ \text{mm} = 2.5\ \text{N}$$

2.3 Adjustment of force sense control

To accurately perform force sense control, it is necessary to suppress the responsiveness (gain) of the force sense control, and the vibration (damping).

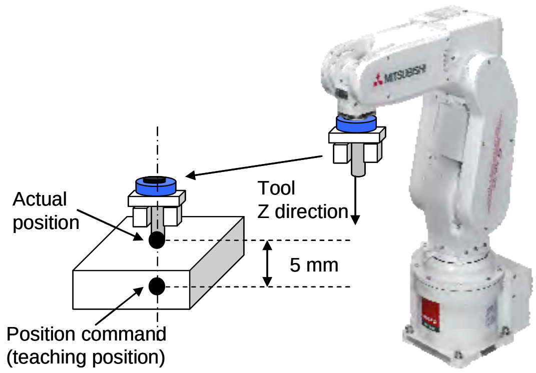


Fig. 2 Stiffness control

2.3.1 Force sense control gain

The force sense control gain is a parameter for adjusting the responsiveness of the force control. The higher the setting value, the higher the responsiveness for a force command and stiffness command (refer to Table 1). However, if the value is raised too much, the working state becomes unstable due to hypersensitive reaction at the time of contact.

Table 1 Example of force control gain setting

Object stiffness	Force sense control gain
1.0 N/mm	100.0
10.0 N/mm	8.0
100.0 N/mm	0.25

Since this force control gain is affected by the stiffness of a contact object, it is desirable to change the gain setting depending on the object. However, when the force sense control gain is zero, correction by force control is not performed, and the normal position command is performed. Therefore, when changing the gain setting during work, it is possible to switch over from stiffness control to position control and vice versa.

Gain adjustment example

(1) Move the robot at a low speed (≈ JOG OVRD 5%) in the JOG mode in the axial direction where the force sense control (force command control or stiffness control) is enabled, and let the robot touch a work object.
(2) Lower the gain when the robot shows such behavior as rebounding on the side opposite to the moving direction at the time of contact.

2.3.2 Damping coefficient

When using the force control (force command control or stiffness control) and the behavior of the robot vibrates, the damping coefficient is adjusted. The bigger the value, the greater the vibration suppression effect. However, the corrective action for a sudden force change at the moment when contact is made with a workpiece, etc. becomes slow, and so the force acting on the workpiece increases. The actual damping adjustment is changed as needed after adjusting the force sense control gain mentioned above.

2.4 Force sense function and monitoring

The force sense functions can be set as indicated in Table 2. Using these functions, the motion change, the labor saving on teaching by monitoring the force sense data, and the logging of force sense data can be performed.

Table 2 Force sense function list

Function classification		Details
Force sense	Interrupt signal	Monitors the state for a force sense setting value. (Rising and falling signals for force sense setting can be acquired.)
	Data latch	Holds the sensor data and position data of the instant when the force sense setting value is exceeded.
Force control (TB)	Contact sense	Stops the jog movement at the instant the designated force (moment) is exceeded.

2.4.1 Ease of teaching by force sense function

If a sensed value exceeds the value set beforehand during the force sense control, JOG motion automatically stops and a buzzer sounds to notify the operator. This protects the workpiece and the force sensor. In addition, the color of the force sensor data display field in the teaching box can be changed to ensure visual recognition.

Moreover, the teaching work is simplified because a robot can be softly controlled by the stiffness control to teach the insertion completion position while the robot imitates the insertion shape.

2.4.2 Force sense monitoring function

The force sense monitoring function can be used to display the current value and the maximum value of the force sensor in real time. For example, it is possible to teach the position while watching the state of contact with a workpiece and viewing the data displayed on the force sense monitor. Moreover, the force sense monitor includes an edit display of the force sense parameters, and the changes and settings of the control modes and control characteristics of the force sense control can easily be confirmed (Fig. 3).

2.4.3 Log file and viewer function (RT ToolBox2)

As for the log file of force sense data, the relationship between the position and force is easily displayed in a graph by pressing the button on the main screen of the force sense control of ToolBox2 RT (Fig. 4). In addition, it is possible to transfer to a PC via FTP the files of logged data on the robot controller by an exclusive instruction, and to trace the assembly quality at a later date.

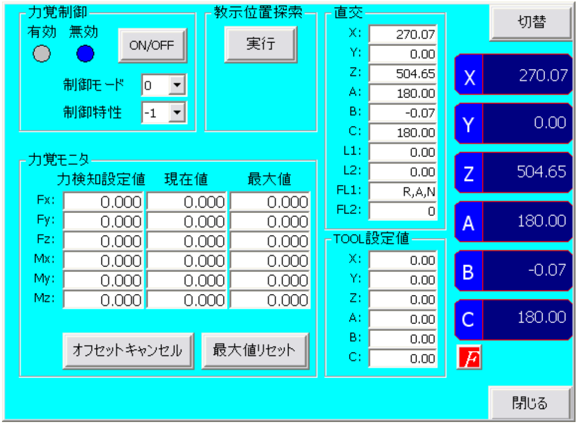


Fig. 3 Force sense monitoring screen

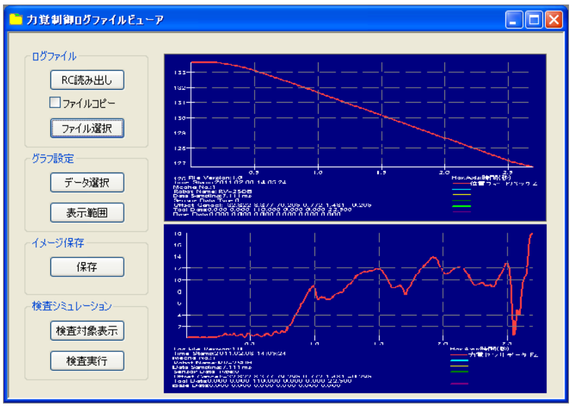


Fig. 4 Force sense log file screen

2.5 Force sense control S/W

Figure 5 shows a block diagram of the force sense control S/W. Sensor data processing is performed to receive the force sensor data from the force sense I/F unit S/W via SSCNET III; force sense control is performed using the data; and the logging of force sense data is performed in the motion control unit of the robot body control S/W in real time (Fig. 5).The control flow is shown in Fig. 6.

The processing of force sense control is corrected by using the latest force sensor data for the position command generated in a motion task to output the data to a servo. The force sensor data is transmitted via SSCNET III communication at a fixed cycle. In order to reflect the latest data in the processing of force sense control, sensor data processing that is executed at a fixed cycle is newly added, and the acquisition and acceptable values of force sensor data are checked.

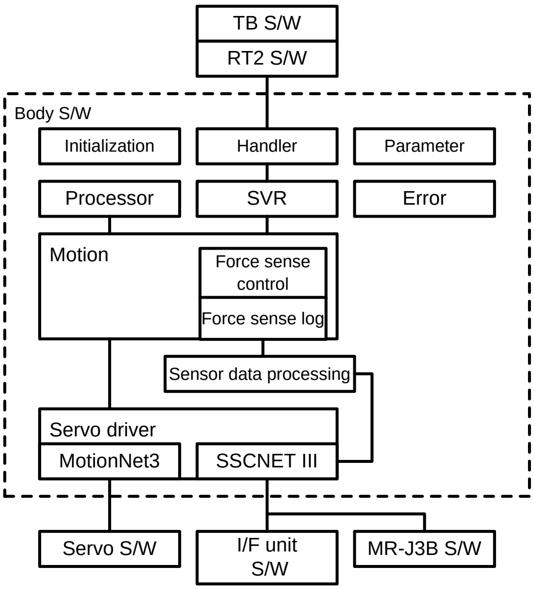


Fig. 5 Outline of S/W structure

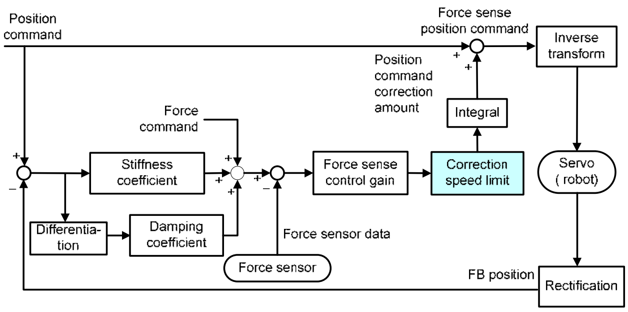


Fig. 6 Control block diagram

3. Application Example of Force Sense System

3.1 Insertion work

With the horizontal direction softened, the insertion work is performed in a push-in direction (Fig. 7). If a force exceeding the designated value is applied at the time of insertion, an error signal can be generated to stop the motion, which makes it easier to carry out the insertion work and error sensing.

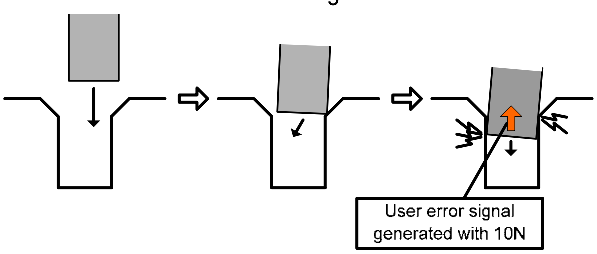


Fig. 7 Example of insertion work

3.2 Polishing work

A robot searches for an object while moving in the Y-axis direction (Fig. 8).When the tool finds the object, it moves in the X-axis direction while applying a constant force to the object. If a force exceeding the designated value is applied, an error signal is generated to stop the motion.

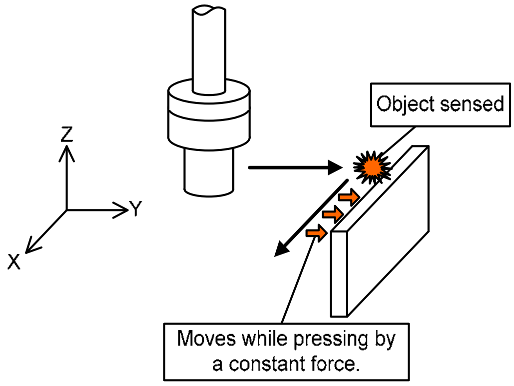


Fig. 8 Example of polishing work

3.3 Connector insertion work

A connector is searched for on the X-Y plane (Fig. 9). When the connector is found, the X-Y coordinate values of the center position are calculated for the insertion.

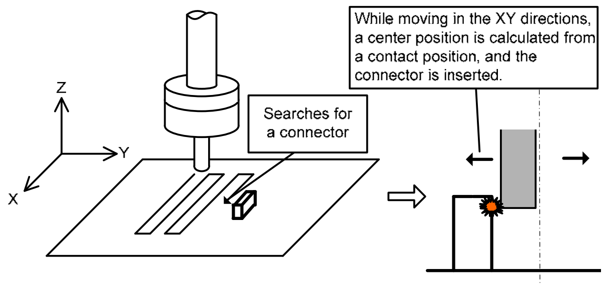


Fig. 9 Example of connector insertion work

4. Conclusion

We have described the function and control of an especially important force sensor system among intelligent systems, and examples of its application to robots. The force sensor can be used for the fitting work of machine parts for which accuracy is required, for buffing and polishing work, and for connector insertion work, etc. Moreover, a broad range of applications can be achieved such as the usage for error recovery operation, labor saving on teaching, and failure analysis using the log data when an error occurs.

We will strive to enhance the response of the force sensor and make the application easier to use for greater customer satisfaction.

GOT1000 Series New Functions and New Products

Authors: *Takahiro Kaneko** and *Tsuguo Kawasaki***

1. Introduction

Aiming at a "true" display at factory automation (FA) workstations, the GT15 model of the GOT1000 series (hereafter, "GOT") and the GT11 standard model were released in July 2004 with enhanced functions for stand-alone use, to provide a rapid response, high-definition display, enhanced troubleshooting, greater work efficiency such as reduced downtime, high value-added equipment, and lower total cost. The GT16 model, which is the successor to the GT15, was released in August 2008 to meet the user demand for easy-to-understand solutions using moving images for large-volume data processing, troubleshooting and downtime reduction, and for network I/F standard features. As a lower-cost medium-size model, the GT14 was released in July 2011 featuring improved display performance and added functionality for data acquisition (logging), to raise the position of the medium-sized model to compete with new products and improved functions introduced by competitors.

Here, we introduce the new functions of the GOT and the development of the recently-launched medium-sized display GT14 model, in order to meet user demands such as for uniform management of information shared between personal computers connected to a network.

2. Functional Enhancement of GOT1000 Series

2.1 GOT Solutions

When a failure occurs in production equipment, rapid detection of the cause and measures to prevent recurrence are essential for reducing downtime. Thus, there is a high demand for various troubleshooting functions on the display for monitoring and viewing the condition of manufacturing equipment. Table 1 shows the main GOT functions as indicators for efficiency and visualization.

With regard to the GOT incorporated in manufacturing equipment, many functions have already been developed not only to improve the equipment operation and status check, but also to ensure a quick response to failures on site by identifying the location and cause of the failure, and to confirm the measures to be taken.

Table 1 GOT Solutions

Solution	Efficiency and visualization	GOT functions
Trouble-shooting	Efficiency of troubleshooting Early investigation and analysis of the cause of troubles on site, and reduction of down-time	Ladder monitor function Operation log function Remote personal computer operation function
Production/ management cooperation	Visualize manufacturing information by linked personal computer Monitor the entire system (on site) and collectively manage data by the personal computer in the office	MES interface FTP server function
On-site monitoring and cooperation	Remotely visualize the screen of the on-site GOT Monitor and maintain the remote system and equipment	SoftGOT-GOT link function **FTP client function** **VNC server function**

As troubleshooting solutions, GOT has a ladder monitor function that searches for the circuit causing equipment failure in order to change the value of the faulty device; a remote operation function for operating a remote personal computer on which an operator is checking the manual; and an operation log function for saving historical data on operations performed on the GOT, to help identify and analyze the cause of faults. These functions facilitate troubleshooting at production sites.

The following functions can be used as production/management joint solutions with the GOT: an MES interface function for promptly transmitting the device values of connected equipment directly to an MES database to save and manage the data; and an FTP server function that allows a computer at an office to read and write information files collected by the GOT and files with the production control data such as mixing conditions and processing conditions of materials.

In recent years, demand has increased for remote monitoring and maintenance of overseas factories, in particular, for viewing and operating GOT screens at production sites. In response, we have provided a SoftGOT-GOT link function as a joint solution for on-site monitoring. With this function, it is possible to display and operate the same screen as that of the on-site GOT using SoftGOT on a personal computer with a network connection to the GOT. The SoftGOT-GOT link function enables monitoring of manufacturing equipment by collecting screen data from the target GOT and using it as the screen data for the SoftGOT to display

*Nagoya Works **Himeji Works

the same screen.

In remote monitoring and sharing, it is necessary to periodically monitor the status of the manufacturing equipment from an office using the FTP server function, but we have now added the following two functions to quickly capture any change or abnormality at the production site, and for monitoring and operating the GOT of on-site equipment without the SoftGOT.

(1) File transfer function (FTP client)
(2) *VNC Server function
*VNC: Virtual Network Computing

2.2 New functions of GOT1000 Series

2.2.1 File transfer function (FTP client)

With the conventional GOT, files for abnormality analysis obtained by the GOT (operation logs, i.e., files created by a logging function described later) can be acquired using the FTP server function by a personal computer with a network connection at the office when an abnormality occurs at the production site, without actually going to get the files. However, if such information could be obtained at the same time as the abnormality occurs, the cause could be analyzed immediately.

As shown in Table 2, the new FTP client function can transmit the files for abnormality analysis to the file server managed at an office from the on-site equipment side, based on the information being monitored by the GOT. These files can then be used to analyze the status of the manufacturing equipment and the causes, and quickly restore the system (Fig. 1).

Table 2 File transfer function and conventional functions

Item	FTP client	FTP server	MES interface
Transmission trigger	On-site GOT	Office personal computer	On-site GOT
Transmission details	File	File	Device value
Transmission Timing	Equipment event, Time period	Polling monitoring from the office	Equipment event, Time period

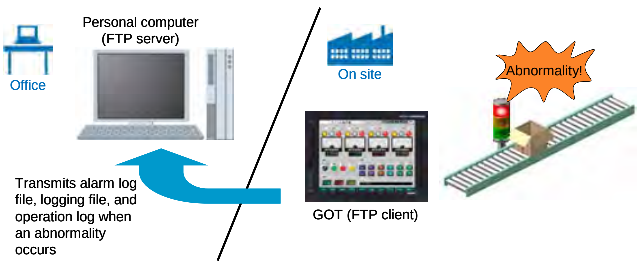


Fig. 1 File transfer function (FTP client)

2.2.2 VNC server function

The VNC server function transmits screen images of the on-site GOT to a remote personal computer through the network for display by the VNC client of the personal computer to monitor and operate the GOT. With this function, both the server and client can be generally operated. However, if operations are simultaneously performed at both the remote and on-site locations, it may cause unintended operation for the manufacturing equipment. To avoid this, the VNC server function has an operation exclusion function: as shown in Fig. 2, the GOT acting as a server exclusively manages the operations. When the client side has operational authorization, the GOT disables touch-panel operation and enables operation only from the client side.

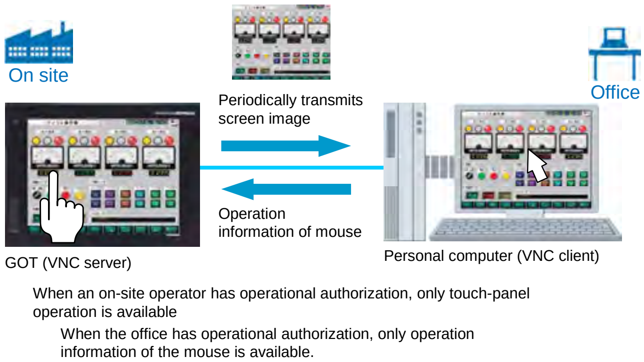


Fig. 2 Authorization of VNC server function

This new function enables the GOT and hence manufacturing equipment to be operated and controlled remotely away from the production site, even from a restricted-access area such as a clean room where precision industrial products such as semiconductors and display units are manufactured.

As shown in Fig. 3, manufacturing equipment in different lines can be monitored and operated by one GOT by connecting each GOT of the equipment in multiple manufacturing systems via a network and using the remote personal computer operation function (VNC client) of the GOT.

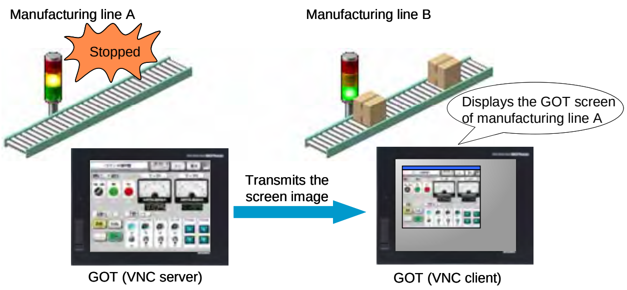


Fig. 3 Combination of VNC server function and remote personal computer operation function

3. Development of Medium-Sized Display GT14 Model

3.1 Market demands and challenges of medium-sized display

For medium-sized displays, there is increasing demand for high-value-added functions to enable clear letters and figures and photos to be displayed, data obtained on site to be brought back to the office using USB memory, and the data of a display to be operated from an upper-level personal computer via a network. However, there were concerns that our medium-sized display GT11 model was inferior in function and appearance, and our higher-level model was functionally sufficient but expensive compared with competitors' products. Therefore, we developed the GT14 model to meet the market demand for a medium-sized display featuring the following at a low price:

(1) Enhanced functions
(2) Differentiation from competitors' products
(3) Lower price

3.2 Development and challenges of GT14 Model

(1) Enhanced functions

The main specifications of the GT14 model are compared with those of the conventional GT11 model in Table 3.

Table 3 Comparison of GT14 model and conventional model

Item		GT14 model	GT11 model (Conventional model)
Display	Liquid crystal	TFT LCD, 65,536 colors	STN liquid crystal, 256 colors
	Backlight	LED	Cold cathode tube
Operation part (touch panel)		Analog resistance film type	Matrix resistance film type
User memory capacity		9 Mbytes	3 Mbytes
USB		USB device (1ch) USB host (1ch)	USB device (1ch)
Ethernet		1ch	None
General-purpose memory		SD card supported	CF card supported
Functions		Added character font, and enhanced functions to improve convenience and to connect with external equipment	-

i) Functional advancement of display screen

The GT14 model offers higher power thanks to its TFT liquid crystal with excellent visibility and 65,536 colors rather than the conventional 256 colors, as well as new fonts. When increasing the color variation, we were careful not to decrease the rendering speed. The increased color variation requires additional color information which increases the load of the rendering process, so we raised the rendering speed by using a more powerful microcomputer and by optimizing the synthesis method for rendering data according to the display properties based on window rendering.

The new model also uses approximately 15% less energy than the conventional model, by using LEDs for the liquid crystal backlight and improving the efficiency of the power circuit.

ii) Efficiency of screen design

Users can freely design the display screen using dedicated rendering tools. The GT14 model allows parts to be arranged at the pixel level, which is not possible with the conventional model, by adopting an analog resistance film-type touch panel. Furthermore, users can design screens without considering memory capacity, since user memory capacity has been tripled to 9 Mbytes.

iii) Enhancement of external interface and logging function

We have developed new functions by adding USB hosts, Ethernet and SD card support. Here, we introduce the logging function as an example.

The logging function collects the values of devices such as a sequencer (or programmable controller) at any time or at a fixed cycle. The collected data can be stored in an SD card in CSV file format beforehand, and the data can be brought back to the office from the production site using USB memory, etc. This allows quality control and productivity to be improved by analyzing the data and giving feedback to the site. It also possible to efficiently obtain data collected from the personal computer at the office via Ethernet (Fig. 4).

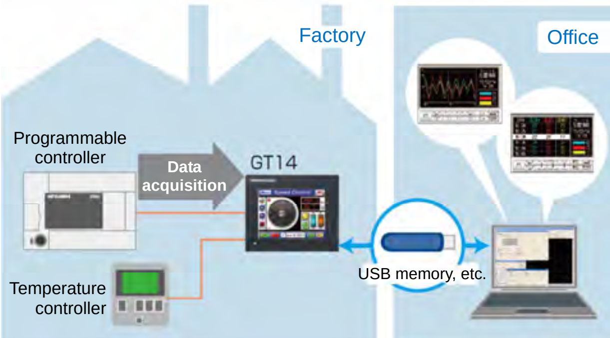


Fig. 4 Logging function

(2) Differentiation from competitors' products

As a leading manufacturer of programmable controllers in Japan, we have developed several functions to enhance compatibility with our programmable controllers. Examples include an FA transparent function for debugging by connecting a personal computer to our programmable controller via the display, and a backup/restoration function. The latter function is used to store (back up) the configuration information (sequence programs, parameters, setting values, etc.) of programmable controllers in an SD card mounted on the display, and return (restore) the stored information to the equipment. This allows a system to be backed up and restored without using a personal computer, and hence easily replace a faulty programmable controller on site and promptly restore the system after a fault (Fig. 5).

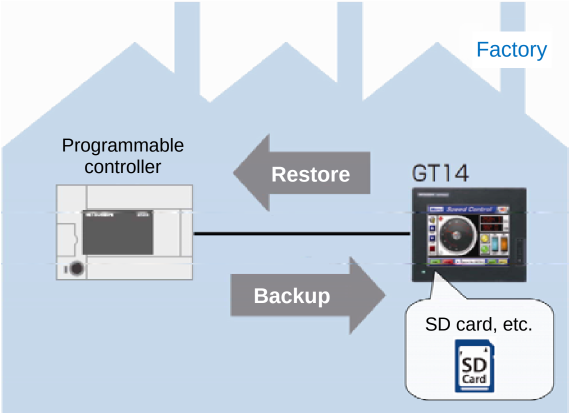


Fig. 5 Backup/restoration function

To ensure reliability, drainage grooves on the housing ensure that condensation water inside the control panel does not penetrate into the display through the fixed metal fittings of the GT14 model.

(3) Lower price

The GT14 features a new hardware configuration from the conventional model. We selected highly reliable microcomputers and memory devices in consideration of the market trend of electronic components, and reduced the number of parts by simplifying the circuit configuration to lower the price.

4. Conclusion

The FTP server function to manage the sending and receiving of data at the office and the FTP client function to send and receive data based on the GOT monitoring information, the SoftGOT-GOT link function serving as a SoftGOT, and the VNC server function to display the GOT screen to operate expanded and optional functions, are similar yet have their own characteristics and can be selected as required. The medium-sized highly functional GT14 model helps to meet a wide range of user needs.

We will strengthen the linkage with FA equipment such as programmable controllers, which is our strength, as well as servos and inverters, and emphasize the benefits of our products to firmly establish our position in the market.

Reference

(1) S. Hashimoto: Graphic Operation Terminal GOT1000 Series “GT16 Model,” Mitsubishi Denki Giho (March 2010).

“MELSEC-L Series” Extension System

Authors: *Kotaro Fujiwara** and *Hirokazu Ishikawa**

1. Introduction

We have developed a system that can extend the number of mountable modules for the MELSEC-L series. The compact system is intended for small- and medium-sized control scales such as transportation equipment and general manufacturing equipment. Its functions, performance and operability are designed for cost performance and ease of use. Thus, the system can meet a wide range of customers' needs. This paper introduces the features of the MELSEC-L series extension system and its development.

2. Overview of L Series Extension System

The MELSEC-L series extension system was developed by connecting a branch module and an extension module, which were newly developed, with an extension cable. This increases the maximum number of mountable modules from 10 conventional modules (only for the main block configuration) to 40 modules (up to three extension blocks). Figure 1 shows the outline of the system and Table 1 shows its specifications.

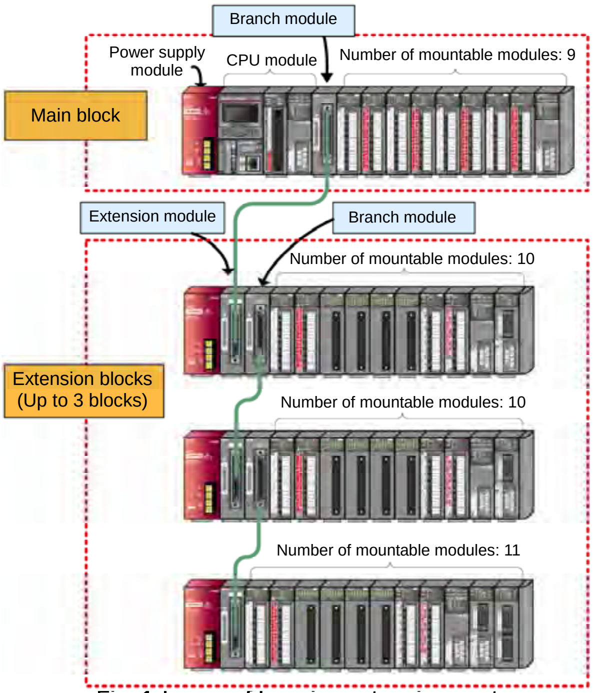


Fig. 1 Image of L series extension system

Table 1 Specifications of L series extension system

CPU modules	Number of extension blocks	Number of mountable modules
L02SCPU L02CPU(–P)	Up to 2 blocks	Up to 30 modules
L06CPU L26CPU L26CPU–(P)BT	Up to 3 blocks	Up to 40 modules

3. Features of L Series Extension System (Easy Layout)

When extending a system, the time required to change the module and wiring configurations should be minimized. The L series extension system allows a branch module to be mounted not only on the left side of the system but also on the rightmost end, as shown in Fig. 2, so the existing system need not be changed. Moreover, the system can be flexibly and optimally extended both vertically and horizontally as shown in Fig. 3.

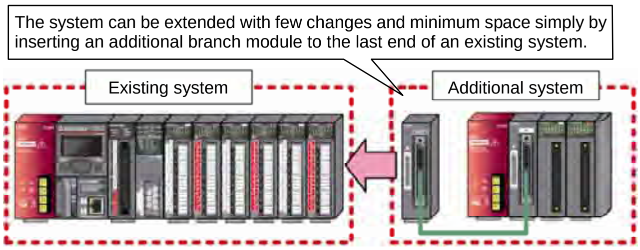


Fig. 2 Extended example of L series system

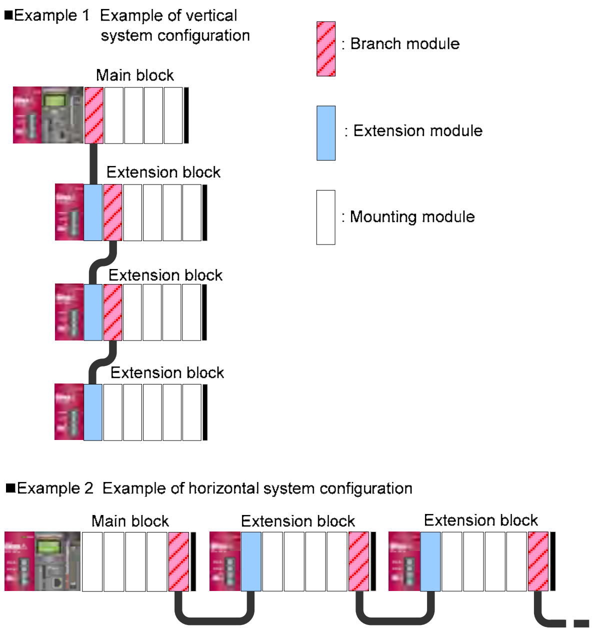


Fig. 3 Configuration example of L series extension system

4. Features of L Series Extension System (Easy Extension)

As shown in Fig. 4, one-touch attachment/detachment reduces the wiring work for connecting the branch module to the extension module with an extension cable.

In addition, when extending the system on site, the customer needs to be able to visually identify branch and extension modules, and the insertion direction of

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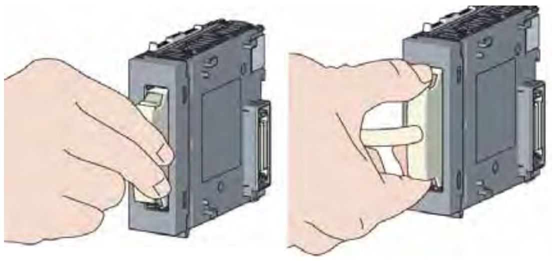
an extension cable without misreading. Therefore, as shown in Fig. 5 and Fig. 6, an easily legible universal font is used for the lettering on the branch and extension modules. The module type name, I/F usage (OUT: signal-sending side, IN: signal-receiving side), and insertion direction of the extension cable are displayed on the front face of both modules.



(a) Attachment (b) Detachment

Fig. 4 Connecting the extension cable

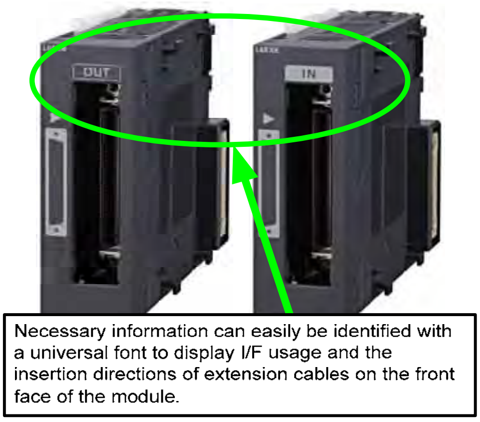


Fig. 5 Appearance of a branch module and an extension module

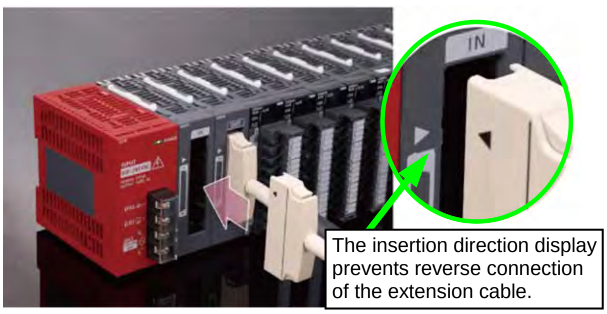


Fig. 6 Insertion direction display of an extension cable

5. Features of L Series Extension System (Easy Troubleshooting)

The functions for diagnosing faults of the bus communication between modules (communication bus connected between L series modules) have been improved so that even if the number of mounted modules is increased due to system extension, the customer can quickly perform troubleshooting when a fault occurs. For fault diagnostics, the CPU module regularly performs module diagnostic processing for the mounted modules and an END cover to detect module and system faults. Figure 7 shows the processing flow, and Fig. 8 shows the checking of each module and END cover. This checking identifies the part that caused the system fault, then the engineering tool allows customers to easily perform troubleshooting.

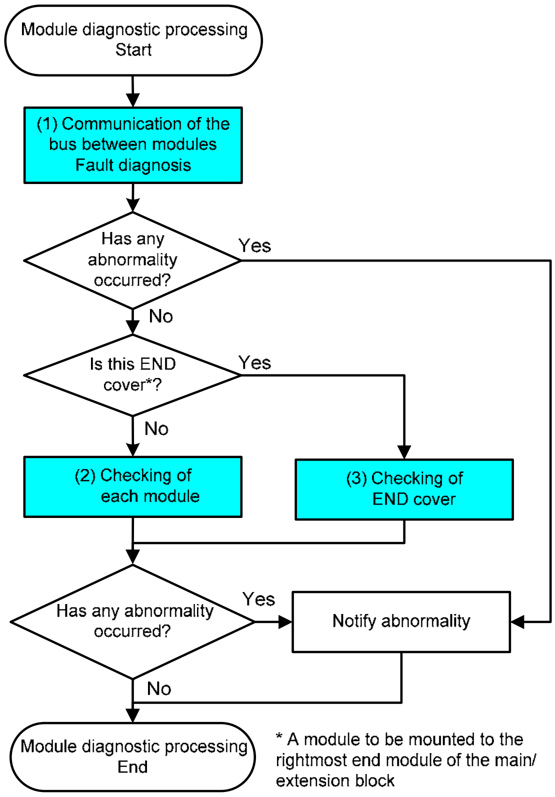


Fig. 7 Flow of module diagnostic processing

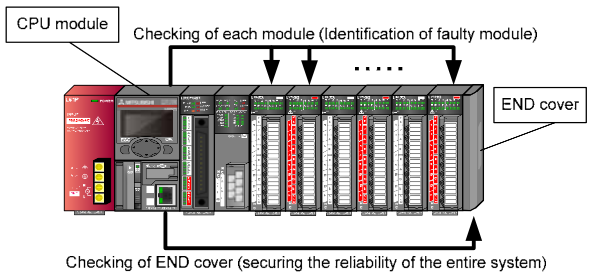


Fig. 8 Collation of each module and END cover

(1) Fault diagnosis of bus communications between modules

If the bus communication signal between modules is faulty, the CPU module cannot check the modules and the END cover containing information on the mounted modules is read out from the bus between modules so that the processing is terminated.

(2) Checking of each module

The CPU module checks whether abnormalities of the mounted modules have occurred (when the I/O module has a different configuration from that at power-on, etc.). The CPU module detects the boundary between the normal module and the faulty module, and sequentially checks the mounted modules from the leftmost to the rightmost end to identify which module is faulty.

(3) Checking of END covers

The bus communication between modules of each block is diagnosed by checking the END cover of each block to ensure the reliability of the bus between modules in the entire system.

6. Conclusion

We will continue to improve the functionality, performance and operability to meet the needs of sites, while maintaining the legacy of the MELSEC programmable controllers, and will develop products that make systems easier to use.

Energy-saving Data Collection Server "EcoWebServer III"

Authors: *Shigeto Toita** and *Hiroaki Sumida**

1. Introduction

Following the Great East Japan Earthquake of March 2011, public awareness of power and energy saving has increased, and the focus of energy management has shifted to electricity usage. For electric power companies, securing a stable power supply and saving energy are crucial. We have developed a tool for visualizing energy via servers which collect data on energy saving, and a function for managing energy, to help save energy. To encourage energy saving and assist monitoring, we have improved the visualization tool and developed a server which collects accurate data on energy saving at each manufacturing facility in consideration of the specific function management.

2. EcoWebServerIII

The EcoWebServerIII has a simple configuration and collects data from measuring instruments connected to the CC-Link of a field network, and then graphically displays the data and current measurements. This makes it easy to analyze the data and hence save energy (Fig. 1 and Table 1).

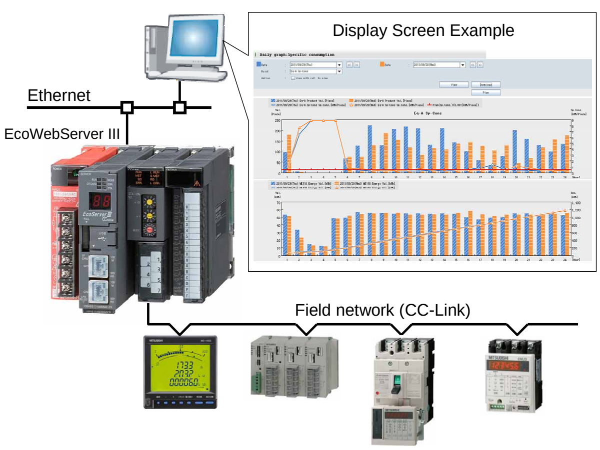


Fig. 1 System constitution

(1) This server collects and stores the manufacturing information captured by measuring instruments such as energy measurement units (EcoMonitorPro), MDU breakers and electronic and multi-indicating instruments with a transfer function, and MELSEC programmable controllers. Data for up to six months (assuming hourly collection) can be stored.

(2) The server sends the information to the intranet/internet by Ethernet and internal HTTP server function. A client personal computer on the Intranet can then be used to monitor and browse the manufacturing and measurement information from anywhere using a Web browser.

(3) The EcoWebServerIII monitors the upper and lower limits for the current values of measuring instruments connected to the EcoWebServerIII, and if a value exceeds the upper value or a value lowers the lower limit, sends a notification email to the mail server on the Intranet, which is then forwarded to the facility administrator's cell phone.

(4) The EcoWebServerIII integrates the hardware and application software necessary to collect and store data and send it over the Web. Customers do not need to create software or make additional arrangements.

(5) The included configuration software displays various data as bar or line graphs on a web browser of a personal computer just by selecting the terminals and data to be measured and written to the EcoWebServerIII.

3. Software Design

In developing the software of the EcoWebServerIII, it was necessary to flexibly handle various field networks such as CC-Link and the MC protocol, and to ensure efficient development of the large-scale system. We focused on the Web application part which accounted for most of the development work, and developed middleware to compensate for the difference between this platform and conventional models. By using this middleware and the same interface among Web applications, the reuse rate was increased. Additionally, within the middleware, the communication control unit acts as a driver for each field network and the linkage between functions has been lowered to make it easy to add functions to support new networks (Fig. 2).

4. Application of Universal Design

This product is designed for the visualization of energy information, so we improved the visibility and operability by applying a universal design to the Web screens that display the information.

*Fukuyama Works

Table 1 Product specification

Items		Details
Type name		MES3-255C-EN (English), MES-255C-CH (Chinese)
Communication		CC-Link
Number of connected terminals		Remote I/O station ····· max. 64, Remote device station max. 42 Local station ·············· max. 26
Measuring point		max. 255
	Virtual	max. 128
	Specific function	max. 64
Logging function	Annual	For five years (collecting logs monthly, on the designated date, and at the designated hour)
	Monthly	For five years (collecting logs daily, and at the designated hour)
	Daily	For six months (collecting logs on the hour or every 30 minutes)
	Zoom	For 62 days (collecting logs every one minute)
Display function	Annual graph	Display data for one year on a monthly basis
	Monthly graph	Display data for one month on a daily basis
	Weekly graph	Display data for seven days on an hourly or half-an-hour basis
	Daily graph	Display data for one day on an hourly or half-an-hour basis
	Zoom (one minute)	Display data for one hour on a minute basis
	Current value display	Display a maximum of 10 measuring points per screen.
	Comparison display	The comparison display of a maximum of 10 points is possible. (Group registration of the downtime of equipment, the number of the conforming products, etc.)
Monitoring function	Information by e-mail	Error, upper/lower limit monitoring, operation monitoring, periodical information, specific function target value monitoring, energy planned value monitoring
	Contact output	Error, upper/lower limit monitoring, operation monitoring, specific function target value monitor-ing, energy planned value monitoring

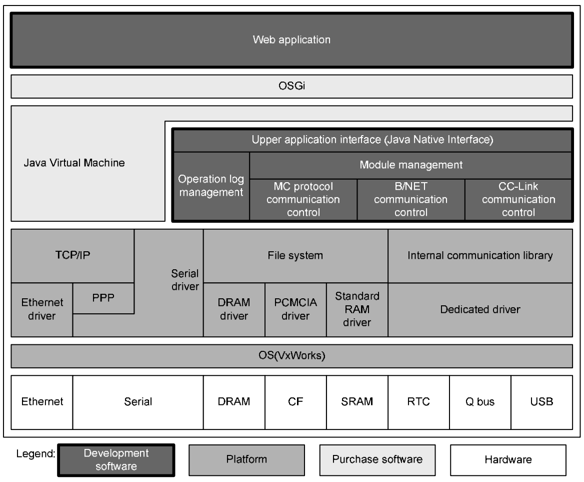


Fig. 2 Software structure

4.2.1 Improvement of visibility (not only by color coding)

When comparing data between different dates, monochrome printing was incomprehensible before this improvement was introduced because the contrast of two values for comparison was small. In bar graphs (time complexity) and line graphs (accumulation), the light and dark of the two values for comparison were reversed, so it was difficult to handle such data (Fig. 3 (a)).

We therefore selected color combinations to increase the graph contrast of the comparison binary and added horizontal lines and slanted lines to the bar graph to help identification. We also matched the contrast between a pair of bar graph and line graph to easily deal with the data (Fig. 3 (b)).

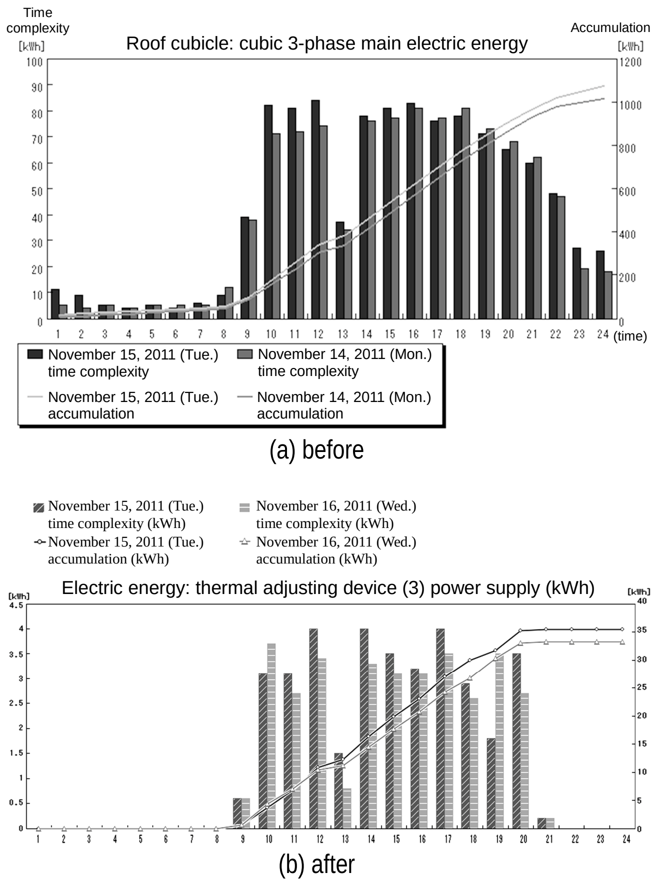


Fig. 3 Visibility improvement of the graph

4.2.2 Improvement of operability

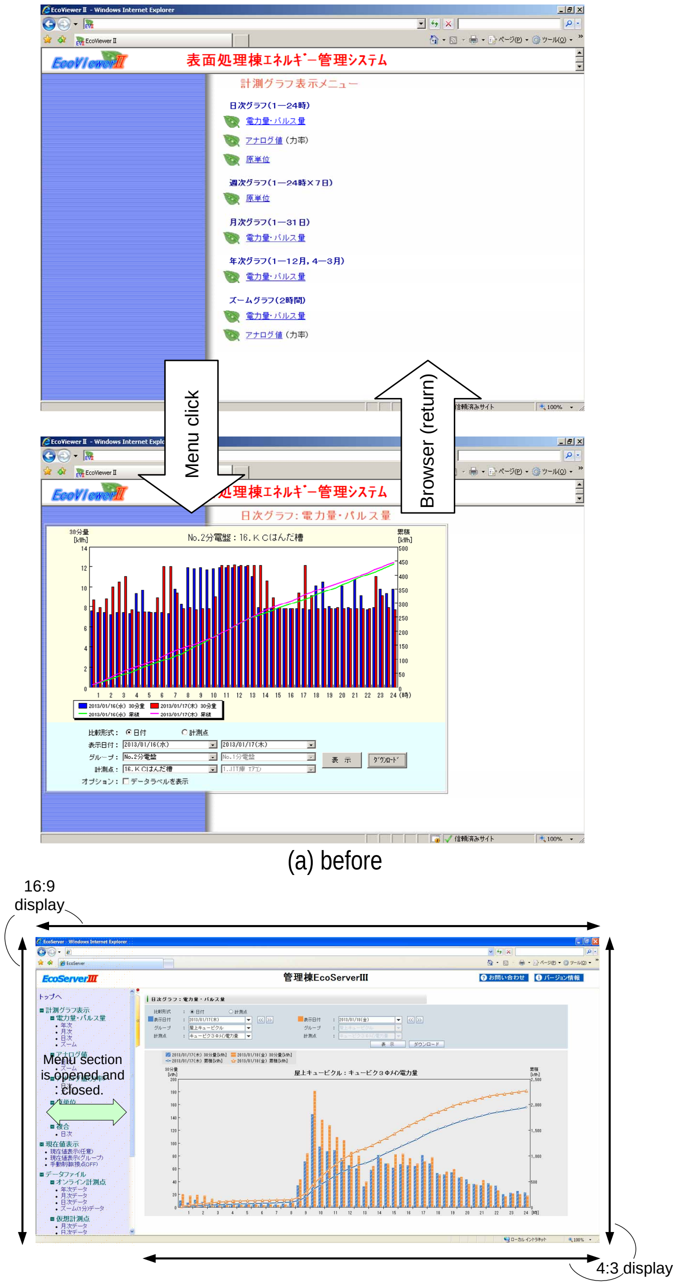
The graph display screen and menu screen are not displayed on the same page in conventional models. Once a graph was selected from the menu, the graph display screen appeared, and to display a different graph it was necessary to return to the menu screen by pressing the return button in the browser. Thus, data drill-down analysis by month → day → hour → minute, etc. required frequent screen changes which hindered the analysis (Fig. 4 (a)).

In the EcoWebServerIII, the menu is on the left side of the screen to be easily opened and closed. The menu is always displayed on a wide display with an aspect ratio of 16:9. On a conventional 4:3 display, the menu is displayed upon selecting the menu to always close the menu frame, making it possible to call up a graph menu at any time and realize seamless operation. This allows users of both wide and normal displays to effectively utilize the full screen area (Fig. 4 (b)).

We have been providing energy-saving support systems and equipment such as energy-saving database servers and energy data collection servers, which embody our energy-saving know-how. We will continue to develop products that comprehensively meet the market needs for energy saving management.

* Ethernet is a registered trademark of Xerox Corporation (US).

* Java is a registered trademark of Oracle Corporation, its subsidiaries and affiliates (US and other countries).



(a) before

(b) after

Fig. 4 Improvement of operability

New eX Series CO_2 2D Laser Processing Systems

Authors: *Junji Kano** and *Hiroyoshi Omura**

1. Introduction

With the manufacturing industry shifting to newly emerging countries and the product cycle becoming shorter, there is strong demand for higher productivity, easy operation that does not require skilled workers, and lower operating cost.

In response to these market needs, we have commercialized the new ML3015eX-45CF-R series CO_2 2D laser processing system based on the concept of the triple "e": (1) excellent, (2) easy to use, and (3) ecology. Figure 1 shows an outline drawing of the system.

Fig. 1 New eX series CO_2 2D laser processing system

2. "Excellent": High-performance Laser Processing Systems

2.1 High-speed cutting of thin plate

Productivity has been greatly improved compared with the LV-45CF-R conventional system (hereafter, "conventional system") due to the reduced processing time for a wide range of materials such as mild steel, stainless steel and aluminum alloy by combining a 4.5-kW high-output resonator, high-speed drive parts, a beam stabilizer that equalizes beam characteristics in all areas of the work table, a beam optimizer that optimally controls beam characteristics and focal positions depending on the processed materials, and electrostatic capacity-type sensors that control the distance between the sensor and the material surface with high accuracy during high-speed processing. As an example, Figure 2 compares the processing time for a 1-mm-thick stainless plate using the new system and the conventional system. In the new system, the maximum processing feed speed increases from 30 to 50 m/min while maintaining a processing accuracy equivalent to the conventional system by applying high-speed drive parts and state-of-the-art control technology. In addition, the acceleration increases to twice that of the conventional system, and the processing time is reduced by approximately 20%.

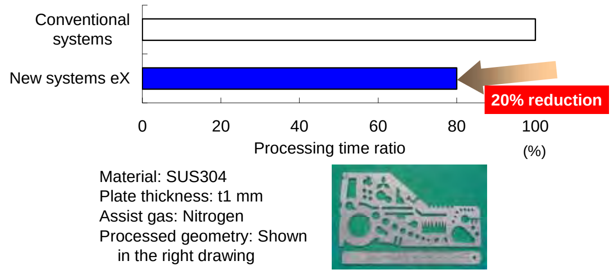


Fig. 2 Reduction in processing time for thin plate

2.2 Reduction in processing time of mild steel by new piercing technology

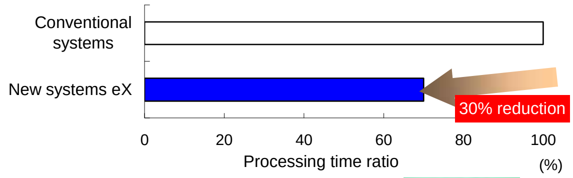
The piercing (drilling of the start point) time accounts for a large proportion of the total processing time for a mild steel plate thicker than the medium-thickness plate. Thus, the new blow piercing technology has been adopted for mild steel of up to 16-mm thickness in the eX series, and processing time has been reduced. Blow piercing can control the oxidation combustion reaction by taking advantage of the output response characteristics featured in our resonators, and by controlling the optimum peak output step-by-step. The technology reduces the piercing time by up to 50% while maintaining a hole diameter equivalent to the conventional one. Figure 3 compares the piercing capacity for mild steel of 9-mm thickness, and a comparison of the actual processing time when this technology was applied to mild steel of 12-mm thickness. In addition to the improved quality of piercing holes, the whole processing time was reduced by 30% and productivity was improved by 1.4 times by reducing the piercing time and the approach time to shift to the cutting process.

2.3 Expansion of capacity for cutting stainless steel

The thickness of stainless steel that can be cut has been increased due to the high beam quality obtained by the original 3-axis cross-flow resonator as well as the lineup of optical systems suitable for thick plate processing. In the conventional system, the nominal cutting capacity is 12-mm thickness, while in the eX series, a 20-mm-thick plate and 16-mm-thick plate can be processed by plasma surface cutting and fine surface cutting, respectively. The surface roughness, Rz, of the lower part of the cutting section of the plasma surface is increased by about two to three times that of fine surface cutting, but the processing speed is in-

*Nagoya Works

Piercing method		Conventional piercing	Reduction-type piercing (blow pierce)
Characteristics		A large amount of molten material adheres around the hole after piercing.	Controls the oxidation combustion reaction and reduces adherence of molten material.
Capacity comparison Material: SS400 Plate thickness: 9 mm	Enlarged photo of pierced portion		
	Piercing hole diameter	3mm	2mm
	Piercing time	1.0 seconds	0.5 seconds
	Cutting approach time	1.8 seconds	1.0 seconds



Material: SS400
Plate thickness: t12 mm
Assist gas: Oxygen
Processed geometry: Shown in the right drawing

Fig. 3 Effect of blow piercing and processing time comparison

creased by 1.5 to two times, thus further reducing the operating cost. Nitrogen was used as the assist gas, and the laser output was set to 4,500 W.

3. "Easy to Use": Simple Operation

"Easy to use" is the second product concept of the eX series. Although the conventional laser processing system must first follow setup steps that include processing data input, confirmation, and the installation of the processing workpiece, the eX series can start processing after only two actions: reading in the processing directions by bar code, and pressing the start button. Figure 4 shows the conceptual diagram. This simple processing operation is called e processing mode, which can automatically measure the size and correct the tilt of a workpiece, and compare the processing program and material size. Additionally, the control device features a high-speed CPU and a large 15-inch LCD touch panel, which have improved the drawing process performance: the drawing time is 1/20 that of the conventional system with geometry check function; and the processing restart position can be designated on the screen display. Accordingly, easy operability has been realized.

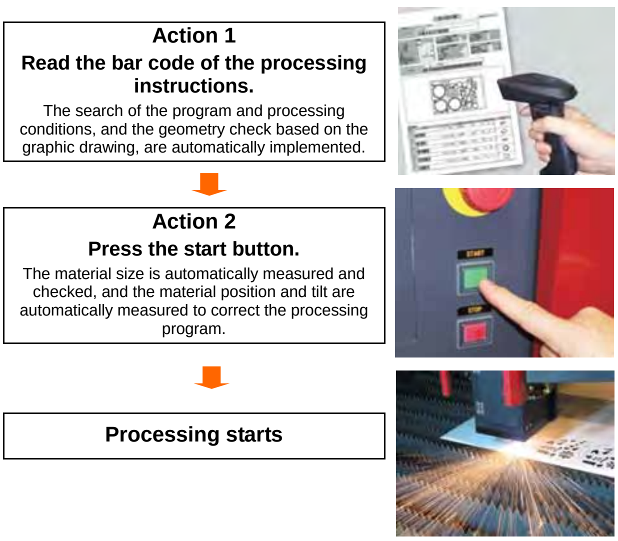


Fig. 4 Concept of two-action processing

4 "Ecology": Eco & Clean by Reducing Operation Costs

"Ecology" is the third product concept of the eX series. The original gas-sealed 3-axis cross-flow resonator has features that substantially suppress laser gas consumption and power consumption in normal operation compared with the general high-speed axial-flow resonator, but the eX series has additional eco mode functions in order to further suppress unnecessary laser gas, purge gas consumption, and power consumption at the time of the processor shutdown. As shown in Fig. 5, in the eco mode, the original control sequence automatically stops the idling of the processor and the resonator to reduce unnecessary expenses during standby by up to 99%. In addition, the operation from stop to return is smooth, and the environment-friendly laser processing system has been realized without decreasing working efficiency.

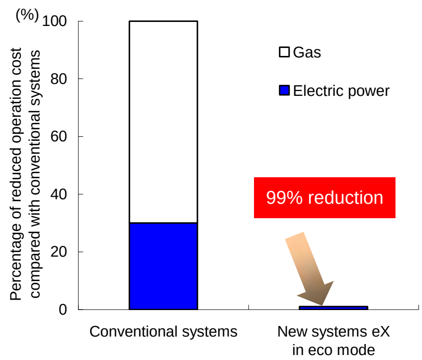


Fig. 5 Operation cost reducing effect by eco mode

5. Conclusion

We have introduced the features of the eX series state-of-the-art 2D laser processing system and presented several processing examples. The technological progress of the system is remarkable compared with that of other machine tools, and further technical improvements are expected. To meet increasing user needs for advancement and diversification, we will further enhance the performance and actively respond to the needs of various production sites, as a comprehensive laser processing system manufacturer.

MITSUBISHI ELECTRIC CORPORATION