Application of "S-MAC" TYPE C (Development of Work Rotation Type Wire Winding Machine)

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1. Introduction

We announced our "Multiple Interface Declaration" in November, 1996, and released "S-MAC" controller that supports the FA open architecture in June, 1997. "S-MAC" is available in three types: TYPE A, B and C. As an application product of "S-MAC" TYPE C, we have developed a work rotation type wire winding machine for our Tsuiji factory.
In "S-MAC" TYPE C, motors are controlled by software without using a motion control card. We briefly introduce here the two types of software that characterize "S-MAC" TYPE C: one is the dialog type operational language INTERACT that is used in the operation block, and the other is the full software motion control language AML that is used in the control block.
The mechanism of this development are described in a separate report entitled "Development of New Type Wire Winding Machines, "Inner Wire Winding Machine" and "Work Rotation Type Wire Winding Machine"" in this issue.

2. Background of Development

2.1 AC Servo Motor

In the AC servo motor, permanent magnets set on a rotor and windings built in a stator. There are many factors that determine the motor performance such as the characteristics of the magnet that is used for the rotor, and increasing the density of the stator winding greatly improves motor efficiency and miniaturization.
The stator is conventionally manufactured by inserting wires that are wound around reels, into a single unit stator iron core. This method causes extra dead space, making it difficult to increase the winding density of the stator.
One solution to this problem is to split the stator iron core, and to wind the wire directly around the split type iron core. (Refer to Yamaura, K. and others, May, 1996, "Development of AC Servo Motors "P6" and "P8"" Sanyo Denki Technical Report Vol. 1.)

2.2 Series Wire Winding Machine

In our "P6" and "P8" AC servo motors, the wires are wound around the split core by a nozzle-controlled series wire winding machine that we developed, to increase the density of the stator winding. The nozzle-controlled series wire winding is performed by controlling three-axes servo motors by a digital controller, and by rotating the nozzle through which the wire is routed around fixed cores. (Refer to Kitazawa, K. and others, Nov., 1996, "Wire Winding Technology Supporting Various

Motors and Recent History" Sanyo Denki Technical Report Vol. 2.)
The diameter of the wires used in the machine ranges from 0.9 to 1.4 mm.

2.3 Trend Toward Larger Servo Motors

In accordance with market needs, we have decided to add eight new models to "P6" series, ranging from 7.5 kW to 30 kW. These models use wires of up to 3.0 mm diameter. Nozzle abrasion and pin holes are likely to occur with the conventional nozzle-controlled wire winding machine, so a new type of wire winding machine is needed.

2.4 Application of "S-MAC" TYPE C

In the new wire winding machine, a system controls the movement of the cores while the nozzle is fixed. This means that the four axes of ψ, X, Y and Z must be synchronously controlled at least. Also it is necessary to control inputs such as switches and actuators other than motors.
We have decided to use "S-MAC" TYPE C as the control system that satisfies these requirements.

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3. Outline of Work Rotation Type Wire Winding Machine

3.1 Basic Concept

The concept of the work rotation type wire winding machine is shown in Fig. 1. Holdback tension is applied to the wire as the core is rotated. When the core is rotated, the X-axis is controlled so that the wire becomes straight. At the same time, the Y-axis is controlled so that the distance from the nozzle and that from the core become the same when the core is rotated by 90 degrees. In addition, the support presses the wire to bend it until it forms a curve shaped like the bobbin, hence the core and wire are brought into as close contact as possible. As the support-axis is added, the five axes are finally driven in synchronous control. The rotary angle of the core and the method of controlling the X-Y axes are shown in Fig. 2.
The Z-axis is moved as far as the diameter of the wire in the range of 180 and 270 degrees as the wire is wound by one full turn, so that the wire is wound perfectly aligned. When the wire winding moves from the first layer winding to the second layer winding, the Z-axis is moved half of the diameter of the wire, and the wire is then wound in between the wires of the first layer winding in order to improve the winding density.

3.2 Outline

Fig. 3 shows the outside view of the work rotation type wire winding machine. The basic structure is a turntable placed on the top of a X-Y table. The Z-axis is controlled by moving the nozzle up and down, and the support is moved up and down as it is interlocked with the nozzle.
In addition, the machine is equipped with a wire tension automatic adjustment mechanism, a wire feeding mechanism during machine setup and an air nipper to cut the wire when winding is complete. Safety devices include a cover switch, wire breakage sensor switch, circuit breaker (MCCB) and signal tower. As a countermeasure against power failure, Sanyo Denki's uninterruptible power supply (UPS) is built in.

4. Operation Display Block (HMI)

4.1 Hardware Structure

The hardware structure of the operation display block is shown in Fig. 4.
The main specifications of the panel computer are as follows.

CPU	i486DX2/66MHz
Memory	2MB
External memory	2 MB flash memory
Display	Display 640×480, 16 colors TFT LCD
Input device	Touch panel
Serial interface	RS-232C×2 channels
I/O	I/O Input×32 channels, Output×32 channels

4.2 Software Structure

The software structure of the operation display block is shown in Fig. 5.

4.3 Outline of INTERACT

INTERACT, which is used in the operation display block of the work rotation type wire winding machine, is software that was developed by CTC (Computer Technology Corporation, USA) to enable to display the status of the equipment and to operate through dialogue. A control panel can be configured simply by laying out the tools such as push switches, meters and indicators on the display (panel). The tool colors can be selected from fifteen colors, and the size and aspect ratio can also be freely modified. It also includes a function to display CAD graphics and animation-like displays.

4.4 Operation Display

Some of the operation displays of the work rotation type wire winding machine, which were created by INTERACT, are given here as examples to describe the operations.
Fig. 6 shows the startup display. The outside appearance that was created by CAD is read and shown. The "Home Return" switch is designed as a momentary type push-button switch with normally-open contact.

To the right of the "Home Return" is the message indicator, which indicates the operating procedure usually, and also indicates the cause and recovery procedure when an abnormality occurs.
Fig. 7 shows the display used to select a model. The vertical column of "1" through "8" under the "No." indication are the latch switches, and one of the eight can be selected. When "1" is pressed, for example, "1" changes from blue to red indicating that it is selected. When "3" is pressed, then "3" changes from blue to red indicating that it is selected, and "1" returns from red to blue indicating that it is released.
The display while the wire is being wound is shown in Fig. 8. During the process, the positions of the respective axes (motors), number of turns and elapsed time in real time are shown. In addition, scheduled productions, number of items completed and the rate of work progress are shown.
When the machine has not started wire winding, the "Start wire winding" button is displayed instead of "Pause", and when the wire winding is completed, the "Cut wire" button is displayed. The display thus does not show unnecessary buttons to

prevent mis-operation.

5. Control Block

5.1 Hardware Structure

The hardware structure of the control block is shown in Fig. 9. The servo amplifier and I/O are directly driven from the SERCOS interface card through the optical fiber cable, without any motion control cards.

5.2 Software Structure

The software structure of the control block is shown in Fig. 10.
The control block is connected with the operation display block through a serial communication line (RS232C). The control block receives the model code and operation commands from the operation display block, and returns the operating status, motor position and other information to the operation display block.
The control block is also connected with the development PC through RS232C or Ethernet, but only when communication is necessary such as for downloading the developed programs or for program debugging. The control block runs independently as an individual target system during normal operation.
The details of AML are described in the following section.

6. AML (Advanced Motion Language)

6.1 Outline

AML is an object-oriented full software motion control language that was developed by AI (Automation Intelligence Inc., USA), and we then customized it. (It is called SML in the Technical Report No.4, but the name was changed to AML in December, 1997.) AML consists of the development environment, the execution environment (SRX = SERCOS Runtime eXecute), and various tools.

6.2 AML Development Environment

AML development environment is a group of software operating under Windows95 (support for WindowsNT is planned), and consists of the following four software tools. (1) AML editor
AML editor is an intelligent text editor used for writing the source code. It has some functions for checking syntax errors in each line, automatic tab addition, automatically creating the corresponding "ENDIF" or "ENDWHILE" when an "IF" or "While" statement is coded, and so on.
AML editor display is shown in Fig. 11. The hatched area indicates that the line contains a syntax error.
(2) Configuration editor
The configuration editor is a text editor used to create the auto load configuration file. The module name that will be loaded during system startup is described in the auto load configuration file.
(3) Log viewer
The log viewer displays the contents of the log file that SRX records. The execution errors detected by SRX, and the occurrence of specific events can also be recorded in the log file. Effective debugging can thus be performed by combining the log viewer and AML debugger that is described next.
(4) AML debugger

AML debugger has functions for executing steps at every line, displaying and modifying the values of variables, and for setting break points.

6.3 Execution Environment (SRX)
SRX is a preemptive multi-task operating system that can execute the application programs that are created by AML development environment. Execution control of the module is managed by event monitoring and time slicing.

6.4 Tools
AML has the following tools, which help shorten the development time, make debugging more effective, and can be used to tune the system.
(1) SRX maintenance tool
This establishes SERCOS loop and manually operates the control system.
(2) SERCOScorp
This enables the operating status of the control system to be monitored from the development environment. When connected through Ethernet, the motor speed, position and current can be displayed in real time.
(3) PIPELINE
This tool is used to perform data conversion and communication so that Windows applications can process the system information of this machine.When PIPELINE is used, the operation display block that is created by INTERACT can also be created by VB.

6.5 AML Programming
(1) Configuration
The control system must be configured before starting to create application programs. The system configuration (of the motor and I/O) are set by this configuration.
Fig. 12 shows the configuration display.
(2) Globals file
One globals file must be created for each application program. The file must contain the declarations but no execution commands. The event identification must be declared in the globals file.
(3) Module file
The local identification declarations and execution commands are written in the module file. The functions to be implemented must be divided into smaller processing units (tasks) which are assigned to modules, in order to achieve an event-driven system that is the feature of AML. Each module must be set to be started from SRX when any change occurs in an event. Thus, monitoring of event changes by polling is not necessary, which simplifies programs and improves the execution speed.

7. Conclusion

We have introduced the work rotation type wire winding machine as the first application of "S-MAC" TYPE C. We have manufactured an actual machine, and the hardware was completed only with minor modifications. As for the profile of the winding wire which is the key issue, we achieved ideal aligned winding and satisfied the planned tact time by flexibly modifying the software through repeated trial windings. The production models can be easily changed simply by selecting the desired model from the model list on the operation display. As a result, the programs and data no longer need to be loaded from floppy disks whenever the model is

changed.
The developed work rotation type wire winding machine showed that "S-MAC" TYPE C is effective for general industrial equipment. We will endeavor to deliver total solutions to users in conjunction with "S-MAC" TYPE A and B.

* Names of companies and products in this report are the registered trademarks of the respective companies.

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Fig.1 Basic concept

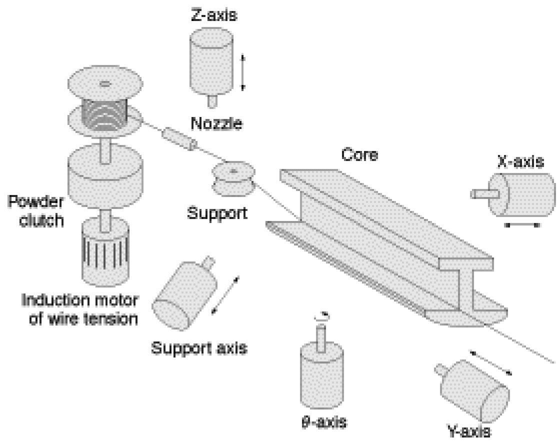

Fig.2 Rotary angle and X-Y axes control

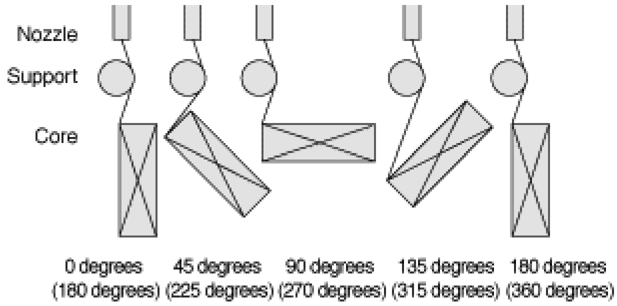

Fig.3 Outside view of the work rotation type wire winding machine

Fig.4 Hardware structure of the operation display block

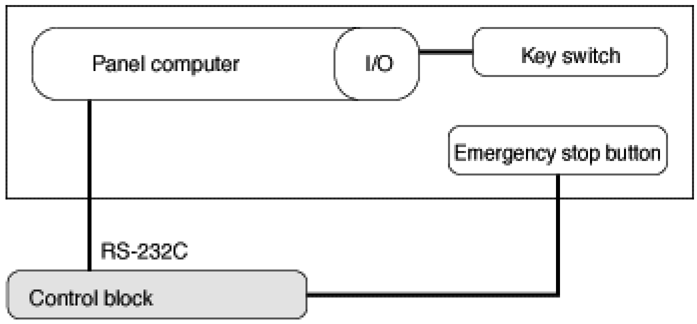

Fig.5 Software structure of the operation display block

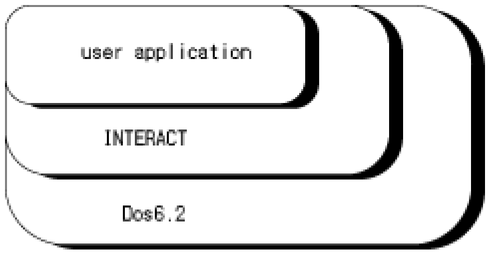

Fig.6 Startup display

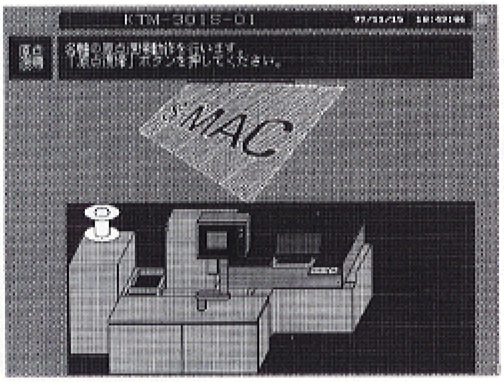

Fig.7 Model selection display

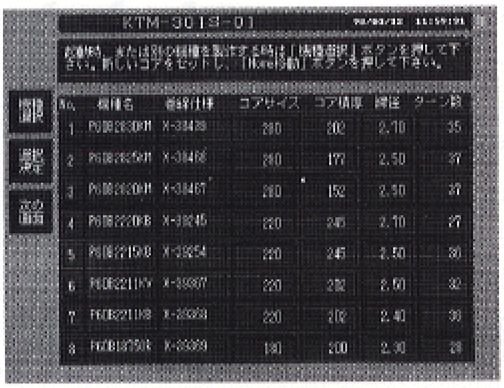

Fig.8 The display while the wire is being wound

Fig.9 Hardware structure of the control block

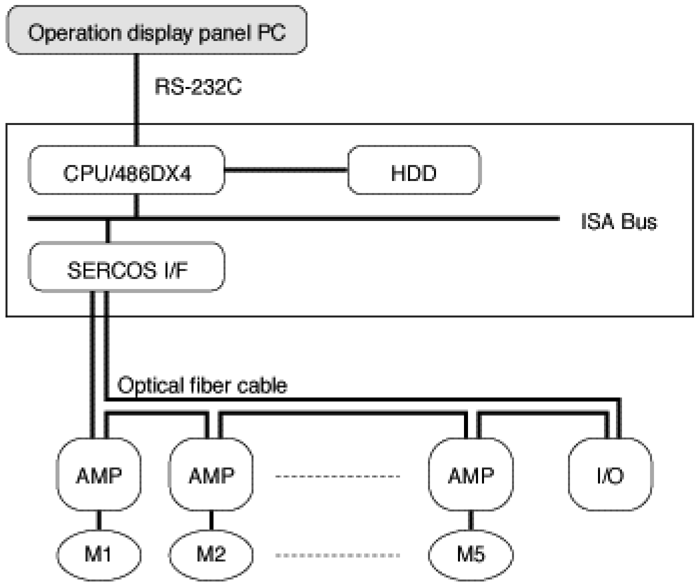

Fig.10 Software structure of the control block

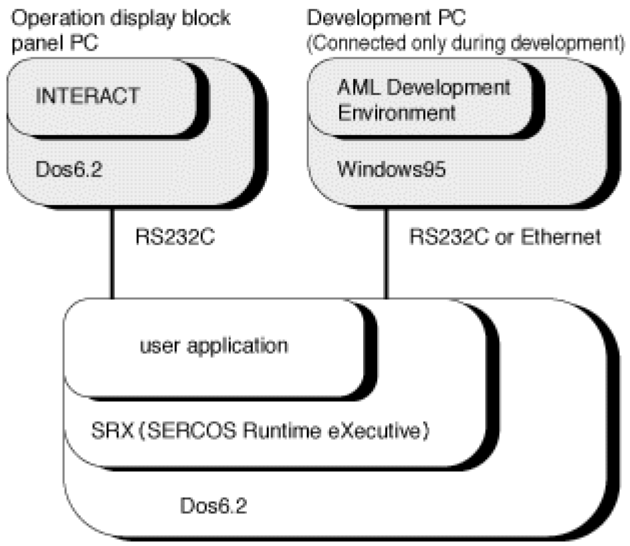

Fig.11 AML editor display

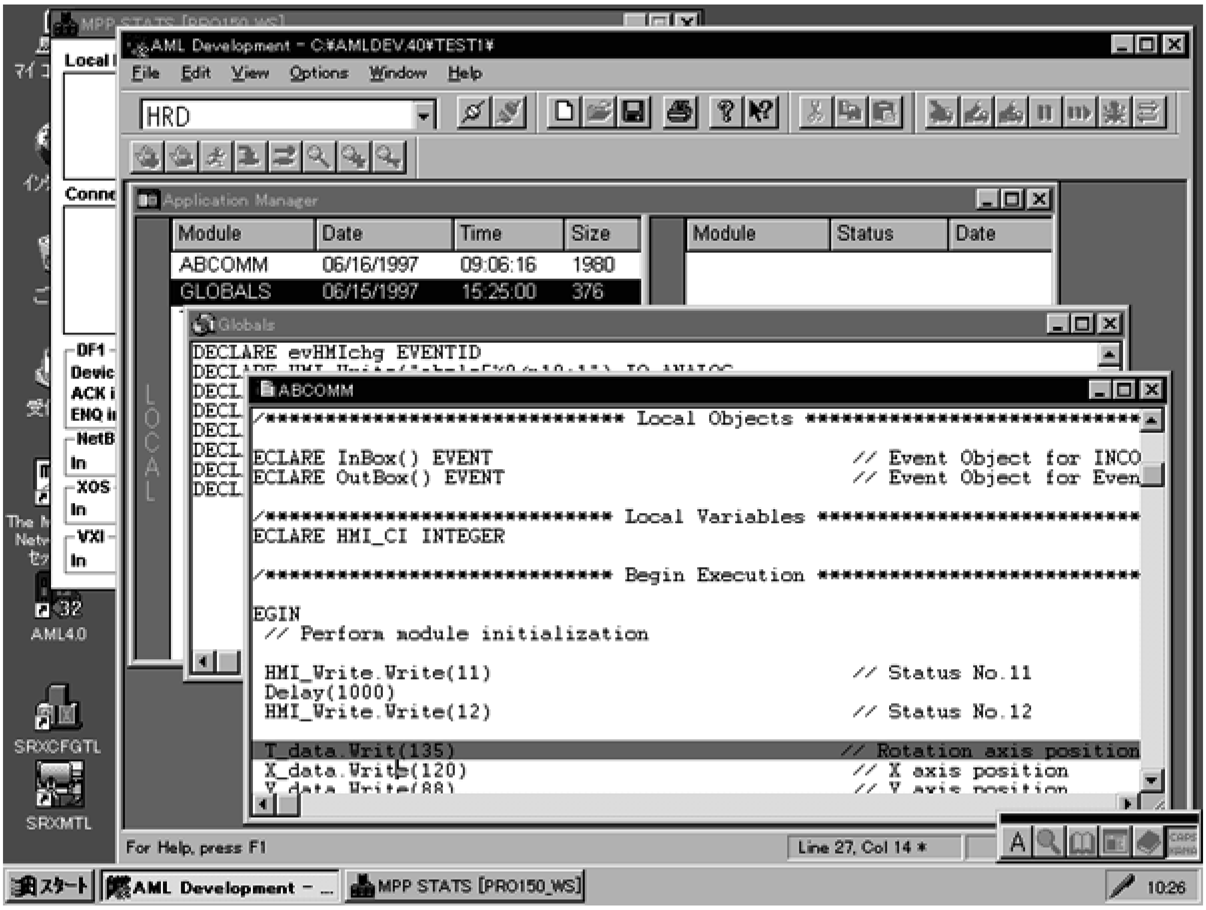

Fig.12 Configuration display