Specialty Technologies for Efficiently Producing Servo System Products

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1. Introduction

The aim of manufacturing ("monozukuri" in Japanese) is to create products with value through processing and assembling materials and parts based on the design information. This value is the value for our customers who use our products. Creating this value swiftly and simply is not only the essence of monozukuri but also our mission.

Since our founding, SANYO DENKI has been devising various ways to create technologies and equipment to deliver value in the form of products to our customers. Through this process, we have developed many "specialty technologies."

In April 2016, we began a five-year mid-term management plan which contained multiple initiatives aimed at "manufacturing innovation." The goal of the plan is to double productivity, cut production lead-time to one-quarter, and halve in-process inventory by building innovative manufacturing lines in pursuit of efficient production.

Using our so-called "Innovation Lines" as examples, this article will introduce the "specialty technologies and ingenuities" we leverage to produce Servo Systems products efficiently. First, we will look at the production process for servo motors, then that of servo amplifiers.

2. Specialty Technologies on the Servo Motor Innovation Line

Many customers use SANYO DENKI's customized products. As such, we have a wide variety of products which are often processed manually to maintain flexible production. In the building of our Innovation Lines, we utilized automation technologies such as robotics and sensing technologies to efficiently produce a wide variety of products with uniform high quality.

This section will introduce the specialty technologies and ingenuities incorporated in the servo motor Innovation Line.

2.1 Specialty technologies in the winding process

In the winding process, copper wire is changed for each motor model to suit its characteristics. During setup changes, the necessary equipment adjustments impede production efficiency.

On this Innovation Line, we developed a method to automatically remove insulation coatings from the copper

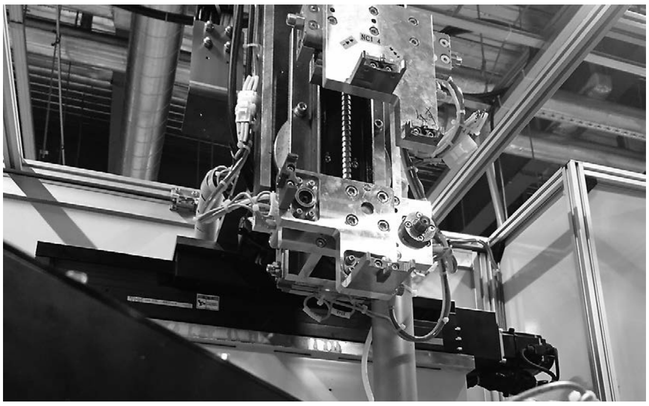

Fig. 1 Laser coating removal system

Table 1 Comparison of conventional technique and innovative technique (winding process)

Items	Conventional technique	Innovative technique
Removal method	Mechanical cutter	Laser irradiation
Jig change/adjustment	Cutter blade positioning adjustment Check using sample workpieces	None
Removal check	Visual	Image-based judgment

wiring using lasers. By focusing on improving production efficiency, we eliminated the need for equipment adjustment during changeovers. Figure 1 shows the laser coating removal system. Table 1 shows a comparison of the conventional technique and innovative technique.

Previously, a mechanical cutter would remove winding coatings. The cutter blades had to be replaced to match the wire diameter, which was time-consuming. We utilized an innovative technique that removes coating via laser, enabling more seamless production just by switching programs when changing copper wires. Moreover, by using image technology, the quality of coating removal is automatically inspected.

By automating the coating removal process for windings, we reduced the time required to change and adjust jigs. A motor production line applying this technology has 2.3 times higher productivity and one-quarter production lead-time compared to conventional lines, as well as zero in-process inventory.

2.2 Specialty technologies in the magnet bonding process

Assuring adhesion quality in the magnet bonding process is vital. Without sufficient bonding, the rotor would spin freely and fail to convey mechanical energy to equipment.

To minimize such occurrence, we integrated automated bonding robots into the Innovation Line. These precision robots delicately apply an even coat of bonding agent then automatically inspect the magnets for any minute fissures and flaws to ensure that parts leave the process defect-free.

Figure 2 shows a magnet bonding unit for a 20 × 20 mm AC servo motors, while Figure 3 shows a similar unit for 40 × 40 to 80 × 80 mm motors. Table 2 is an overview of the systems that these bonding units use to check the bonding condition.

Failure modes of bonding agent application include when bubbles in the bonding agent tank prevent the agent from discharging, and when the discharged agent does not adhere to the magnet. We have built a system that utilizes sensing technology to detect these failure modes and introduced it to the Innovation Line.

As shown in Figure 2, the bonding agent application unit for 20 × 20 mm AC servo motors measures the thickness of the applied bonding agent using a non-contact sensor to verify its condition. Similarly, Figure 3 shows the unit for 40 × 40 to 80 × 80 mm motors using an image sensor to verify the uniformity of the application. These specialty technologies realize an automatic line with uniform bonding quality. Since its installation, the new line has increased productivity six-fold, cut production lead time to a quarter, and eliminated in-process inventory.

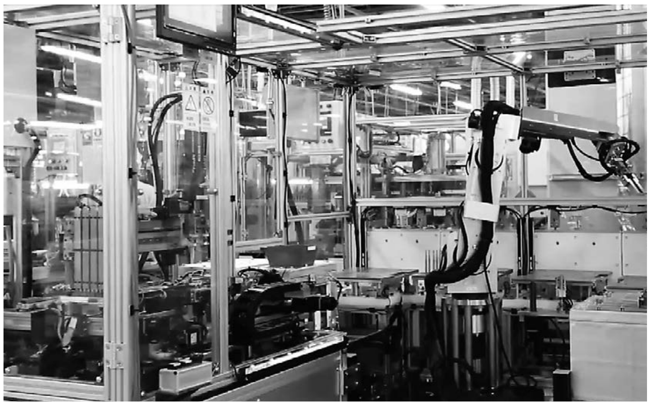

Fig. 2 Magnet bonding unit for 20 × 20 mm AC servo motors

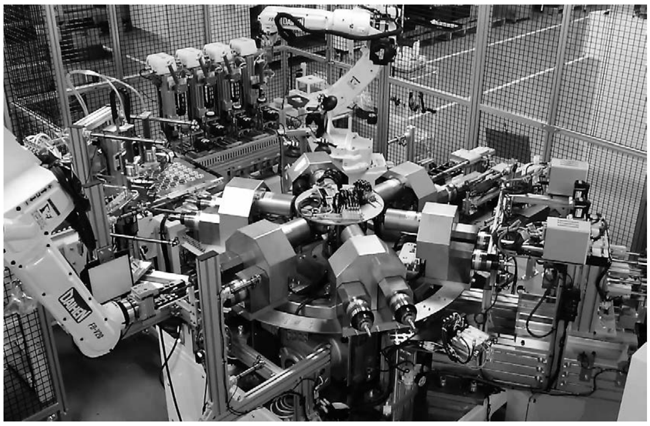

Fig. 3 Magnet bonding unit for 40 × 40 to 80 × 80 mm AC servo motors

Table 2 Overview of the bonding application check systems

Items	Flange size 20 × 20 mm line	Flange size 40 × 40 to 80 × 80 mm line
Inspection sensor	Laser	Camera + Image processing
Detection method	Measure the thickness of the applied bonding agent	Verify whether or not the bonding agent is applied uniformly

2.3 Specialty technologies in the part machining process

This section will introduce an example of the part machine process: machining the sheet metal plates used for linear servo motors.

As Figure 4 shows, this process consists of an automatic line combining an articulated robot and machine tool.

Table 3 is a comparison of the conventional line and the Innovation Line. Conventionally, plates were loaded and unloaded in and out of the machine manually. The heavy plates put a significant burden on operators, making handling difficult. Metal scraps and chips also had to be removed in the middle of the process.

On the Innovation Line, however, a robot and machine tool operate in tandem to automatically load plates, process, remove scraps, and unload plates. When loading a plate to the machine tool, we fashioned a way to utilize a sensor to detect whether or not the plate is seated properly to prevent machining defects.

2.4 Specialty technologies in motor inspection

For motor inspection, we built an automatic inspection line that can “swiftly and simply” inspect a wide variety of products.

Figure 5 shows a section of this automatic inspection line. Table 4 compares the new line with a conventional inspection line.

Previously, different equipment was required for each inspection criteria, causing in-process inventory to build up before and after each task. Furthermore, motors had to be manually attached and removed at each equipment.

For the Innovation Line, we developed an inspection unit integrated with a conveyor. We built a line which connects to this unit and conveys motors on pallets. Each inspection unit scans the 2D code on the motor nameplate, enabling it to automatically load the inspection program with required settings, then secure and connect the motor. The result is zero in-process inventory.

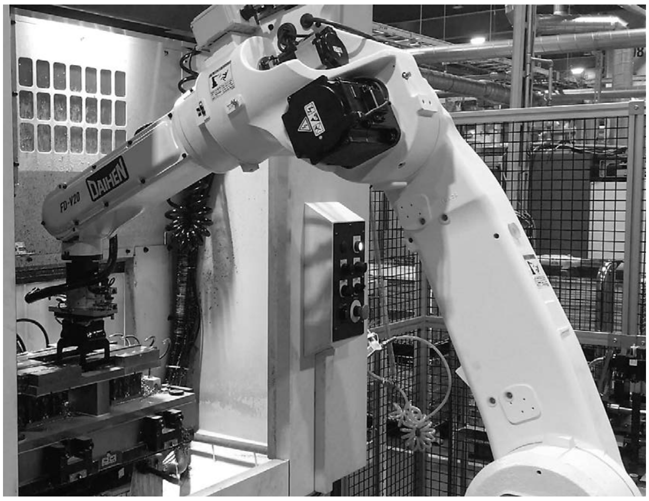

Fig. 4 Tandem operation of a robot and machine tool

Fig. 5 Automatic inspection line for motors

Table 3 Comparison of a conventional line and the Innovation Line (part machining process)

Items	Conventional line	Innovation Line
Conveying method	Operator carries heavy parts	Robot conveyance
Scrap removal	By operator	By robot

Table 4 Comparison of conventional line and Innovation Line (inspection process)

Items	Conventional line	Innovation Line
Conveyance and attachment/removal	By operator	Automatic
In-process inventory	Yes	None
Equipment setting/adjustment	By operators	Automatic

3. Specialty Technologies in the Servo Amplifier Innovation Line

Of our servo amplifier manufacturing processes, we revamped the processes for electronic component mounting, assembly, and inspection. For the Innovation Lines, by utilizing robots and sensing technologies, we engineered a way to automate work once done exclusively by our workers.

3.1 Specialty technologies in the mounting line

Roughly speaking, we have two PCB related processes: surface mounting technology (SMT) and through-hole technology. Our SMT process, where small electronic components are mounted to PCBs, have already been automated using chip mounters and other SMT equipment. However, inserting larger through-hole components with leads (known as lead components) had to be done manually by our workers.

Operators would intuitively correct positioning while inserting leads, without paying much attention to the lead component and through-hole positions.

Figure 6 shows the newly built component insertion line with an array of robots. For this line, we crafted a way to measure and reproduce the “unconscious movements” of our component insertion operators to make our robots more human-like.

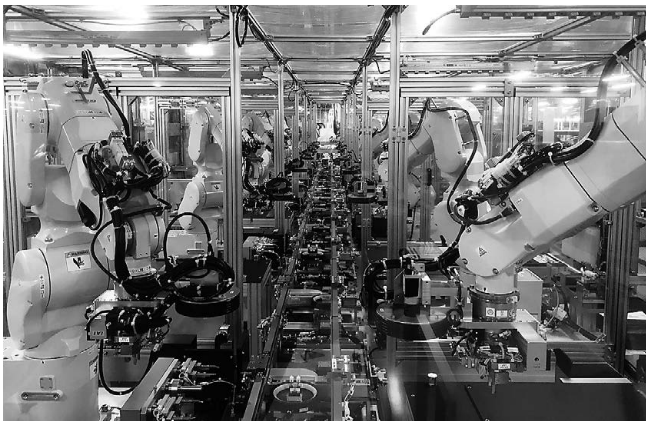

Fig. 6 Component insertion line with robots

3.1.1 Lead component picking

We came up with two solutions to ensure that the robots would accurately pick up the correct components.

First, we used pattern matching to search for components. Figure 7-1 shows an example of using pattern matching for connectors. Using pattern data, the robot will identify then pick up components to be inserted within the robot camera’s search area. With this function, even if components are arranged haphazardly during setup, robots can pick up the right ones.

The second solution involves using a camera to check the orientation and position of components in relation to the robot gripper. Figure 7-2 shows an example of the positional relationship between a component and robot gripper. This function quantifies the displacement between the gripper and lead component, and the amount of lead bend so that the robot can judge whether it is correctly picking up the component. Moreover, this function is used to correct positioning during insertion.

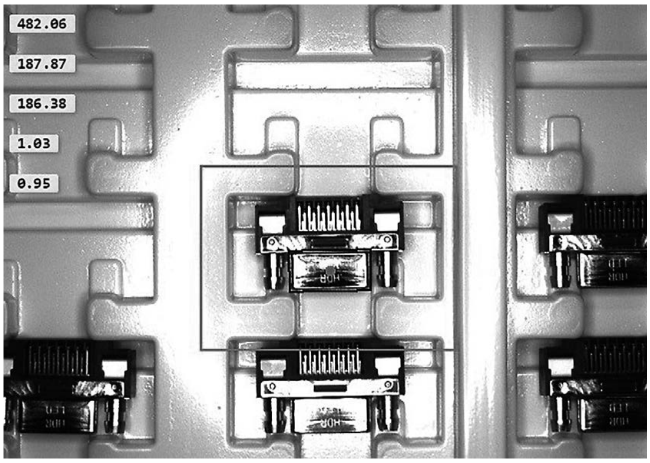

Fig. 7-1 Component coordinate detection using pattern matching

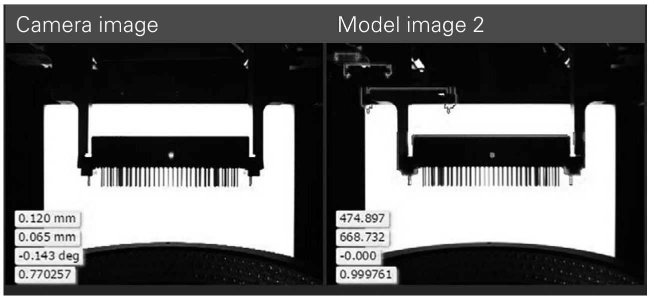

Fig. 7-2 Positional relationship between components and robot gripper

3.1.2 Lead component insertion

As shown in Figure 8, we added a force sensor and an image sensor to ensure that the robots correctly inserted components into the correct position.

First, the image sensor detects the PCB’s through-hole position. Next, the robot corrects positioning, then inserts the component. When a lead component contacts the PCB, force is exerted. A force sensor detects this force, allowing the system to calculate the positional relationship of the lead and through-hole.

If a force greater than the set value is detected, the sensor will determine that the lead position and through-hole position are misaligned then direct the robot to perform a search operation. This search operation involves monitoring force at the time of insertion with a force sensor, then moving the robot arm slightly along a horizontal plane. If the force detected in the search operation is less than the set value, the sensor will determine that the lead and through-hole position are aligned, then signal the robot to insert the component.

3.1.3 Post-insertion checks

To check that a component is correctly inserted, we installed the mechanism shown in Figure 8, which uses a laser displacement sensor.

After the insertion operation, a laser is applied to multiple points of the lead component's top face to detect its height. If the measurement exceeds the set height, it will be judged as not sitting correctly. This prevents defects caused by a component not being fully inserted.

As described above, we combined robotics and sensing technology to allow robots to perform the same movements that human workers do unconsciously. Compared to the conventional process, the new component insertion process is four times more productive, has one-third the production lead-time, and produces zero in-process inventory.

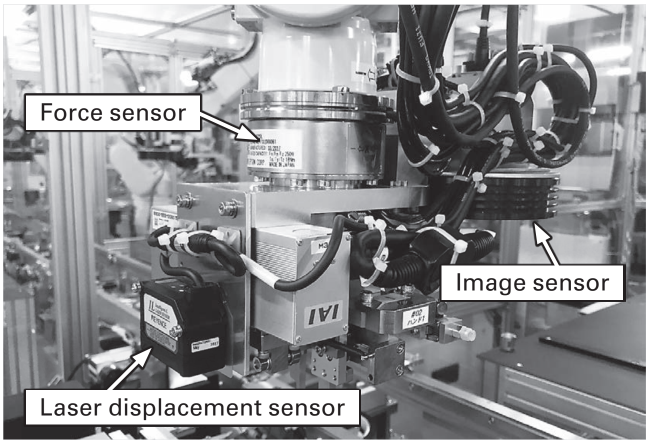

Fig. 8 Sensors on a robot arm

3.2 Specialty technologies in the assembly and inspection line

Following component mounting is servo amplifier assembly, inspection, and packing. Figure 9 shows the newly built assembly and inspection line.

On this Innovation Line, as with the mounting process, manual work has been replaced by robot work, creating an automated line capable of efficient product manufacturing.

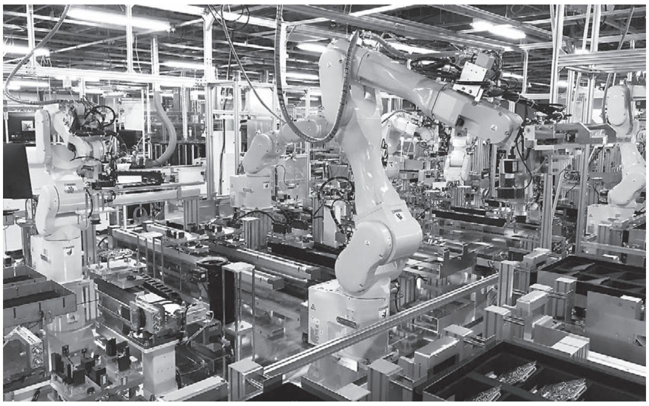

Fig. 9 Assembly and inspection line

3.2.1 Automation of the assembly process

The assembly process consists of a part supply section and a product assembly section.

In the part supply section, robots pick and place parts from the stocker to the assembly station. Here, image sensors prevent incorrect part supply by confirming that it is the correct part, and that it is placed in the correct position.

In the product assembly section, for each part positioned on the assembly station, a robot performs screw tightening, grease application, and cover mounting.

Torque screwdrivers ensure that screws receive the appropriate amount of torque. When grease is applied, an image sensor verifies grease application. Moreover, when the cover is mounted, the force sensor detects the engagement force while the image sensor checks engagement.

We introduced tool changers, as shown in Figure 10, to enable a robot to perform multiple tasks. A tool for the specific application is set in the tool changer, and the robot changes tools automatically for each task. This has made it possible to assemble efficiently within a limited space.

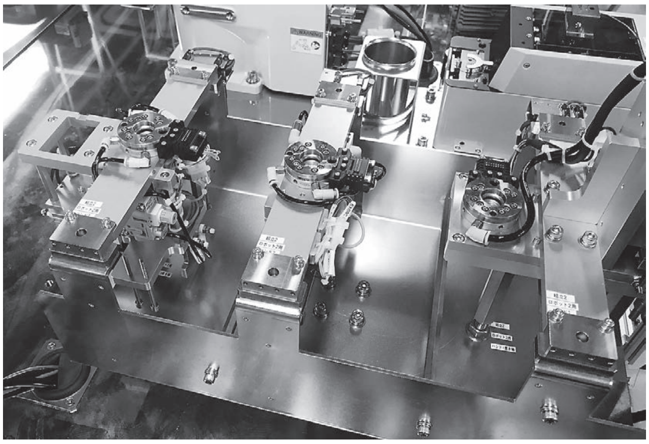

Fig. 10 Tool changer

3.2.2 Automation of the inspection process

In the inspection process, characteristics are inspected to check that servo amplifiers operate correctly.

During characteristics inspection, various cables and connectors must be connected to the servo amplifiers. This work, previously done by human operators, is now done by robots. Multiple connectors are used for inspection; therefore, as shown in Figure 11, an image sensor captures images of the various connector shapes to differentiate them.

The image sensor detects the positions of the connectors on both the receiving and insertion sides. Then robots insert the connectors while the force sensors ensure that the appropriate force is applied. Because the required insertion force differs depending on the connector shape, we set the insertion force for each connector to enable automation.

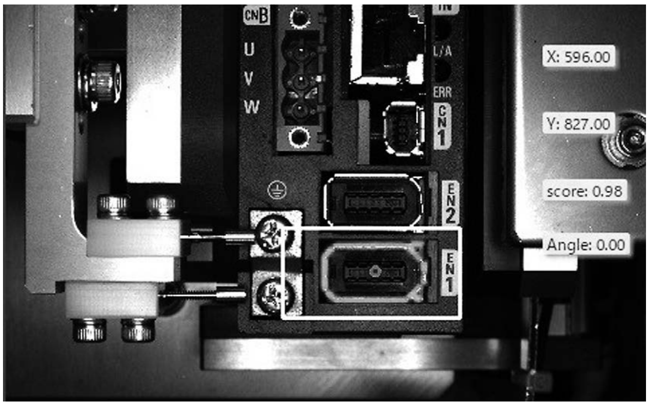

Fig. 11 Connector imaging screen

3.2.3 Automation of the packing process

Figure 12 shows a line where completed servo amplifiers are automatically packaged. Robots complete all the tasks (i.e. box making, bagging, boxing, and sealing) previously done by human operators.

When building the packaging line, we focused on packaging form. The conventional packaging form was designed around human workers and was not suited to automation. However, we changed packaging specifications to enable robots to perform packaging. Changing the product design to suit automatic assembly was one area in particular where we took an uncompromising stance.

We optimized everything from robot operations and gripper shape to outer box size, fold shape, and cushioning material shape in order to make automation possible. Moreover, by changing the label sticker attached to the cardboard box to direct inkjet printing, we eliminated the sticker attachment process.

As a result of the above efforts, productivity increased by 4.7 times, production lead-time was cut to one-quarter, and in-process inventory was eliminated on the new assembly and inspection line compared to the conventional line.

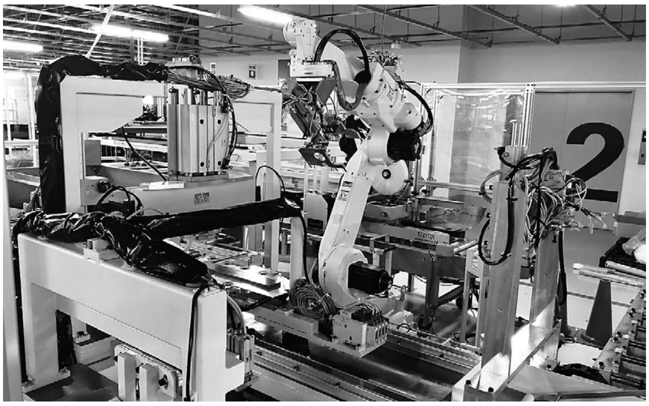

Fig. 12 Automatic packaging line

4. Conclusion

This article has introduced the specialty technologies and ingenuities of the Innovation Lines for our Servo Systems products. Each process incorporates specialty technologies and ingenuities unique to SANYO DENKI.

Our uncompromising stance is “efficiently making a wide variety of products with stable quality.” To achieve this, we engineered various robotics and sensing technology techniques for our Innovation Lines.

Moving forward, SANYO DENKI will pursue manufacturing innovation to continue providing customers with products and services that deliver value.

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