Technology Introduction

Construction of an MAG small A2 line

CHEN Wei

1 Introduction

The MAG[Note 1)] small A2 line[Note 2)] is designed to produce its core product MAG-33 (Fig. 1), which is positioned as a key product for the company's cost reduction activities. In addition to cost reduction, it is also necessary to reduce variable costs and internal processing costs for the A2 line. In the company's assembly lines, labor costs account for a large percentage of the combined labor, operating, and equipment costs (Fig. 2). To achieve cost reduction, reducing labor costs is effective. In addition, as the birthrate declines and the population ages, the future shortage of labor on the production lines is becoming an issue of concern. To cope with this problem, it is necessary to reduce the burden on workers and promote automation.

On the other hand, the A2 line should be compact to satisfy the customer need for higher production capacity while it has to be installed in a limited space since the hydraulic pump/motor processing and assembly lines were put together at Sagami Plant located in Sagamihara City.

Fig. 1 Drive motor with reducer (MAG-33)

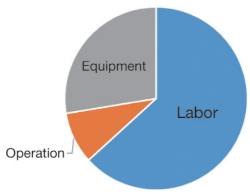

Fig. 2 Assembly line cost distribution (labor, operation, and equipment costs)

Note 1) An acronym for Motor Axial piton Gear box.
Note 2) An abbreviation of Assembly Line.

2 Purpose

To achieve the target internal processing cost and construct an assembly line using automation and digital technology without relying on human skill.

3 Targets

Table 1 shows the related target values:

Table 1 Target values

Item	Target (from conventional level)
Space	40% lower
Productivity by results	30% higher
Labor, operation, and equipment costs	18.9% lower

4 Requirements

[1] Development of new technologies for assembly automation
- Off-the-shelf components shall be used.
- Assembly of heavy components shall be automated in a small space at low cost.

[2] Development of automated data collection technology for hydraulic fluid contamination information
(Improving traceability: To follow customer demands)
- A system shall be built in collaboration with data analysis experts.
- Automated measurement shall be realized using advanced particle counters[Note 3)].
- The introduction cost shall be equivalent to that for existing equipment.

Note 3) Particle number measurement device

5 Overview of the Line

The MAG small A2 line is a high-mix and low-volume production line consisting of parts cleaning, assembly, and inspection (for air tightness and performance) processes (Fig. 3).

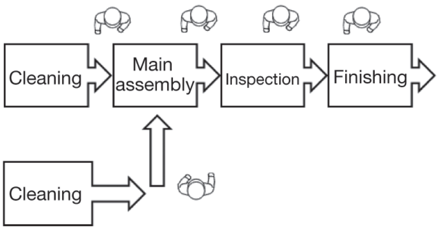

Fig. 3 Block diagram of assembly line

6 Activities

6.1 Development of New Technologies for Assembly Automation

6.1.1 Introduction of Automated Assembler for Housings and Flange Holders

This process assembles five parts (Fig. 4): a housing, an angular bearing, two floating seals, and a flange holder. The process involves lifting of the heavy housing (approx. 15 kg).

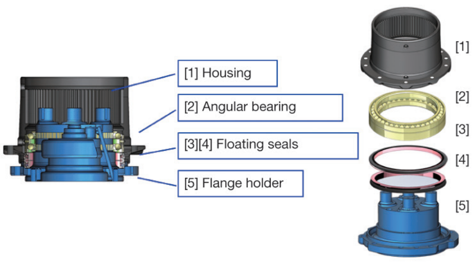

Fig. 4 Parts to be assembled

Traditionally, the heavy part was assembled manually (Photo 1). To improve safety and quality, we considered automating the manual task. At first, we studied the use of a heavy parts assembler robot, but the resulting robot was too large to be installed in the target space and cost significantly more than budgeted (Fig. 5). Therefore, we adopted a basic automation concept that the heavy parts assembler should have a simple structure. Based on this concept, we developed and introduced a simple structure assembler that can assemble heavy parts only by linear movement of its electric cylinder. Finally, we achieved the automation of heavy parts assembly with compact, low-cost equipment (Photo 2).

Photo 1 Manual lifting

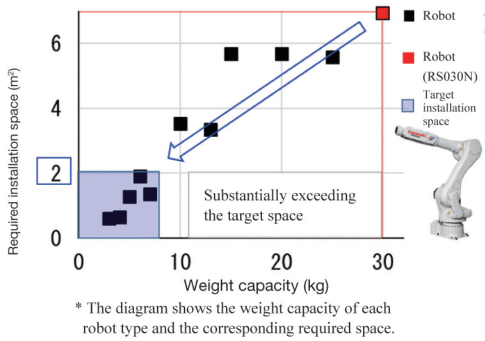

Fig. 5 Weight capacity and required space of robots

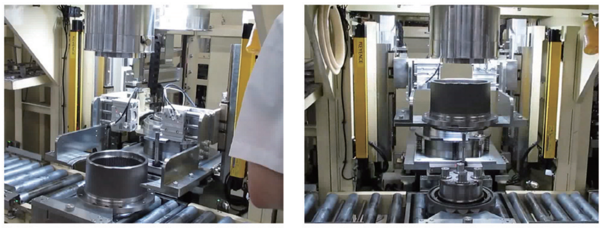

Photo 2 Automation of heavy parts assembly

6.1.2 Introduction of Automatic Plug Height Measuring Device

A claim was made that the sprocket could not be mounted to the drive motor because the plug was protruding from its seat on the sprocket mounting surface (Fig. 6). As a countermeasure, a step to measure the height of the plug with a dial gauge was added to the tightening error prevention system. However, this manual measurement process eventually resulted in variations in handling time, measurement time, and measurement results.

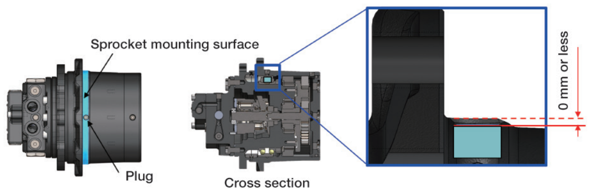

Fig. 6 Overview of plug protrusion

We then attempted to automate the plug height measurement process. The challenge was that the line produced a variety of motor products with different plug heights and positions. However, we were able to automate the plug height measurement process without increasing the number of devices or installation space by determining the optimal plug installation angle and height using a commercially available laser sensor (Fig. 7).

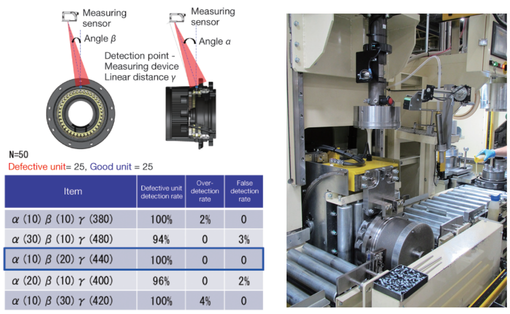

Fig. 7 Automated plug height measurement

6. 1. 3 Sequential Setup of Performance Tester

The line was analyzed for downtime to improve line availability (Fig. 8). The result showed that setup time accounted for 41.4% of the downtime. In particular, the setup of the performance tester was a bottleneck, indicating the need to eliminate unnecessary setup time.

In order to improve the setup of the performance tester, a work study was conducted, and it was found that it took a long time to eject the products, which resulted in a loss of time (Fig. 9).

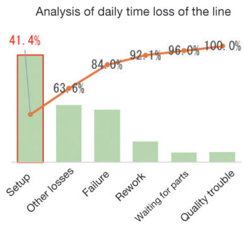

Fig. 8 Downtime analysis

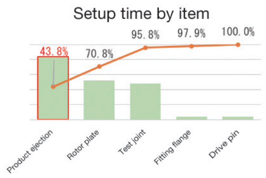

Fig. 9 Breakdown of setup time

For performance testing, the product is coupled to the shaft of the performance tester before being rotated with a pressure oil supply. The tester measures the speed, torque, pressure, and other parameters of the rotating product to determine the performance. The product can be coupled to the tester shaft by inserting the pin of the product's drive pin fixture into the hole of the rotor plate fixture attached to the shaft (Fig. 10). When connecting a different size product, the rotor plate fixture setup must be changed.

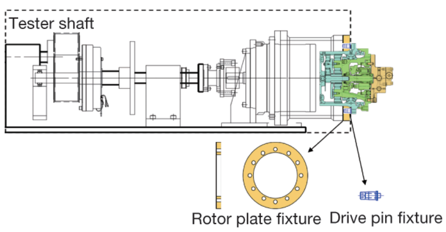

Fig. 10 Tester shaft and product

The performance tester is equipped with two shafts in order to reduce machine cycle time. While one product is being tested on one shaft, another product can be connected to the other shaft for alternate performance testing. The rotor plate fixture is located in a small space at the end of the performance tester's conveyor (Fig. 11). This means that the rotor plate fixture cannot be set up without ejecting the product from the tester, shutting down the equipment, and entering the tester for the setup change. Thus, the performance tester is not designed for sequential setup changes.

We then discussed how to achieve the sequential setup changes (Table 2).

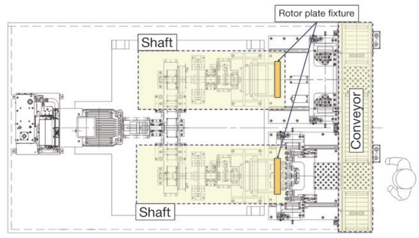

Fig. 11 Overview of performance tester

Table 2 Measures to achieve sequential setup changes

No.	Measure	Consideration for commercialization	Commercialization
1	Install a safety fence between the shafts to allow a setup change even while testing with the other shaft.	The safety fence may interfere with the test joint fixture moving between the two shafts.	×
2	Allow one type of rotor plate to accommodate all products.	Commercializable, although the structure of the drive pin fixture needs to be modified.	○
3	Automatic setup of the rotor plate	Automation has demanding space/cost requirements because the installation of this heavy object requires tightening operations.	×

As a result, we decided to use the drive pin fixture to accommodate products of different sizes. The drive pins to be inserted into the rotor plate were designed to have the same pitch so that one type of rotor plate fixture could accommodate all products. The drive pins were manufactured to have different pitches of the hole for product fixing to accommodate products of different sizes (Fig. 12).

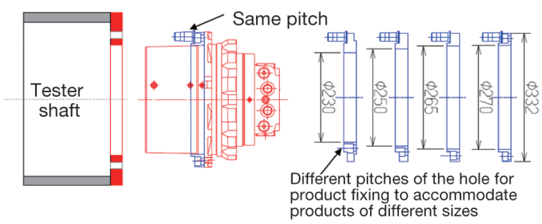

Fig. 12 Drive pin fixture [1]

In addition, we designed and fabricated another drive pin fixture with strength and weight optimized to maintain operability. This drive pin fixture has three holes for product fixing in the same manner as the conventional counterpart (Fig. 13), allowing the operator to complete the fixing within the same time as before.

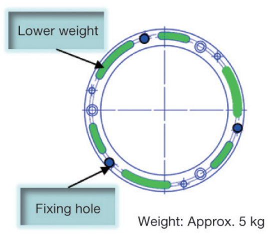

Fig. 13 Drive pin fixture [2]

By eliminating the setup changes of the rotor plate fixture and eliminating the product ejection for setup changes, we reduced setup time (Fig. 14) and achieved sequential setup changes of the tester.

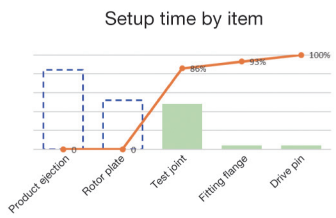

Fig. 14 Breakdown of setup time (after improvement)

6. 2 Development of Automatic Data Collection Technology for Hydraulic Fluid Contamination Information

6. 2. 1 Reduction of Fluid Contamination Analysis Time

Contamination of the hydraulic fluid in the performance tester is measured manually once a day. Measurements are recorded and maintained manually. It is desirable to measure product contamination for all units and use the measurement data to determine filter change frequency and ensure traceability, but it is difficult to measure all units by the conventional measurement method. We then discussed automating all units measurement with a new particle counter. However, there was no track record for the measurement accuracy of the new particle counter, which needed to be verified before implementation (Table 3).

Table 3 Comparison of particle counters

Particle counter	Conventional	New
Measurement method	Manual	Automatic
Measurement frequency (time/day)	1	220
Price (thousand yen)	3,000	1,500
Traceability	×	○
Measurement accuracy	○	?

The verification revealed that the measurement results of the new particle counter did not match those of the reference particle counter. The probable cause was that the new particle counter had a short measurement time in order to complete a measurement of all units. It was believed that the short measurement time resulted in variations in contamination from the products. We then worked to improve the measurement accuracy.

Specifically, we measured the contamination three times at the time of the product performance test while the hydraulic fluid was flowing into the return line (Fig. 15). The results were averaged within the PLC[Note 4)] to successfully reduce variations in product contamination. As a result, the new particle counter achieved automated measurement with the same accuracy level as the reference particle counter.

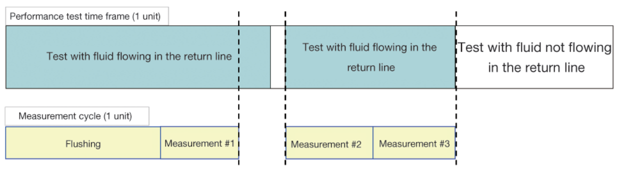

Fig. 15 Measurement averaging

We were also able to collect contamination data for each product. By analyzing the collected data, we were able to predict the right time to change the filter. In addition, with the support of the Production Innovation Div. in August, we successfully built a system that can write equipment data into the MES [Note 5)] (Fig. 16), thus increasing the human resources capable of building an MES at the Sagami Plant.

We will link the fluid contamination measurements with the dimensional data of machined parts and consider how to reduce the time for identifying products assembled with defective units.

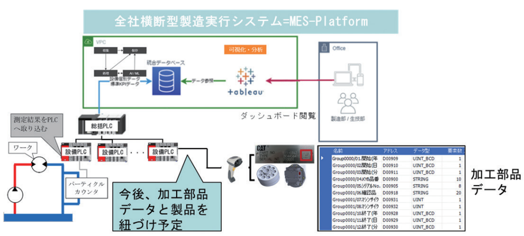

Fig. 16 MES system

Note 4) A control device used to control equipment and facilities.

Note 5) An acronym for Manufacturing Execution System.

7 Results

The results of the activities are shown in Table 4.

Table 4 Results of activities

Item	Target	Result	Mark
Space	40%	41%	○
Productivity by results	30%	30%	○
Labor, operation, and equipment costs	18.9%	19.5%	○

8 Conclusions

By horizontally expanding a low-cost, small-space automated assembly technology for heavy parts and using a small robot for light parts handling, we were able to build a compact, fully automated assembling machine. In addition, we achieved higher traceability of the key items of production and quality, and established a data collection and analysis base that enabled big data analysis. With the collected data, we will carry out activities to further improve productivity and quality.

9 In Closing

I would like to take this opportunity to express my sincere gratitude to the departments that have cooperated and to all those who have provided guidance and support in constructing this line.

Author

CHEN Wei

Joined the company in 2018.
Production Engineering Dept., Sagami Plant, Hydraulic Components Operations.
Engaged in design of assembly process and introduction of assembly equipment.