Technology Introduction

Construction of Self-Assembly Line Using Multi-purpose Assembly Robots

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1 Introduction

At the KYB Sagami Plant, workers must perform heavy lifting and learn many tasks, which makes them feel burdened (futan), dissatisfied (fuman), and anxious (fuan). (These three feelings may be referred to as the “3Fs” in Japanese workplaces). Additionally, the plant faces the risk of production stoppage due to the difficulty of retaining personnel because of the declining birthrate and aging population. The plant also faces an increasing risk of production line stoppage due to equipment failure, as the amount of complex, highly productive equipment has increased. One effective countermeasure is to develop anomaly prediction technology based on automation and digital technology, which is the focus of the company's internal innovation plant project. This paper reports on the construction of a line through technology development.

2 Background

The Sagami Plant manufactures travel motors for hydraulic excavators with a machine mass of up to 5.0 tons (Fig. 1). The speed reducers (Fig. 2) for these motors are purchased from a partner company. The purchased speed reducers are placed on the travel motor assembly line at the Sagami Plant and then assembled with the motors to form the finished product.

Fig. 1 Travel motor with speed reducer

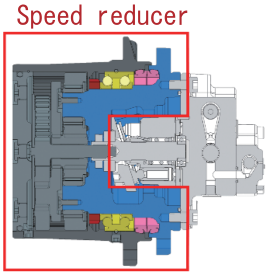

Fig. 2 Cross section of travel motor

As there is a plan to increase the production volume of travel motors, the supply of speed reducers was expected to be insufficient.

We then planned to manufacture speed reducers in-house (Table 1) to meet the demand for higher production. However, the Sagami Plant has limited space for an additional assembly line. Under the difficult space conditions, we had to construct a compact self-assembly line.

Table 1 Matrix of internal and external assembly/production

Hydraulic excavator	Speed reducer	Motor
～5.0ton	Partner company ＋KYB	KYB
5.0～8.0ton	KYB	KYB
12.0～35.0ton	KYB	KYB

3 Purpose

To construct an assembly line to meet the demand for higher production of travel motors for hydraulic excavators with a machine mass of up to 5.0 tons, and to allow workers to feel less burdened, less dissatisfied, and less anxious.

4 Targets

Table 2 shows the target values:

Table 2 Target values

Item	Target (compared to conventional level)
Space	20% lower
Output productivity	30% higher

5 Requirements

[1] Develop a new technology for assembly automation.
[2] Develop a predictive maintenance (anomaly prediction) function for lines where production (monozukuri) never stops.

6 Line Overview

The speed reducer assembly line consists of parts cleaning, assembly, and inspection processes. To improve output productivity, the first half of the line among these processes has been fully automated (Fig. 3).

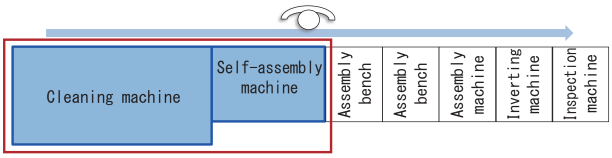

Fig. 3 Block diagram of assembly line

The self-assembly machine installed in the first half of the line is shown in Fig. 4. It is designed to efficiently perform various assembly tasks on workpieces carried on the conveyor using a 6-axis robot, hands, and fixtures arranged around it.

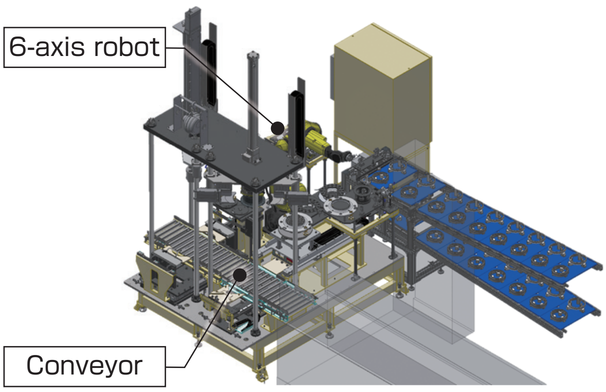

Fig. 4 Self-assembly machine

7 Implementation

7. 1 Establishing Self-assembly Technology for Heavy Parts

Until 2021, assembly work at Sagami Plant mainly depended on manual labor. Workers performed heavy lifting, such as lifting a 13 kg workpiece with their hands (Photo 1).

Photo 1 Heavy lifting work[1)]

In 2022, the plant semi-automated assembly operations as Step 1 of an improvement program. Specifically, a semi-automatic machine was introduced to assemble heavy work with a cylinder (Photo 2) and assemble light work using manual means. The cylinder was chosen instead of a robot because the heavy work could only be lifted by a large robot, which took up a lot of space.

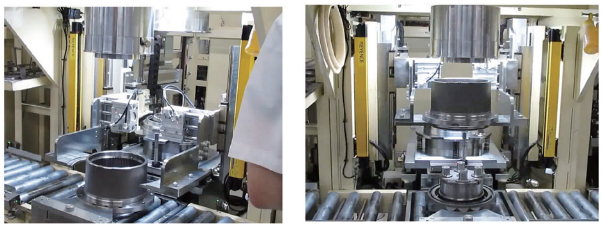

Photo 2 Semi-automation[1)]

In 2023, Step 2 of the improvement program involved fully automating the semi-automated equipment established in Step 1. Specifically, the cylinder is used to assemble heavy work, while a robot assembles light work (Fig. 5). The equipment is designed so that the robot is only used for light assembly, including fixtures and small workpieces, thereby reducing the robot's payload. This makes it possible to use a small robot (Fig. 6).

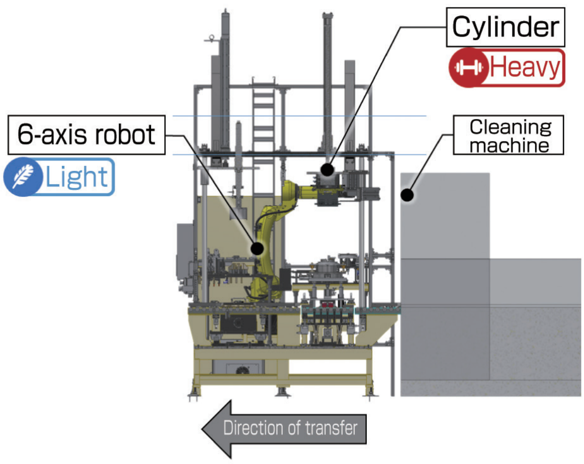

Fig. 5 Self-assembly machine (front view)

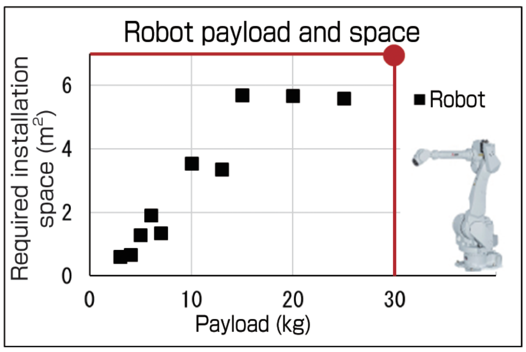

Fig. 6 Robot payload and space

7.2 Development of Technology to Create Lightweight, Multi-Purpose Robots Compatible with a Variety of Fixt

There were 27 processes that needed to be automated. Using 27 units for these processes would result in complex equipment that requires a high cost and large installation space.

We then decided to use multi-purpose robots. Of the 27 processes, 17 were selected to be handled by a single robot to minimize the number of units. The multi-purpose robot has four types of hands and seven types of fixtures (Figs. 7 and 8), which can be changed many times in a cycle to achieve lower equipment costs and smaller installation space.

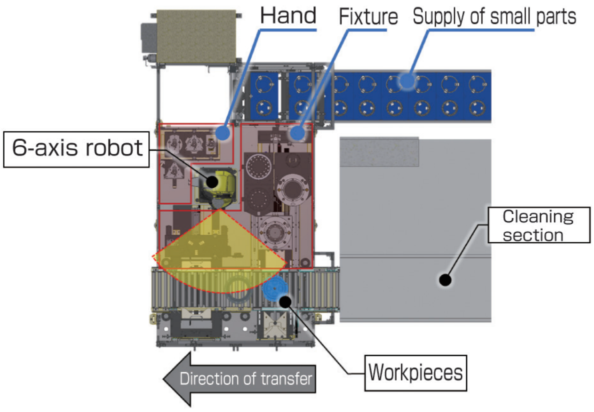

Fig. 7 Self-assembly machine (top view)

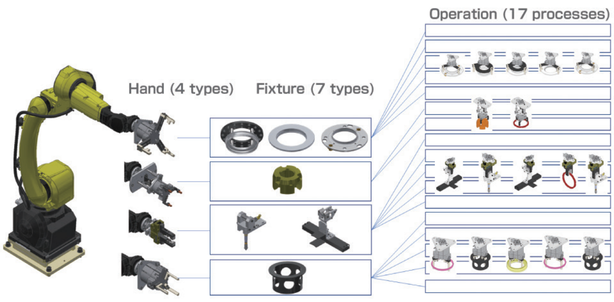

Fig. 8 Robot with a set of hands and fixtures

In addition, it was very difficult to verify beforehand that operations relying on the experience and intuition of skilled workers could be performed properly by the robot. In particular, in the operation of tightening the ring nuts[Note 1)], which are very thin, the nuts were tightened at an angle in some cases, resulting in galling (Fig. 9).

In the existing process, workers temporarily tighten the nuts by hand before finally tightening them with a tightening tool to prevent galling. This temporary tightening is a very difficult job that requires some experience.

Note 1) Large nuts of about M130.

We then iterated on a prototype fixture for horizontally inserting ring nuts (Photo 3) to successfully develop a final fixture. By using rapid prototyping with a 3D printer, we were able to explore effective solutions quickly and inexpensively.

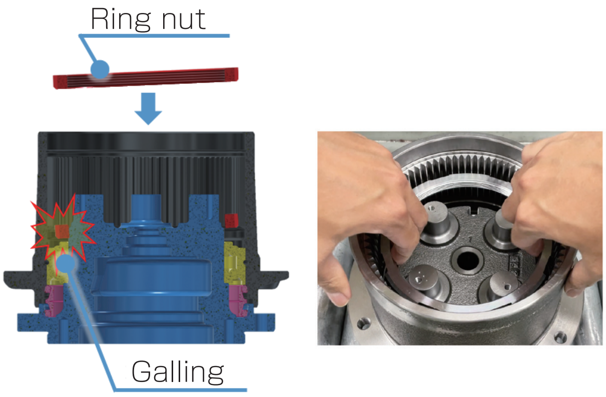

Fig. 9 Galling due to ring nut tightening

This fixture acts as a guide for the ring nuts, allowing a ring nut to be set exactly level. Now the ring nuts can be fully tightened with a tightening tool without manual temporary tightening. In this way, we have successfully replaced skilled labor with robot operation.

Photo 3 Horizontal insertion fixture (prototype)

In addition to the angled setting, we had another challenge. When a ring nut was inserted into the fixture, it was necessary to align the rotation phase. To solve this problem, we designed a special hand (Fig. 10). This special hand allowed the phase alignment to be performed without the need for advanced robot controls such as force sensors.

Fig. 10 Special hand

7.3 Reducing the Risk of Production Stoppage by Developing a Predictive Maintenance Capability

As production equipment becomes more automated, the number of sensors must increase, raising the risk of a sporadic failure. The majority of components are subject to corrective maintenance, although some are covered by preventive maintenance (Table 3).

Table 3 Current maintenance scheme

Equipment units	Equipment maintenance
Robots	Preventive maintenance * Annual maintenance by manufacturer
Parts that break frequently	Preventive maintenance * Periodic parts replacement
Other parts	Corrective maintenance

As a countermeasure, we embedded a function that monitors the operating time of the actuators and issues an alarm if it deviates from the control value (Fig. 11). We connected the equipment to PCs in the office via the internal LAN so that we could graphically view the changes in operating time. This allowed us to monitor trends in equipment movement, implement predictive maintenance, and reduce sporadic breakdown time.

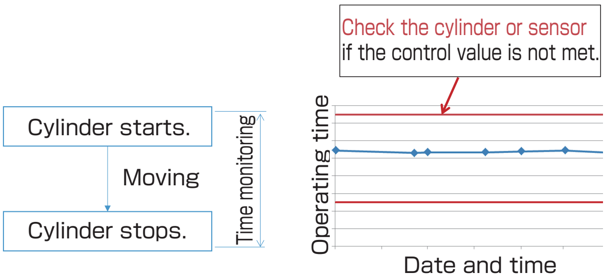

Fig. 11 Predictive maintenance

8 Results

The results of the implementation are shown in Table 4.

Table 4 Results of implementation

Item	Target	Result	Evaluation
Space	20% reduction	27% reduction	○
Output productivity	30% improvement	30% improvement	○

9 Conclusions

We have prepared technology to increase the production volume of travel motors for hydraulic excavators with a machine mass of up to 5.0 tons. We have also constructed a more worker-friendly assembly line that makes workers feel less burdened, less dissatisfied, and less anxious.

During the construction of the line, the Production Engineering Dept. and Machine Tools Center[Note 2)] held weekly specification review meetings from the stage of discussing the specifications. In addition, personnel from the Production Engineering Dept. were internally transferred to the Machine Tools Center to jointly prepare equipment drawings, manufacture the equipment, and conduct commissioning. This close coordination between the two departments for the start-up of the equipment led to the successful construction of the line. The internal transfer allowed us to learn robot technology, which is essential for promoting automation in future capital investments.

From now on, we will work with internal research departments and the Machine Tools Center to address elemental technologies for highly difficult operations.

Note 2) A department for KYB's in-house equipment manufacturing.

10 In Closing

We would like to take this opportunity to express our sincere gratitude to all the departments that cooperated in the construction of this line and to all those who provided guidance and support.

References

1) CHIEN: "Construction of an MAG small A2 line", KYB Technical Review No. 68 (April 2024).

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