Technology Introduction

Skill-free Machining with Smart Monitoring

ITO Yusuke

1 Introduction

The Sagami Plant is one of KYB's production bases for hydraulic equipment. However, it has limited space for expansion, making it difficult to accommodate increased production. To address this challenge, we are constructing an integrated machining, assembly, and painting line (Ship'30), which will minimize transport, inventory, and manual work [Note 1)]. This will establish a waste-free production line (Fig. 1). However, achieving uninterrupted production in the integrated line requires eliminating equipment failure, poor quality, and other losses.

As a first step, we are minimizing manual work in the machining line by utilizing elemental technologies, such as automatic measurement and monitoring systems, to address these challenges and achieve our goals. Through these efforts, we are preparing for the future of our production system.

Note 1) An abbreviation for Self-Handling Innovation Plant 2030. This initiative aims to establish a self-sustained, innovative plant by 2030.

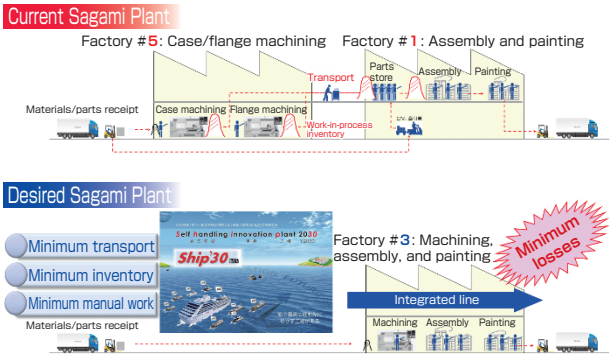

Fig. 1 Desired Sagami Plant

2 Background

The Sagami Plant's production of the piston pump (Fig. 2) is expected to increase by 2030.

To ensure profitability with this increased production volume, we have been assigned a challenging cost target. We are also required to achieve a specified internal machining cost target. However, conventional methods result in significant manual labor due to precision measurement on the production line and in-process defects. Consequently, we would not achieve the internal machining cost target.

To overcome these challenges, we will build a skill-free machining line that automates precision measurement, monitors and displays measurement results, and issues alarms.

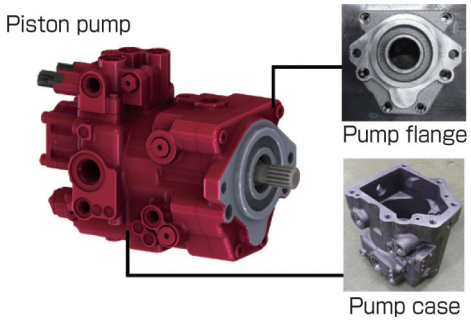

Fig. 2 Piston pump and its in-house parts

3 Purpose

The purpose of this project is to build a machining line that requires minimal manual work and contributes to the profitability of the Sagami Plant.

4 Objectives

The target values are shown in Table 1.

Table 1 Target values

Item	Conventional	Target
In-process defects	BM	25% lower
Labor, operating, and equipment costs	BM	36% lower
Cycle time	BM	29% lower
Machine availability	BM	11% higher
CO_2 emissions	BM	36% lower

5 Requirements

(1) Defects shall be prevented.
(2) Manual work shall be minimized through automated measurements.

6 Project Details

6. 1 What is Smart Monitoring?

"Smart monitoring" is a coined term derived from the words shown below (Fig. 3). It creates predictive technologies from data and visualizes them so that personnel can explore ways to minimize losses. In this project, we focused on preventing quality defects and minimizing manual labor.

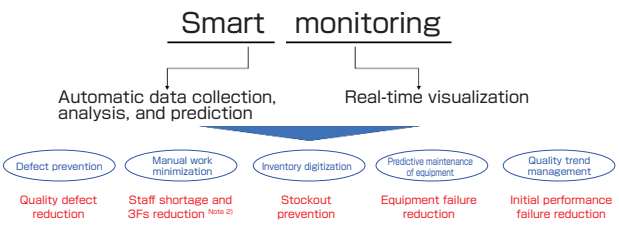

Fig. 3 Overview of smart monitoring

Note 2) "3Fs" stands for the initials of Japanese words "*futan*" (burden), "*fuan*" (anxiety), and "*fuman*" (dissatisfaction).

6. 2 Development of Smart Monitoring

Conventional in-process defects may include deviations from micron-level tolerances.

Micron-level machining is difficult to control because work dimensions change significantly if the cutting tool (Photo 1) wears out. Traditionally, operators performed 100% inspections. However, these inspections affect cycle time. Additionally, operators with insufficient skills might fail to keep up with dimensional changes, resulting in defects (Fig. 4).

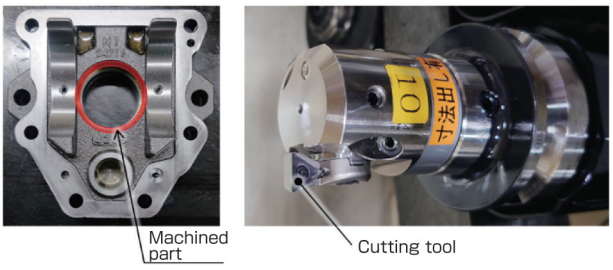

Photo 1 Cutting tool

To solve these problems, we devised a system that provides machining dimensions in real time. The system displays the measurement results in the machining center as a graph on the monitor so operators can constantly check for dimensional changes (Photo 2) (Fig. 5).

Furthermore, the production instruction screen shows an alarm message immediately before a dimensional defect occurs. Operators can then notice the abnormality before a defect occurs, which leads to a reduction in in-process defects (Fig. 6).

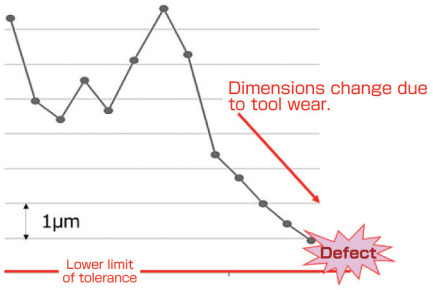

Fig. 4 Dimensional changes

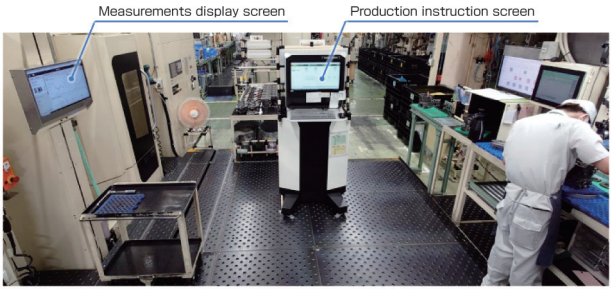

Photo 2 Appearance of the production line

Fig. 5 Dimensional changes visualized in real time

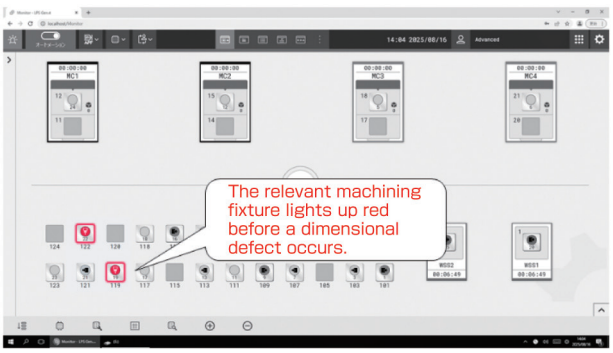

Fig. 6 Alarming window

We successfully developed these systems by integrating the standard features of the machining

center with the existing cloud service of the equipment manufacturer (Fig. 7). The measurement results are recorded in the equipment, which is under constant monitoring by the cloud service. The cloud service includes a function to plot measurements. The latest measurements are plotted in the graph each time the measurement results change. The graph is displayed on the monitor in the operation area to allow operators to identify dimensional changes.

In the future, we plan to analyze the accumulated measurement data using AI to optimize tool service life and stabilize product quality.

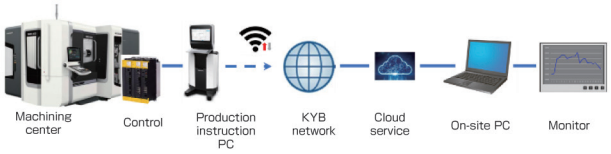

Fig. 7 Monitoring system

6. 3 Establishing a Measurement Technology Using Machining Centers

Although a visualization system has been established, equipment-based measurement cannot provide micron-level reliability, as is possible with coordinate measuring machines.

A comparison of the same workpiece subjected to manual and automatic measurements on the machining center revealed differences in measurement results of up to 8μm (Fig. 8).

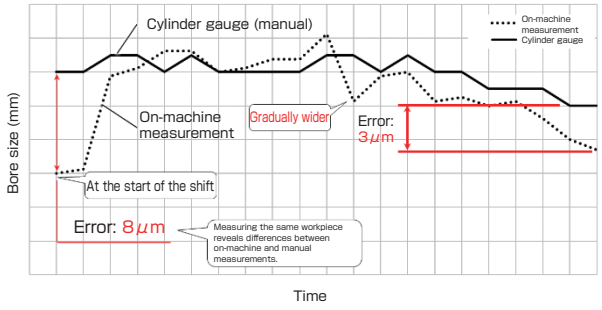

Fig. 8 Differences between manual and on-machine measurements (before improvement)

One of the main factors causing measurement errors is the change in outdoor temperature between morning and evening. When exposed to these changes, the machining center undergoes thermal expansion and contraction, which leads to measurement errors (Photo 3).

Fig. 9 shows the relationship between outdoor temperature and spindle position. As the outside temperature rises, the spindle position shifts downward.

We then developed a program to automatically detect and calibrate measurement errors [Note 3)].

First, a reference hole is made in the machining fixture. This hole is measured after each machining cycle. Any error of 2μm or more is automatically calibrated (Fig. 10).

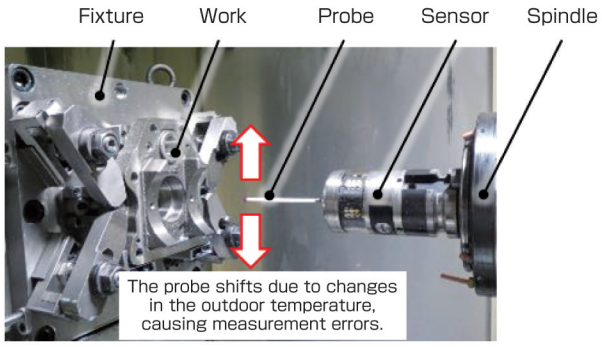

Photo 3 Measurement affected by shifted spindle position due to changes in outdoor temperatures

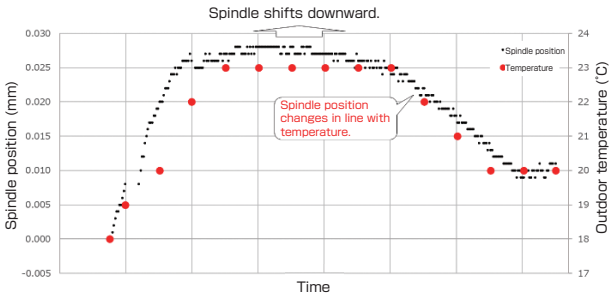

Fig. 9 Relationship between spindle position and outdoor temperature

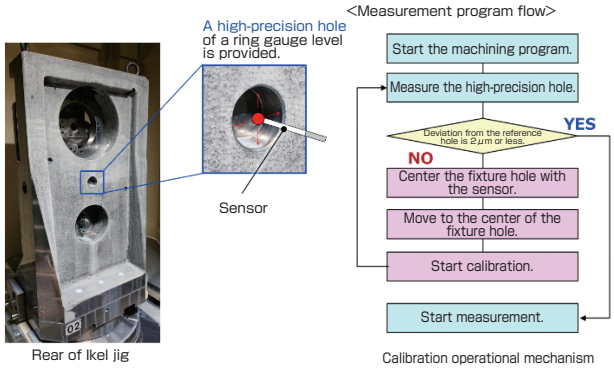

Fig. 10 Calibration mechanism

The introduction of this program resulted in an error of 2μm or less between manual and on-machine measurements (Fig. 11).

These measurement technologies allow 100% inspection and first- and last-piece inspection to be done on the machining center. This reduced manual labor time and improves the machine availability.

Note 3) Correcting the difference through comparison with the reference.

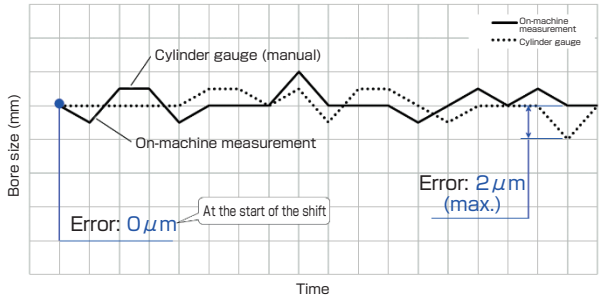

Fig. 11 Differences between manual and on-machine measurements (after improvement)

7 Results

Table 2 shows the results of the project.

Table 2 Results of the project

Item	Results	Evaluation
In-process defects	25% lower	○
Labor, operating, and equipment costs	36% lower	○
Cycle time	29% lower	○
Machine availability	11% higher	○
CO_2 emissions	36% lower	○

8 Conclusions

We successfully built a machining line that requires minimal manual work to establish a lean production line integrating machining, assembly, and painting.

In particular, we have developed reliable measurement technologies to reduce in-process defects independently of human skills.

Furthermore, this project has achieved automatic collection of machining data, alarming, and real-time visualization to implement smart monitoring. In the future, we will use this system as a stepping stone to develop defect prediction technology (Fig. 12).

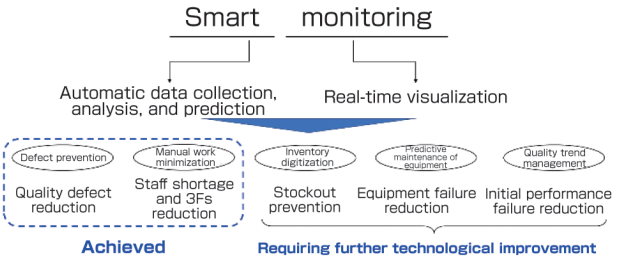

Fig. 12 Realization of smart monitoring

9 In Closing

I would like to take this opportunity to express my gratitude to the departments involved in developing this line, as well as to everyone who provided guidance and support.

Author

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Joined the company in 2017.
Production Engineering Dept., Sagami Plant, Hydraulic Components Operations.
Engaged in the process design of piston pumps.