Technology Explanation

Building the Foundation for MES Services in the New Era

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Abstract

With the advancement of digital technology, the manufacturing industry is becoming increasingly digitalized. Companies all over the world are using the Internet of Things (IoT) to build “smart factories” where each device in the factory is connected to the Internet to improve the efficiency of the manufacturing process.

Japan’s manufacturing industry has maintained quality through improvement activities and worker training. For this reason, there has been little progress in digitalization efforts. However, in recent years, with the decline in the working population and rapid changes in the international market, production systems need to be more productive and flexible than ever before. This is why MES, which analyzes data from manufacturing processes to improve productivity and support workers, and SCADA, which monitors and automatically controls equipment data, are attracting attention.

KYB is also working on MES and SCADA, and has several systems in operation to acquire and utilize data from production lines and equipment. In order to collect, accumulate, analyze, and utilize data, an analysis platform called “IoT Platform” has been developed in-house. However, the systems that have been in operation for a long time are not linked to the IoT Platform, so only limited analysis can be done within the systems, and they are not being fully utilized.

Therefore, in this development, we have developed a new service that solves these problems by first linking the IoT Platform to a single production data collection system. This system utilizes IoT and cloud technologies to build its functions. This paper describes the integration with the IoT Platform and the functions we have developed to utilize data in the manufacturing process.

1 Introduction

With the recent rapid advancement in digital technology, the world's manufacturing industry has changed significantly. Companies are actively introducing digital technology to use the Internet of Things (IoT) [Note 1] for building "smart factories" [Note 2] where all devices and equipment are connected with each other via the Internet. Such a smart factory can collect and accumulate data from its manufacturing process and analyze it using advanced technologies including artificial intelligence (AI) [Note 3]. This system can be expected to provide the following effects:

- To identify any inefficient parts of the manufacturing process and solve problems, achieving higher productivity, higher product quality, and lower cost
- To create a database of techniques and expertise of skilled technicians to allow for automation and transfer of their skills to younger technicians
- To use the accumulated data to predict the demand and supply and plan predictive maintenance

However, Japan's manufacturing industry has been left behind on digitalization. Japan's manufacturing (often called "Monozukuri") has maintained quality through human efforts including (skilled technicians' improvement activities leveraging their skills and experience and worker training to enforce workplace discipline. Only a few companies have heavily invested in digitalization programs. Quality maintenance has mainly been assured with human-based approaches relying on the expertise of technicians. In recent years, however, Japan has failed to successfully deal with the decline in the working population with fewer children and aged adults as well as the rapid changes in the international market, resulting in lower competitiveness. Owing to such situation, digitalization efforts are attracting attention in the Japanese manufacturing industry as well.

Today, many systems to promote enterprise digitalization are available. Among them, the following three are considered significant in the manufacturing industry:

- Enterprise Resource Planning (ERP)
- Manufacturing Execution System (MES)
- Supervisory Control And Data Acquisition (SCADA)

The ERP is the integrated management of main business processes. The ERP system centralizes management of business resources including humans, things, money and information. General systems to collect and control information necessary for financial, customer, inventory and human resource management are packed in an ERP system to help companies make decisions.

The MES is used to identify, manage and support manufacturing processes. The system makes use of data on production equipment, production control and product quality for improving productivity and quality and for supporting workers. While the ERP system covers management of an entire enterprise, the MES can be said to be a management system tailored to its manufacturing process. With this difference in mind, the MES can be linked to the higher-order ERP system to allow decision making based on real-time data collected from the manufacturing process.

The SCADA system monitors and controls manufacturing processes. It monitors how production devices are being operated and measured and, if necessary, controls them. While the MES analyzes and utilizes production data, the SCADA system monitors what is happening in the manufacturing process in real time. With this difference in mind, the SCADA system can be linked to the higher-order MES to allow for management of the manufacturing process and its automatic control in case of abnormality.

These three systems linked to each other will enable all employees and management to get a whole grasp of data from upstream to downstream and to carry out various activities based on the data, including decision making, improvement, and new business development.

KYB has also promoted efforts to manage and utilize data collected from its production lines and devices from an earlier time. The typical systems of this kind include the Point of Production Information Collection System (POPICS) and the line monitoring system (the details of these systems will be described in the following chapter). These systems that collect and utilize operation data from production lines and devices are considered to be positioned within the production system as shown in Fig. 1. Our POPICS has certainly achieved data sharing among the ERP, MES and SCADA regions, but only to a limited extent. Our line monitoring system is being reviewed to provide various functions for the SCADA region by introducing new technologies. However, its integration with higher-order systems such as MES or ERP has not yet been discussed, resulting in insufficient use of data from the manufacturing process.

We have built a foundation to provide new MES services (Fig. 1) using a SCADA collecting data from the line monitoring system linked to an MES that has been designed to be able to have additional functions. The following describes the details of the foundation and its related systems.

Note 1) An acronym for Internet of Things. The IoT refers to general attempts to connect things to the Internet and utilize them.

Note 2) A factory where devices therein are connected with each other via the Internet to improve the manufacturing process and enhance the operation efficiency. Data collected from the devices is analyzed and utilized in a sophisticated manner to optimize the factory/production management.

Note 3) An acronym for Artificial Intelligence.

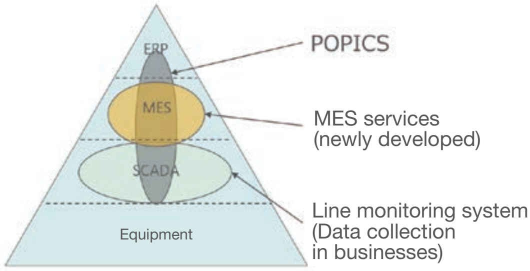

Fig. 1 Scheme of systems for MES services (KYB's effort)

2 Current Systems in KYB

2.1 POPICS (Fig. 2)

KYB developed and introduced a production line data collection system called POPICS 20 or more years ago [1].

Via panel computers installed on the production lines, POPICS transfers production instructions and other data from higher-order systems, collects cycle time data using device I/O, and collects nonconformance reports by operators and other data from lower-order systems. POPICS summarizes collected data into KPIs [Note 4] such as productivity and presents them to manager-class personnel using a visualization application program.

Part of POPICS has already been linked to higher-order systems so that POPICS data can also be viewed on the systems that manage cost data and inventory control information.

A problem is that POPICS only collects data in production lines. Collected data for each line is not sufficient to develop measures against device failures or conduct improvement activities, failing to satisfy user needs.

Note 4) An acronym for Key Performance Indicator. This major performance evaluation indicator is intended to evaluate achievements against goals.

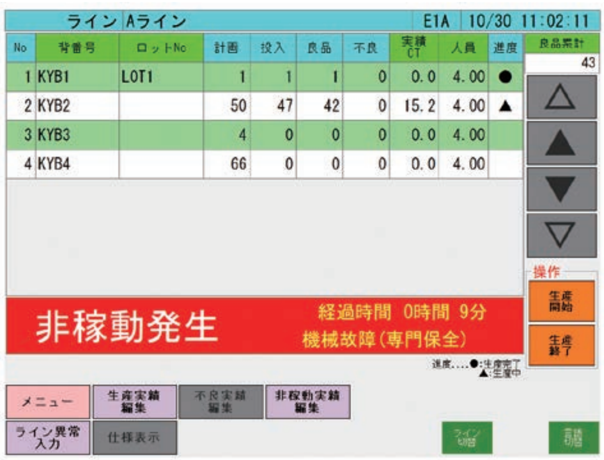

Fig. 2 Example of POPICS window (sample data shown)

2.2 Line Monitoring System

KYB is promoting Innovative Monozukuri mainly on the production lines in its factories for manufacturing shock absorbers, which are one of the company's key products. This activity aggressively makes use of AI and IoT technologies to recreate a manufacturing system from design to production, with the aim to achieve the following goals:

① To double productivity
② To halve design-to-production lead time
③ To achieve zero nonconformance

Then, KYB introduced IoT technology to the production lines and developed a new line monitoring system for visualizing the manufacturing process in an easy-to-understand way to ensure higher productivity and higher quality. This system was developed in 2017 as an improved version of the POPICS described in the previous section and has been sequentially introduced to KYB facilities. While the conventional POPICS can only collect data in production lines, the new line monitoring system can collect data in production devices, thereby enabling real-time monitoring of individual devices.

In this line monitoring system, PLCs [Note 5] for individual devices collect operation data, which will be put together by a general PLC installed on each line and stored in a database (DB) built on a line server. Furthermore, a visualization software program running on the line server displays data on a large-sized monitor in an easy-to-understand way (see section 4.3 for the system configuration).

The monitor displays data as shown in Fig. 3. Production information including KPIs and the operating status of each device, quality information including measurements, and processing condition information can be viewed on the screen. [Note 6] Personnel can easily view these types of information in real time to identify any anomaly in each device and take appropriate measures.

However, the current line monitoring system cannot provide line comparison or long-time data analysis, posing a challenge of diversified analysis to be available.

Fig. 3 Example of display on the line monitor screen (sample data shown)

Note 5) An acronym for Programmable Logic Controller. This control device developed as an alternate to a relay circuit is often used to control production devices.

Note 6) The information includes undisclosed information that has been intentionally deleted or blurred.

2.3 KYB-IoT Platform (Fig. 4)

In order to analyze and utilize all in-house data, KYB internally developed a data analysis base called KYB-IoT Platform [Note 7] in 2020. The Platform was developed under the concept that "anyone can easily analyze and use data anywhere anytime". Storage of collected data as well as data analysis and use with AI or BI [Note 8] can be started easily and quickly.

The KYB-IoT Platform has been built on the public cloud Amazon Web Service (AWS) where the storage and processing capability can be scaled up/down depending on data volume and throughput. The cloud-based platform can be used anywhere and can easily be deployed throughout the world. Leveraging the abundant cloud services available on the AWS will efficiently develop new services and provide additional functions.

One of the systems operating on the KYB-IoT platform is the equipment predictive maintenance system. [2] This system collects data for identifying the equipment status such as vibration and temperature and then analyze it with AI, thereby enabling prediction of failure signs. The results are visualized with BI tools to be available to the department users belong to, implementing predictive maintenance.

In this case example, saving, AI analysis and visualization with BI tools of collected data are all implemented on the KYB-IoT Platform. Beside these, the platform implements the function that issues an alarm when a failure exceeds a threshold level and has an improved visualization monitor. The KYB-IoT Platform has thus been added with new functions and has been improved as necessary.

Note 7) A system base to collect, visualize, analyze and control large volume of data from IoT devices connected to the network.

Note 8) An acronym for Business Intelligence. It refers to collecting, accumulating and analyzing data to support decision making on enterprise activities.

2.4 Problems with the Current Internal Systems

KYB has different systems shown in Fig. 5. However, it cannot be said that these systems are properly interfaced to each other so as to optimize the company's total operation. If these systems could share and exchange data, we would be able to identify more clearly what the company is actually doing or what we have not noticed so far. The company should leverage the potential of the systems.

Some production systems have been developed and deployed recently, including the line monitoring system described in section 2.2 and the KYB-IoT Platform described in section 2.3. Unfortunately, these systems have not been linked to each other, failing to use data effectively.

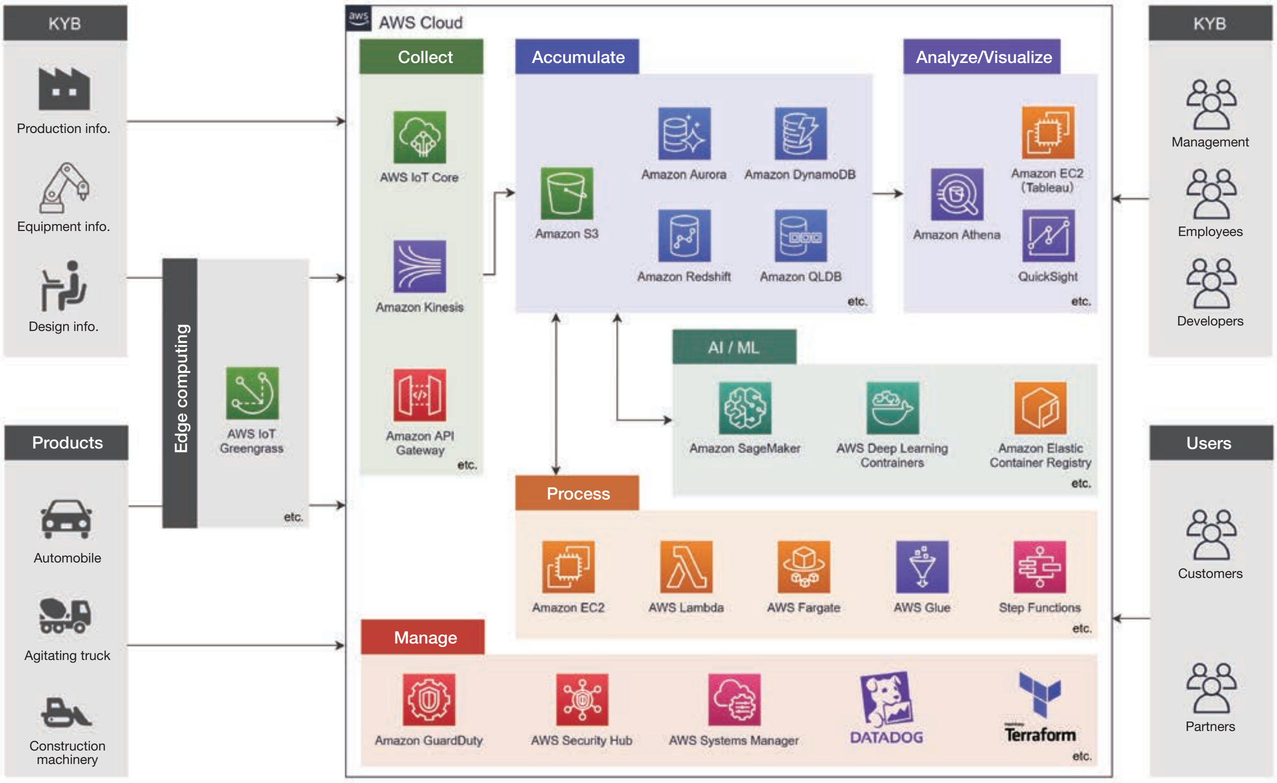

Fig. 4 Overview of IoT Platform

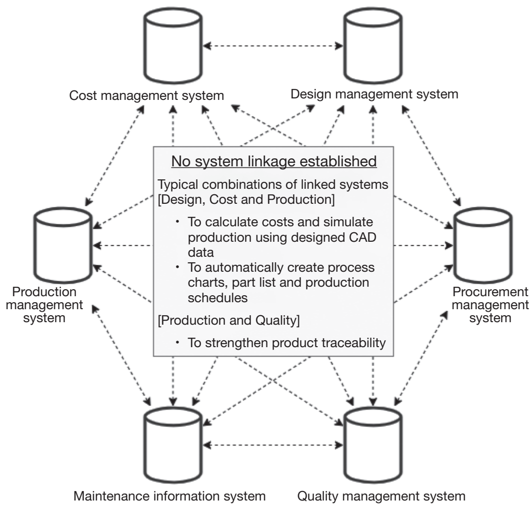

Fig. 5 Current internal systems

In addition to the line monitoring system, the company has also discussed or developed other data collection systems to be deployed in internal source locations. Still, these systems have been designed to display and store data in different ways because they use their own data formats. This is one of the reasons why the systems can hardly share data.

To overcome these challenges, KYB is discussing to centralize data in the KYB-IoT Platform. In addition, to solve the problem that several data collection systems gather different data items from internal source locations, it is necessary to decide what data is to be collected in what format, such as the standard data set including "CT [Note 9)], MT [Note 10)] and anomaly time".

In this development, we have built a foundation of a total system to centralize manufacturing process data in the KYB-IoT Platform and to link the platform to other systems. The following sections explain it in detail.

Note 9) An acronym for Cycle Time. It refers to the operation cycle time from when a task is completed to when a next task is completed.

Note 10) An acronym for Machine Time. It refers to the machining time of machine tools.

3 Requirements

The following shows the requirements for ensuring that the total system is operated properly for effective use of production data:

① To standardize data items to be collected so that collected data can be saved in the KYB-IoT Platform
② To ensure that all necessary data items are collected and accumulated in the KYB-IoT Platform
③ To enable data analysis in devices and long-time data analysis
④ To link the KYB-IoT Platform to other internal systems to share design and cost information
⑤ To build a total universal system for global use
⑥ To ensure that horizontal deployment of and function addition to the system can easily be done

4 Development of MES Services

4.1 System Overview

This development has the purpose of building a total system linking the aforementioned KYB-IoT Platform to the line monitoring system for analyzing and utilizing manufacturing process data. The development is underway with another future goal of achieving company-wide and even global deployment of the total system.

Fig. 6 illustrates how the total system is configured. The line monitoring system collects data from individual devices and save the data in a predetermined format. All the collected data is saved in the KYB-IoT Platform for centralized control of company-wide production data. Once saved, the data will be immediately visualized to be available for analysis.

The KYB-IoT Platform can easily be linked to other systems because of its collective data management and can also provide diversified analysis using data from other systems.

This development roughly covers the following four major tasks. The details will be explained in the following sections:

- To standardize data to be collected and data format
- To determine how to collect/transfer data
- To determine how to save data
- To determine how to display and analyze data

4.2 Standardizing Data to Be Collected and Data Format

We have standardized data to be collected to ensure that data collection systems at various source locations can write common data items to the KYB-IoT Platform in the same data format. This makes it possible to utilize data for analysis with a unified set of indicators. We have selected important data items needed by all locations to carry out improvement activities. These data items can be categorized by data collection timing and data content into four groups shown in Table 1. We have specified a data format for each data group, achieving standardization of data collection.

The first data group is production results (including actual CT & MT and setup change time) to be stored in the KYB-IoT Platform. With these types of data available, the user can find possible causes of lower production while viewing CT/MT, setup change time and availability data on the screen.

The second data group is equipment alarm (including alarm date and time, alarm type and downtime) to be stored in the KYB-IoT Platform. With these types of data available, the user can narrow down equipment alarms to be handled in higher priority and check the equipment alarm log.

The third one is jig and tool change data (including date and time of change and the remaining number of times of use) to be stored in the KYB-IoT Platform. With these types of data available, user can identify what caused the jigs and tools to be changed.

The fourth one is measurement data (including measurement values and items) to be stored in the KYB-IoT Platform. With these types of data available, the user can manage the daily data trend using control charts and find possible causes of an anomaly in connection with the alarm information. In addition, some devices may measure and save multiple measurement items at the same time. The style of tables accepting data in this case has been standardized to "vertical" Note 11), thereby enabling the user to easily switch over devices and measurement items or to analyze data more conveniently.

On the other hand, some source locations may collect data in a data format other than that stated above in some cases. Then, we, in this development, have decided to save data collected from individual source locations in a common file format. In the format, first comes the identification information including production line, production device, date and time of data collection, and type of data collected. This general information is followed by source-specific data. Although data items to be collected and the number of data items vary by target device or object, the KYB-IoT Platform identifies data and executes subsequent processing (including pretreatment and DB storage).

Note 11) A kind of data table structure. It refers to a type of tables where data is added in the longitudinal (line) direction.

Table 1 Data to be collected

Data group	Data to be collected
Production	• Actual CT • Actual MT • Setup change time
Equipment alarm	• Date and time of alarm • Type of alarm • Downtime
Jig change	• Date and time of change • Remaining number of times of use after change
Measurement data	• Measurement item • Measurement value

4.3 Data Collection/Transfer

This section explains the line monitoring system, although several other data collection systems are being discussed in various sites. It should be noted that any data collection system could be linked to the KYB-IoT Platform even if the system does not have the same configuration as that of the line monitoring system.

The line monitoring system is generally configured as shown in the Data Collection region in Fig. 6. The line monitoring system centralizes operation data held by the equipment PLCs to the general PLC and stores data in the database (DB) built in each line server. By using a visualization software program running on each line server, the system displays data on a large monitor in real time. It also transfers data from the general PLC to the KYB-IoT

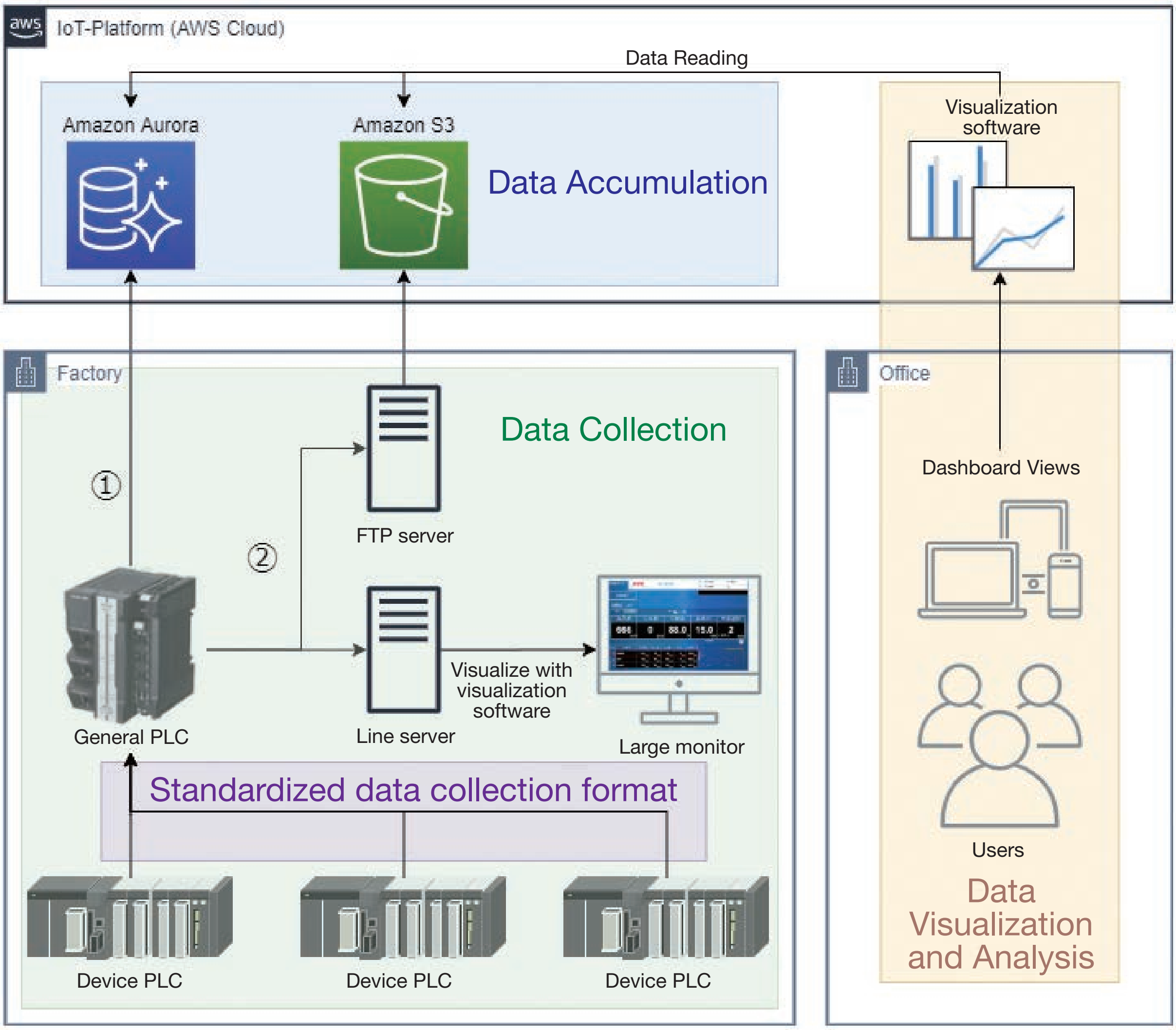

Fig. 6 Configuration of MES services (overview)

Platform in the following two methods to store data in the Platform (Fig. 6, ① and ②):

① Directly write data from the general PLC into the DB on the KYB-IoT Platform

② Transfer file data in CSV or other format created in the general PLC by using the file transfer protocol (FTP)

The method ① should be selected for structured data Note 12) occurring infrequently (in several seconds) that will be utilized frequently (i.e., accessed) after saved. Specifically, CT, MT and equipment alarms will be transferred in this method and written into the DB on the Platform one by one when the equipment cycle is completed or any alarm is reset. It should be remembered that this method can only be used with a PLC that supports data writing to a database. It is thus necessary to prepare in advance a PLC supporting the data writing.

In method ②, the system saves data gathered by the general PLC in a file format and transfers it to an internal FTP server using the FTP before saving in the storage on the KYB-IoT Platform. This method should be selected for data that cannot be accepted by the DB, for example, data that is generated in a large size per unit time such as millisecond or non-structured data. Specifically, measurement data and equipment machining condition data (current and temperature) will be recorded in the general PLC as required at a certain sampling rate. Several data sets will be put together to be saved in a file when a setup change or a production session has been completed. Such files will be periodically transferred using the FTP. In fact, this type of data saved in files can be viewed at a lower retrieval speed than that for the DB. Still, our understanding is that no significant problem with system operation will arise because data utilization (access) has been assumed to take place infrequently. This method has been verified to be supported by a wide range of PLCs. How to store data in these two methods will be described in detail in the following section.

Note 12) "To structure data" means to preliminarily define the type and sequence of data items and arrange them in a specified structure.

4.4 Data Storage

As described in the previous section, we have established two different ways of storing data (Fig. 6).

For method ① in Fig. 6, a database (DB) has been created on the KYB-IoT Platform (cloud) to store acquired data. The DB uses an AWS fully managed [Note 13)] high-performance RDB [Note 14)] service called "Amazon Aurora" featuring high performance, high expandability, high safety and high availability. Thanks to its high data reading performance, Amazon Aurora allows user to quickly retrieve data by linking multiple data sets using SQL. [Note 15)]

Method ② in Fig. 6 uses a cloud storage service called "Amazon S3" (hereinafter "S3") to store data saved by the general PLC in files. This service features high durability, high safety and high availability. Furthermore, S3 can offer many other benefits including virtually infinite storage capacity and lower cost than Amazon Aurora. One disadvantage is that the data retrieval service for S3 is not designed to allow the user to easily retrieve data in an advanced way, resulting in lower retrieval speed than for RDB.

Furthermore, it costs more for S3 to store large amounts of data than for Aurora as shown in Table 2. The data storage cost may be reduced by changing where to store data depending on the data use frequency. It is vital to select a better one from these two destinations with consideration given to frequency of data occurrence and frequency of data use.

Table 2 Comparison of data storage

	Aurora	S3
Data volume	Low	High
Frequency of use	High	Low
Storage cost [Note 16)]	0.12 USD/GB/month	0.025 USD/GB [Note 17)]

Note 13) AWS undergoes server/operating system (OS) management and failure correction for users. Users can focus on their use of service, leading to higher development efficiency and lower operation cost.

Note 14) An acronym for Relational Data Base. An RDB manages data in multiple tables and defines the relationships among the tables to be able to handle the relation among complex data sets.

Note 15) An acronym for Structured Query Language. SQL is an internationally standardized database language used to operate and control the RDB management software.

Note 16) The figure shows the price in Tokyo Region as of December 21, 2021. The figure for Aurora only indicates the data storage cost.

Note 17) The price for S3 becomes lower in stages as the data capacity becomes lower. The figures shown in the table indicate the service fee for 50 TB/month.

4.5 Data Visualization and Analysis

We have developed a data display system using a BI tool called Tableau [Note 18)] to visualize and analyze collected data.

This visualization and analysis system reads data on the KYB-IoT Platform. Once data is saved in the system, the data immediately becomes available on the screens. Fig. 7 shows how these screens are configured. All the screens shown in Fig. 7 are standard views for all the sites. A total of 18 screens are available at this moment. Some of these screens cover two or more types of data to allow for diversified analysis. The screens are linked with each other so that the user can view several screens to find more detailed analysis screens for deeper analysis. This section will explain some of these screens we have developed.

Note 18) This industry's leading BI tool allows the user to easily visualize and analyze data. KYB is also introducing and deploying the tool.

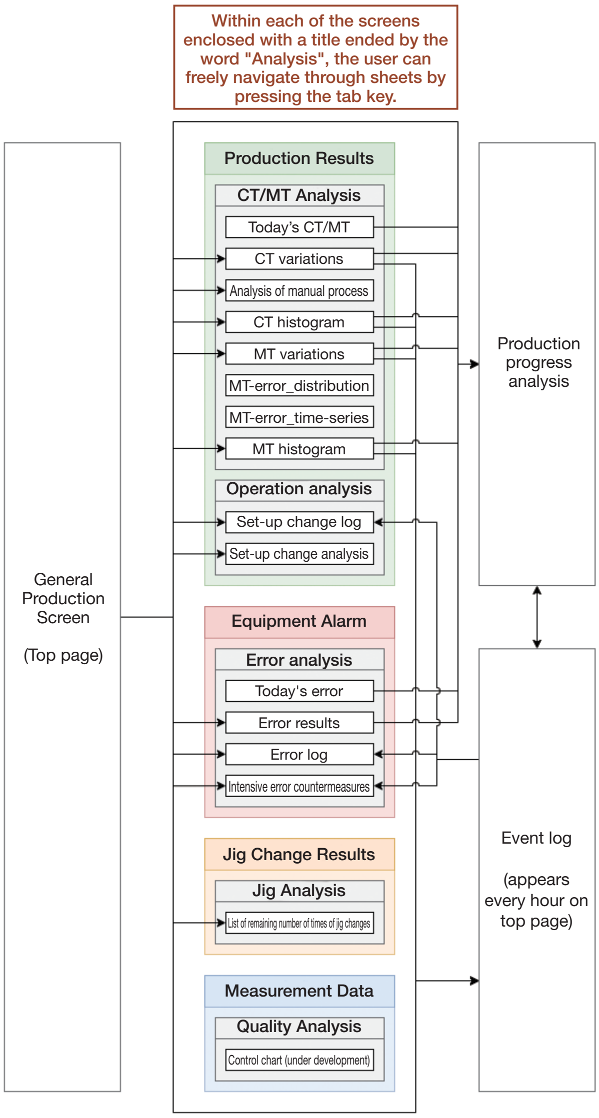

Fig. 7 Linkage of visualization and analysis screens

4.5.1 General Production Screen (Top Page)

Fig. 8 shows the general production screen where the user can view actual results of production. Views showing CT, MT, setup change, availability, alarm and jig changes for each device are tiled on the screen, enabling the user to narrow down possible causes of any lower productivity from various angles. [Note 19)] This screen displays how daily-compiled data changes day by day. The user can look at the graphs on the screen to be able to easily identify any data showing an anomaly (for example, longer CT or more errors than the criteria). If this is the case, the user can move on to another analysis screen linked to the top page for deeper investigation.

Note 19) The information on the screen includes undisclosed information that has been intentionally deleted or blurred.

Fig. 8 General production screen (Top page)

4.5.2 CT Histogram Screen

Fig. 9 shows the CT histogram screen that displays the CT results over a specified period of time in the form of a time-series two-dimensional histogram. The upper half of the screen provides the CT histogram over a specified period with the X-axis showing CT bins in the unit of one second and with the Y-axis showing the magnitude. The lower half of the screen indicates how CT changes by each day in light and dark in color. A dark colored cell represents a high magnitude. The Y-axis shows the date in units of one day (time elapses from top to bottom with the top oldest and the bottom newest), representing daily CT variations (distribution in a day). User can first identify normal CT on the histogram over the entire period and then check variations for each day to determine whether any worse CT than the normal level is attributable to a spontaneous or chronic cause. If spontaneous, it is advisable to narrow down possible causes on the screen stated in the previous section and take appropriate measures. For chronic ones, it is effective to review the work and machining programs and check any other chronic error.

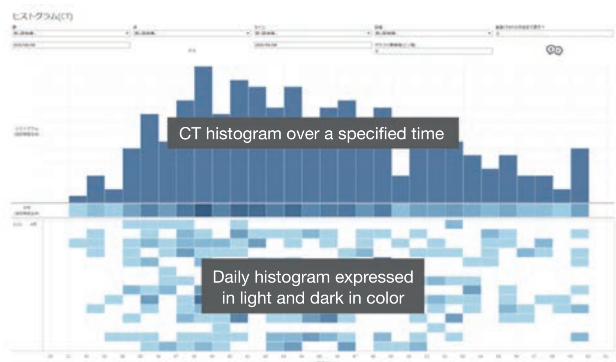

Fig. 9 CT histogram screen

4.5.3 Alarm Screen for Intensive Measures

Fig. 10 shows the alarm screen for intensive measures where the user can identify device alarms in the form of Pareto charts. The Pareto charts are intended to show the occurrences of device alarms (the left chart on the screen) and their downtime (the right chart on the screen). If a device has an alarm of frequent occurrence involving short downtime, the device should have been frequently stopped. If a device has an alarm of non-frequent occurrence involving long downtime, the device should have been troubled with major stoppages. As a general rule, focusing frequent alarms involving long downtime will relatively easily improve productivity. First, it is good to narrow down device alarms into those involving poor productivity. Once this is done, you can now tackle improvement activities including device adjustment and work improvement.

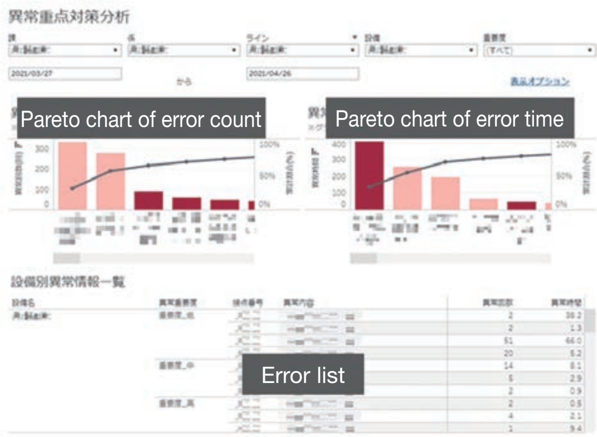

Fig. 10 Alarm screen for intensive measures

4.5.4 Screen Customization

The visualization screen system we have developed provide standard screens for all sites. Only using these standard screens allows for basic data analysis, but some sites may have to carry out more detailed analysis. For such sites, an environment is available for users to be able to create their own necessary visualization screens using Tableau. Once having created a visualization screen, the user can easily share it with personnel from other departments via the Internet or easily download any screens created by personnel from other departments and then customize them so that they can easily use within their own department.

The screen creation procedure (how to use Tableau) has been designed so that users can build programs as they like as a scheme of developing human capital Note 20) is established to promote evolvement of this system.

Note 20) KYB uses the term "human capital", instead of "human resources".

5 Future Prospects

Through this development, we have built the foundation of a system that utilizes manufacturing process data. We are now improving the system and adding functions to it based on user feedback on the lines whose data is saved on the KYB-IoT Platform. We are also promoting the linkage between the system and other data collection systems than the line monitoring system, thereby enabling us to collect data from existing devices that have long been operated and then to utilize the data.

From now on, we will further improve the system and add functions to it while promoting its global deployment. In promoting the global deployment, we are facing some challenges. As the global deployment progresses, data will be saved more frequently, which will require us to review the processing capacity and the way of writing data from data collection terminals. The visualization screen system is also anticipated to have lower display speed and lower operability as it handles more data. These possible problems will have to be discussed as required.

We are also going to discuss establishing a linkage between the system and other systems. The systems that have already been put into service and have collected data should be put together to collectively save their data on the KYB-IoT Platform. For systems to be built and introduced in future, we will sequentially develop their linkage mechanisms.

Our final goal is to establish a comprehensive scheme to centrally control data sets from different functions of the company, closely link these data sets, and allow the user to utilize the data as necessary and make decisions based on the data. Through the scheme, we will aim at strengthening the engineering chain including strengthening the inter-functional connection and reducing the production lead time as well as at strengthening the supply chain including enhancing the product reliability and making the production scheme flexible.

6 Concluding Remarks

Through this development, we have successfully established a scheme to utilize manufacturing process data. MES can connect upstream systems and downstream devices in promoting digitalization of manufacturing industry. The function we have developed is part of the MES in the production management system. With this in mind, we will continue promoting the system improvement and function addition and the linkage with other systems, contributing to the higher productivity and higher quality.

Finally, we would like to take this opportunity to sincerely thank all those concerned from internal related functions who extended great support and cooperation to this development project.

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