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Next-generation IoT-based Production System for High-mix Low-volume Products in an Era of Globalization

—Activities at Hitachi's Omika Works—

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OVERVIEW: Hitachi's Omika Works supplies information and control systems that underpin the social infrastructure and deals with high-mix low-volume products that are customized to suit specific customer requirements and applications. To ensure that it can continue to supply these high-value-added products in a timely manner and at reasonable cost, the plant is seeking to implement smart manufacturing practices that utilize the IoT. The first step involves making factory information available (visualization) based on the concepts of obtaining a more accurate understanding of production capacity and coordinating production information at the site. Along with RFID and other sensors to track actual production progress, this includes optimizing the overall plant by improving coordination between departments, between processes, and between management and the workplace.

INTRODUCTION

HITACHI'S Omika Works supplies information and control systems that underpin the social infrastructure and deals with high-mix low-volume products that are customized to specific customer requirements. While attention to detail in the design and manufacture of customized products is a strength of Hitachi, market competition in this era of globalization has raised challenges of speed and cost. Hitachi has identified the following three requirements that it must satisfy if it is to succeed in global markets without compromising its strengths, and is currently developing the next generation of its production system.

(1) Respond quickly to fluctuating demand
(2) Supply high-value-added products in accordance with customer requirements
(3) Maintain the same level of cost-competitiveness as products produced in high volumes

This article describes the concepts behind the next-generation production system at Omika Works that uses the Internet of things (IoT), and presents examples of its use.

Level		Function to be established
6	Symbiosis	Symbiotic optimization among stakeholders
5	Prediction	Mfg condition prediction & proactive measures
		Eng condition prediction & proactive measures
4	Measurement	Mfg planning, eng problem-solving
		Eng planning, eng problem-solving
3	Analysis	Mfg bottleneck analysis
		Eng bottleneck analysis
2	Connection	4M resource track & trace
		Eng info track & trace (dwg No. , ID, …)
1	Visualization	4M resource visualization
		Mfg result visualization
		Eng result visualization

4M: man, machine, material, method dwg: drawing
Mfg: manufacturing Eng: engineering info: information
ID: identification

Fig. 1—Process Maturity Metrics for Factory of the Future.
This model has been proposed by Hitachi for measuring the maturity of production systems.

CONCEPTS AND SYSTEM ARCHITECTURE

Concepts

In preparation for the development of its next-generation production system, Omika Works evaluated its current system. Based on a model proposed by Hitachi for measuring the maturity of production systems (see Fig. 1), this analysis and evaluation found that, while individual systems had a high level of maturity, overall the capabilities of levels 1 (visualization) and 2 (connection) were inadequate.

This meant there was insufficient ability to identify the true bottlenecks and a tendency for production improvement activities to focus on individual items.

In response, the first step in the next-generation production system project was the development of a factory visualization system to boost level 1 and level 2 capabilities. The objectives (concepts) were to obtain a more accurate understanding of production capacity and to coordinate production information at the site (both horizontal and vertical coordination). These concepts are described below.

(1) Concept 1: Obtain a more accurate understanding of production capacity

As noted above, Omika Works deals mainly with high-mix low-volume products that are made to order, such that, while there may be a degree of similarity between products in the same category, most are custom designed. The resulting variation in product lead times means that, compared to products produced in high volumes, it is more difficult to determine production capacity in a routine and quantitative manner.

To deal with this difficulty, Hitachi established capabilities for recording (sensing) the 4M (man, machine, material, method) factors of production to provide an accurate view of what is happening in the workplace, including information on the movement of goods and work progress. In addition to analyzing this information to provide an accurate assessment of production capacity, it also identifies which bottlenecks genuinely require action.

(2) Concept 2: Coordinate production information at the site (both horizontal and vertical coordination)

Past production improvement activities at Omika Works have tended to focus on the work systems and other processes associated with individual product ranges, targeting the efficient production of specific high-mix low-volume products. Furthermore, coordination between departments and processes has been impeded by cases where links between different items of information are sporadic, and where information is difficult to collect and use because it is not available in digital form.

These problems were overcome based on the following two vertical and horizontal considerations to identify links between information that facilitate system-wide improvements.

(a) Provide information on how individual workplace activities influence management indicators (vertical coordination)

(b) Share information and updates across departments and processes by linking the 4M flows, from reception of new orders to the actual site (horizontal coordination)

Based on these considerations, Hitachi centralized information that was spread across different departments and processes and linked it to other information to transform it into new and valuable forms. Hitachi also adopted data collection and archiving practices for transforming site information into usable formats without human intervention by converting data on past defects and know-how into digital form.

The following section describes the system architecture used to implement these concepts.

System Architecture

This section describes the approach to collecting and archiving for information use.

First, an IoT approach to information collection was adopted for factory visualization. At Omika Works, the IoT is recognized as a way to generate new added value while also improving overall product quality and efficiency by linking and using digital data collected by existing information systems that were developed and used in the past.

Next, a cooperating field approach was adopted to the collection of information for factory visualization. The conventional practice is to define separate information systems as autonomous entities, to process the digital data they hold based on how it is to be analyzed, and to store this information in shared repositories called "cooperating fields" (see Fig. 2). This data collection requires a matching process of converting between the different coding practices used in each information system and a cleansing process to deal with duplicated or missing data, but allows digital data to be collected without having to modify existing information systems and makes information from the cooperating fields available via visualization screens (views).

DEVELOPMENT METHODS

Rather than the waterfall development process used in the past, the factory visualization screens were developed using lean startup practices that involve working rapidly through a cycle of hypothesis formulation, implementation, and course correction. As requirements change according to the circumstances, it is difficult to specify all of the information that users will want to see in advance. This is because enabling users to see what is actually happening prompts

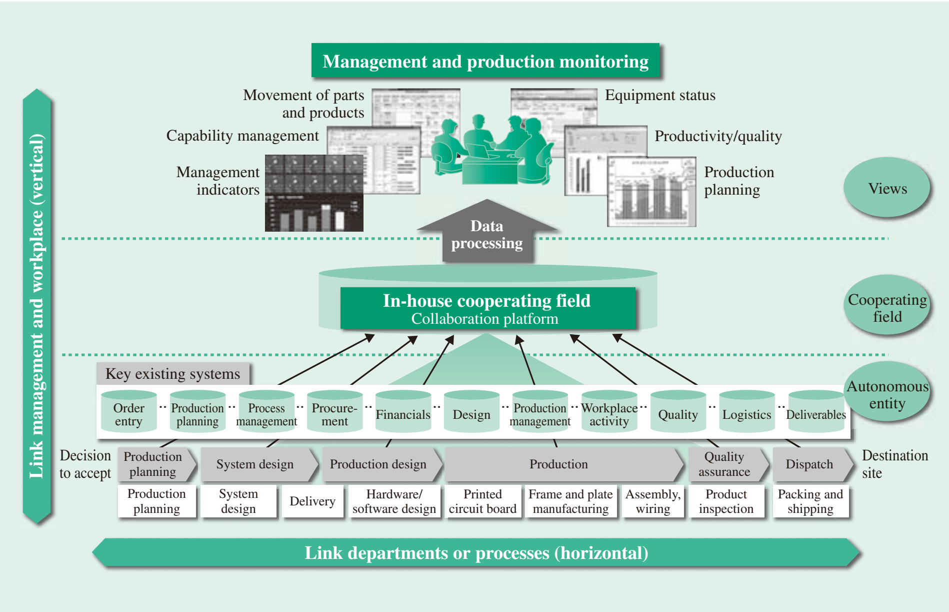

Fig. 2—Architecture for Data Collection Using In-house Cooperating Fields.
The system architecture is intended for the collection of data from in-house systems in data cooperating fields, and the processing and presentation of this data.

additional requirements as users ask for the ability to perform visualization and analysis from different perspectives. Accordingly, the development involved working through a cycle of quickly developing systems with the functions needed for testing hypotheses and obtaining rapid feedback about users' reactions.

The lean startup development process included the adoption of Pentaho, an open source software (OSS) business intelligence (BI) tool. Past in-house system development has tended to design and build systems from scratch based on a requirements specification. This resulted in long development times with upfront investment and ongoing maintenance costs.

Pentaho comes with a screen-builder tool that works by combining information visualization components and the Pentaho Data Integration (PDI) extract/transform/load (ETL) tool for processing digital data. As the source code is available (in accordance with the open source policy), the various plug-ins have considerable scope for expansion. Thanks to these features, using Pentaho enabled development to be completed quickly while minimizing the initial investment and maintenance costs.

Some of the screens developed using Pentaho are described in "Problem Visualization Using Management Information" below.

IMPLEMENTATION EXAMPLES

This section provides examples of factory visualization by describing how the information acquired by sensing and collected by information systems is used. This information, which has not been easy to interlink in the past, is collected in the cooperating fields and presented to users in ways that make it valuable to them. This provides an integrated overview of information that in the past could only be reviewed by accessing a number of different information systems, and enables it to be combined in ways that facilitate different types of analysis.

The following sections provide examples that relate respectively to obtaining a more accurate understanding of production capacity (Concept 1), and to horizontal and vertical coordination of information (Concept 2).

Visualization of On-site Movement

Omika Works has adopted radio-frequency identification (RFID) as a way to obtain a comprehensive overview of the movement of goods at the site. As of October 2015, the plant had approximately 450 RFID scanners and approximately 80,000 RFID chips in use. Attaching RFID tags to the labels and instruction forms that are circulated through the production site provides a mechanical means for collecting progress information. Attaching a label tag to goods shipped to the factory, for example, allows the movement of those goods to be tracked. Similarly, using work instruction card tags and manufacturing instruction card tags ensures the correct work instructions are issued to match the product specifications (see Fig. 3).

This provides accurate information on 4M movement at the plant and makes it possible to determine the production capacity of the overall

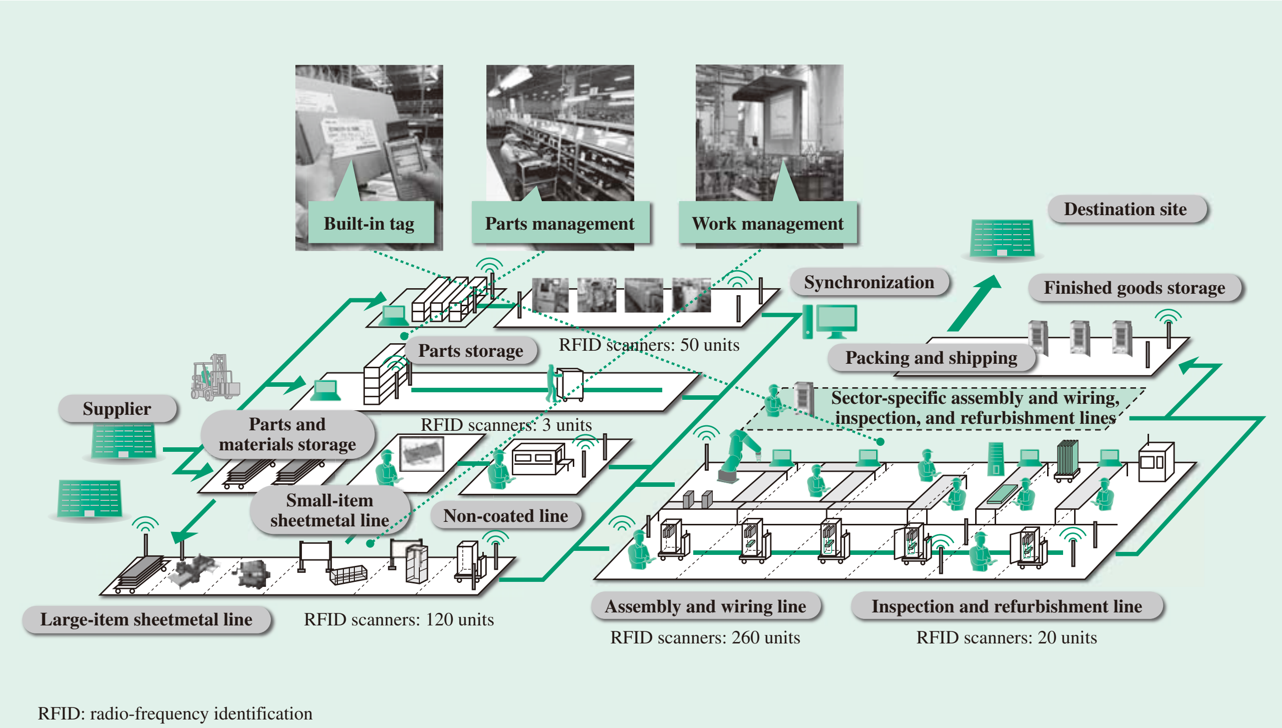

Fig. 3—Use of RFID for On-site Tracking.
Omika Works attaches RFIDs to parts, work instruction cards, and other items to enable the sensing of 4M movement and work progress at the site.

production line with a high degree of accuracy. This accuracy provides the following benefits.
(1) More accurate estimation of product costs and lead times (more accurate cashflow management)
(2) More accurate estimation of work backlogs at the plant (optimization of plant utilization)
(3) Greater ability to judge whether urgent jobs and other work can be accepted or not (increased sales opportunities)

Defect Visualization for Hardware Design

To improve product quality, Omika Works goes to great efforts to prevent product defects from being designed in. However, information on past failures or know-how built up through experience was often held only by individual people or departments, with the resulting lack of experience and knowledge making it difficult to eradicate defects entirely. Other inadequacies included the rotation of staff and transfer of skills between generations.

In response, data on past defects together with tools and other know-how held by the design and production departments were converted to digital form so that they could be shared across departments and processes. Hitachi also established mechanisms for identifying when there is a risk of defects being incorporated at the design stage by making this digital data available in the structural computer-aided design (CAD) system (see Fig. 4).

This enables the production of high-quality products in accordance with individual customer specifications while also minimizing unnecessary costs by preventing rework.

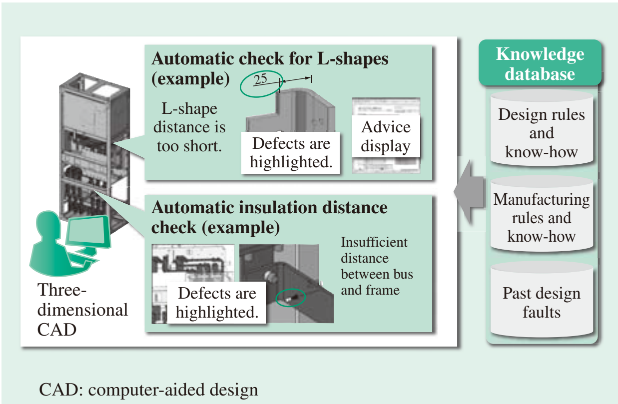

Fig. 4—Automatic Structural Design (Sheetmetal) Checking by CAD System that Supports Designer Awareness.
Checks are performed at the design stage using three-dimensional CAD. Site standards, know-how, and information on past failures are recorded as digital data and used to identify potential design faults.

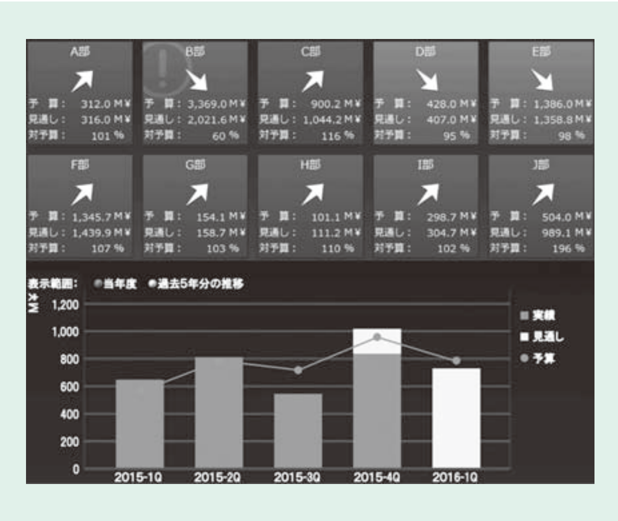

Fig. 5—Screen Showing Departmental Financial Performance.
The screen uses a heat map and cumulative bar chart (developed on Pentaho) to show departmental financial performance. The user interface was designed to suit management use cases.

Problem Visualization Using Management Information

In the past, financial data was collated in the accounting system and used by management to review performance and make decisions. However, it takes time to collate the different types of plant data and this was an impediment to timely situation assessment and decision making. In response, timely preliminary results were made available by collating the production information that serves as the source for financial data and storing it daily in the data cooperating field.

As presentation is an important aspect of data visualization, Hitachi developed user interfaces that follow management decision-making processes. BI tools were used to facilitate rapid implementation, including the use of heat maps, a form of presentation that provides an overview of the full situation, the presentation of detailed data to those departments to which it is of interest, and the ability to switch between displaying different type of information such as quarterly trends or annual trends going back five years (see Fig. 5).

Outcomes

The work has provided the capability to collect site information from existing information systems or through such means as RFID sensing, and to utilize it in data cooperating fields. It has also established a development cycle involving rapid development techniques that minimize up-front investment by using OSS, and verified their performance.

CONCLUSIONS

This article has described the development of a next-generation production system with a focus on on-site use of information.

In the future, Hitachi intends to enhance its production methods that use information obtained from cameras by image processing, or such technologies as augmented reality (AR) and robots designed for manufacturing products in a wide range of variants. Hitachi also plans to extend the use and visualization of information more widely, including at overseas plants, by acquiring experience in Japan and subjecting it to evaluation.

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