Innovation of Manufacturing Engineering Based on IoT Technologies at Production Sites

Authors: *Kazuhiro Kambara** and *Junichiro Abe***

To meet the diversified consumer needs of recent years, it is important for the manufacturing industry to make greater use of IT and IoT technologies. Nationwide initiatives involving the use of IT and IoT in the field of manufacturing are growing in the U.S. and in European and Asian countries. Accordingly, this paper describes our future image of manufacturing, together with some e-F@ctory case examples as specific approaches to achieve this vision.

1. Manufacturing Environment and e-F@ctory Initiatives

1.1 Future image of manufacturing

In the future, the use of IT and IoT and the digital space will progress in all aspects of manufacturing (Fig. 1). The demand is forecasted based on market information analysis; preventive maintenance is controlled using big data collected from production equipment; machines and workers are allocated to optimal positions using a production line simulator; and prototypes are manufactured with 3D printers. This will dramatically boost efficiency and reduce the time required for individual processes.

Along with the technology advancement that enables the sophisticated operation methods described above, the importance of data will increase; it is essential to optimize the operations and processes involved in manufacturing. In recent years, automation and optimization of manufacturing processes using artificial intelligence (AI) have shown remarkable growth. Nevertheless, the simulation results do not always match the actual results due to all the changes and differences in environments. Human knowledge is indispensable for evaluating whether results are acceptable and for making adjustments. We must bear this in mind when pursuing the ideal vision.

In order to perform the plan-do-check-act (PDCA) cycle in the operating processes as efficiently and fast as possible to optimize the manufacturing process flow by effectively using the latest technology and data, it is necessary to create the systems, basic technologies and required standards.

We have been working on innovative manufacturing by providing e-F@ctory solutions which integrate state-of-the-art FA and IT technologies since 2003, aiming to achieve the future image of manufacturing.

1.2 Integrated FA solution: e-F@ctory

With IT/IoT technologies quickly advancing, production sites need to optimize operations using data collected from equipment. e-F@ctory has provided a series of products that link production sites to IT systems (host information systems including manufacturing execution systems and enterprise resource planning systems) and networks that enable seamless connection between devices, such as sensors, and IT systems, thereby visualizing and improving production sites based on feedback obtained through real-time analysis of the collected data. This has improved the productivity, product quality, environment, and safety of production sites, and helped reduce customers' total cost of ownership (Fig. 2). In addition, we are building a total solution to support advanced

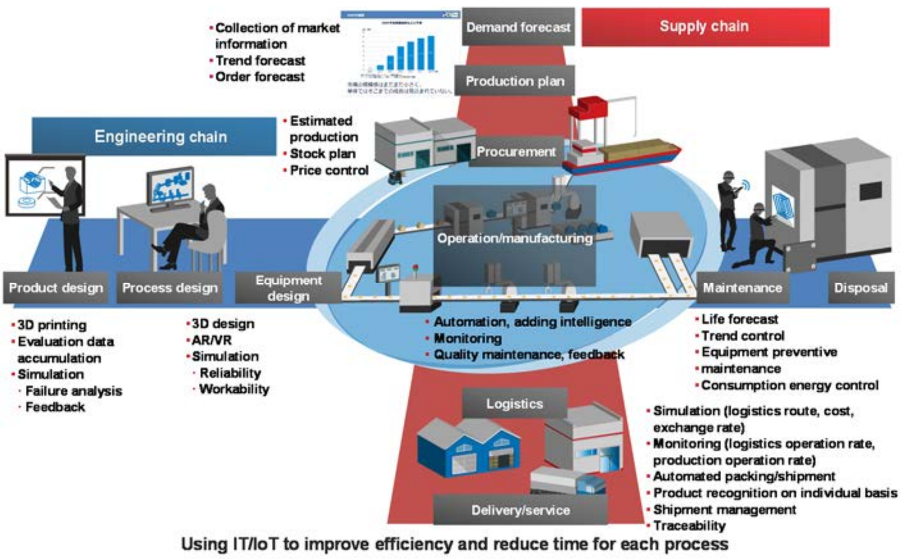

Fig. 1 Intelligent manufacturing achieved by using IT and IoT

*Nagoya Works **Solution Business Strategy Division

manufacturing through higher-speed control by making different machine models work together, information linkage between IT systems and production sites, and coordination with partners (e-F@ctory Alliance).

The intermediate layer between FA and IT plays a role in optimizing the entire system, in addition to enabling seamless linkage. We call the intermediate layer “Edge-computing,” and consider that it is a remarkable feature of e-F@ctory.

e-F@ctory solutions connect FA and IT and effectively use data in such an architecture, thereby advancing manufacturing and improving corporate value.

2. Application Examples of e-F@ctory

Even when developing diverse products to meet both domestic and overseas market demand, or when producing multiple products in different quantities to cope with demand fluctuations, manufacturers must keep both product quality and productivity high. To do this, the production line must respond quickly to variation factors (changes in produced models/amount). Manufacturers need to take measures to optimize the entire production line, not just parts of the line as conventionally performed.

e-F@ctory involves collecting various types of real-time data including data on operators and equipment, thereby performing the PDCA cycle at the production site efficiently and quickly. This allows users to balance high product quality and productivity, and to immediately analyze and use the data for improvement.

Here, the initiatives at one of Mitsubishi Electric Corporation’s FA equipment production sites are described as an example of flexible production that allows multiple products to be produced in variable quantities.

2.1 Factory monitoring

The production of programmable controllers, a component of FA equipment, consists of three main phases: (1) surface mounting, (2) board assembly, and (3) product assembly/testing. ((1) and (2) constitute the board mounting process.) About 3,000 models are produced while moving between multiple equipments and testers for each phase.

To maintain high product quality and productivity, it is necessary to comply with the specified production method, and to satisfy the specified quality standard. It is best to repeat the same work at a constant interval. However, in daily production work, fluctuations arising from emergency orders, equipment problems, work delays, etc., often occur and require immediate action. The programmable controller factory has a structure that allows the factory-wide production progress to be monitored in real time (Fig. 3), and also allows equipment operation information, percentage of defect-free tested products, and other fluctuating factors to be integrally visualized, analyzed and evaluated. The production information is used for planning and adjusting the production schedule of each phase and facility. By combining the restrictions on production resources, including material stock information and personnel arrangements, with the production progress and equipment operation information, highly accurate production schedules are created. As a result, when a production delay or quality problem occurs, the production resources can be quickly changed. Line downtime is minimized to maintain high productivity and quality.

2.2 Factory-wide optimization of surface-mounting line

A surface-mounting line is an automated production line for mounting electronic components on the surface of each printed circuit board at high speed, yielding high productivity. When producing multiple products in variable quantities, it is necessary to perform production efficiently and flexibly in response to changes in the model or amount to be produced. To do this, a surface-mounting operation management system is used for the line at the site to minimize losses due to equipment downtime and maintain the optimum operation cycle time by collecting equipment data for visualization and analysis (Fig. 4).

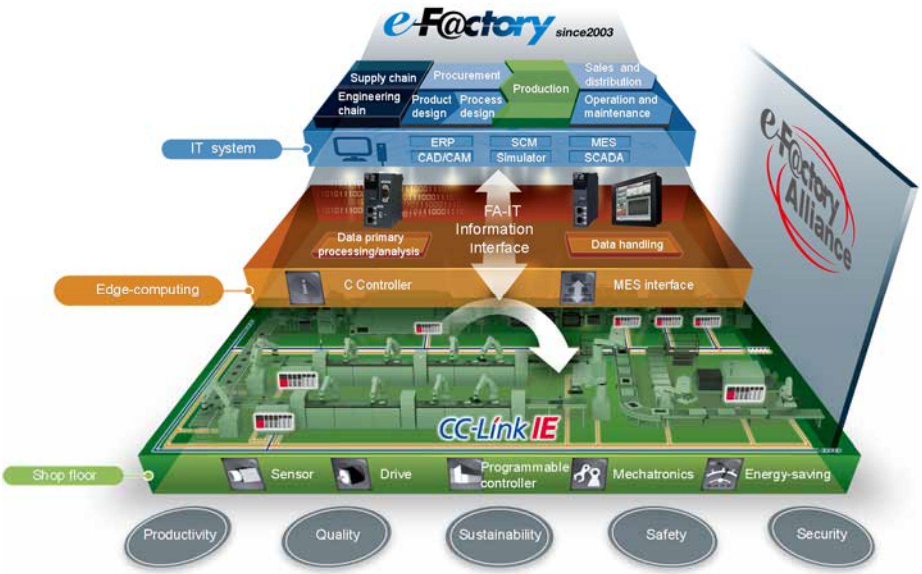

Fig. 2 FA integrated solution “e-F@ctory”

The mounter, which is the main machine in the line, collects real-time information through FA equipment including the equipment operating status and mounting status for each component to allow centralized monitoring. The four major features of this functionality are described below.

2.2.1 Improvement of the operation ratio

Causes of equipment downtime are made visible in real time. A problem existing at a point during the setup time and mounting time (equipment downtime loss) can be viewed. To reduce the setup time, the timing for a model change is determined for the production plan by managing the component locations in the factory and visualizing the setup progress for each line, and then a priority order for the setup of multiple surface-mounting lines is determined. Based on the priority instructions, operators can change models with minimal downtime of the line by setting the components on a setup cart in advance. The progress of the setup work is visualized in real time, and any delay in work can be addressed immediately by instructing other operators to assist, allowing the work to be completed as planned.

2.2.2 Reduction of equipment downtime loss

To prevent equipment downtime during the operation, real-time information on the production plan and the number of components remaining in the mounting machine is collected to prepare replenishing components in advance. At equipment sections where regular maintenance (for jigs/tools and equipment parameters) is required, systematic preventive maintenance can be conducted based on trend management using the collected real-time equipment information.

2.2.3 Quality improvement

The information on product defects found in various sections of the equipment is used to manage trends, thereby identifying the causes of defects to improve the product quality. For capturing true defects at an early stage, the appearance checker analyzes the results of actual defect collected through visual inspections to revise the inspection judgment formula, thereby improving the overdetection rate of defects. For improving the product quality, the soldering inspector analyzes defect detection results to provide feedback regarding production conditions for each section of the equipment. In addition, the product serial number printed on the board for ensuring production traceability, production lots of components/boards, and inspection/test results are associated with each other, thereby enabling the production history and variation points to be managed.

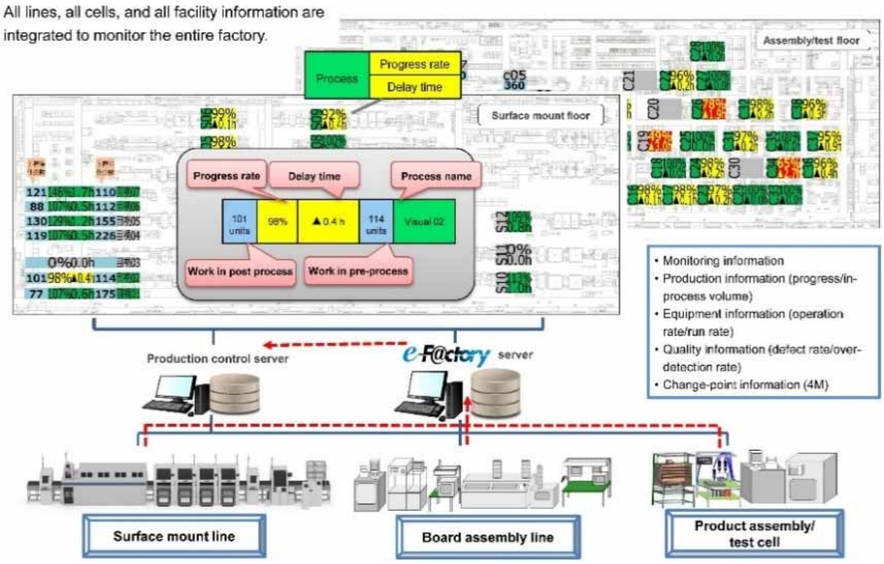

Fig. 3 Factory-wide visual control

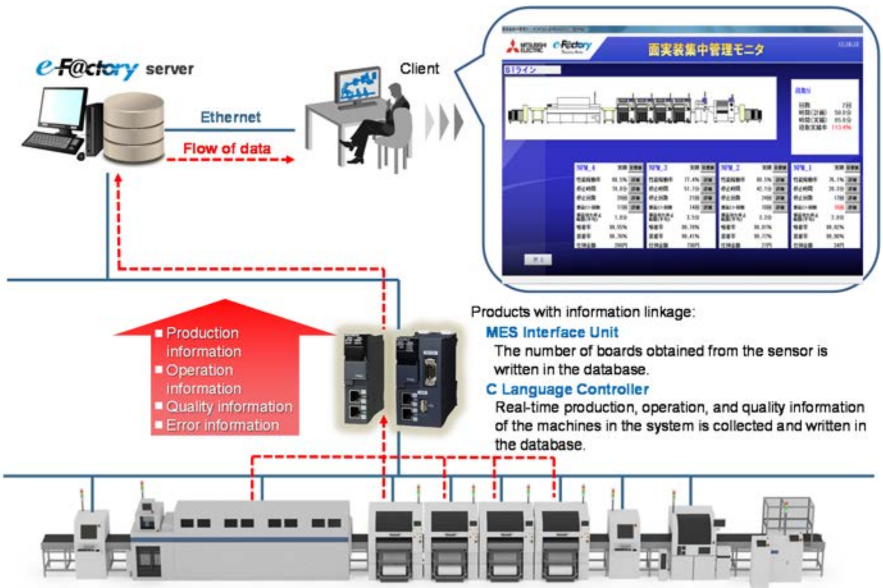

Fig. 4 Surface-mounting operation management system

2.3 Work assistance system for product assembly cells

At the production site where programmable controllers are assembled, many models are produced within a short delivery time. Accordingly, a production system is used in which human assemblers work in groups in cells (human cells), allowing small-lot multiple-cycle production. The system of human cells often causes the productivity and product quality to depend on the skills of the workers, and so work errors must be prevented and training on improving efficiency must be given.

The screw-tightening instruction system uses a programmable controller for system control that displays the procedure for each work phase on the screen. Human workers assemble components and tighten screws referring to the display. When tightening screws, information on the position for screw tightening, screw type, electric screwdriver that should be used, etc., is displayed on the screen, and the workers can complete the tasks as instructed. The operation status of the electric screwdriver is constantly monitored with the programmable controller. Whether the necessary number of screws have been tightened using the specified screwdriver, whether the correct screws have been used, etc. is automatically checked, preventing errors during the work (Fig. 5).

Furthermore, to respond to the demand for multi-model production, the time for creating work manuals needs to be reduced. This is done by using the design data already prepared for product design and by using a dedicated procedure creation tool.

Information on the operation of electric screwdrivers is automatically collected in the database as part of the operation record. The operation record is visualized using a general-purpose analysis tool to analyze simply the operation procedure for each phase of an assembly cell and the hours taken by each worker. When a change in the working time is detected, the system checks whether the change is caused by using an incorrect component, thus preventing quality defects. By analyzing the time taken by each worker, the skill level of a worker and the type of work where the worker is less skilled can be determined. This shows supervisors the areas where workers need advice, so e-F@ctory can reduce the training time for workers by about 50%.

3. Conclusion

Regarding production innovation using IT at production sites, we have described our future vision of manufacturing and an example of the initiatives to achieve the vision at surface-mounting lines and product assembly cells using e-F@ctory. These initiatives take production technology innovation one step further, using an enormous amount of data collected from the entire production site for information association and analysis, thereby finding new correlations.

In future, it is important to identify latent problems at a production site in advance through data analysis technology. We will actively promote manufacturing innovations that involve prevention and control by taking preventive measures and recurrence preventive measures. We will do this by organically associating various data remaining independent with other data, and by performing the PDCA cycle for efficient, rapid improvement by combining the knowledge accumulated based on the three conventional factors of production sites, products/materials, and current situation, together with state-of-the-art IT technologies. In doing so, we will strive to create a highly reliable production site that operates without any downtime or product defects.

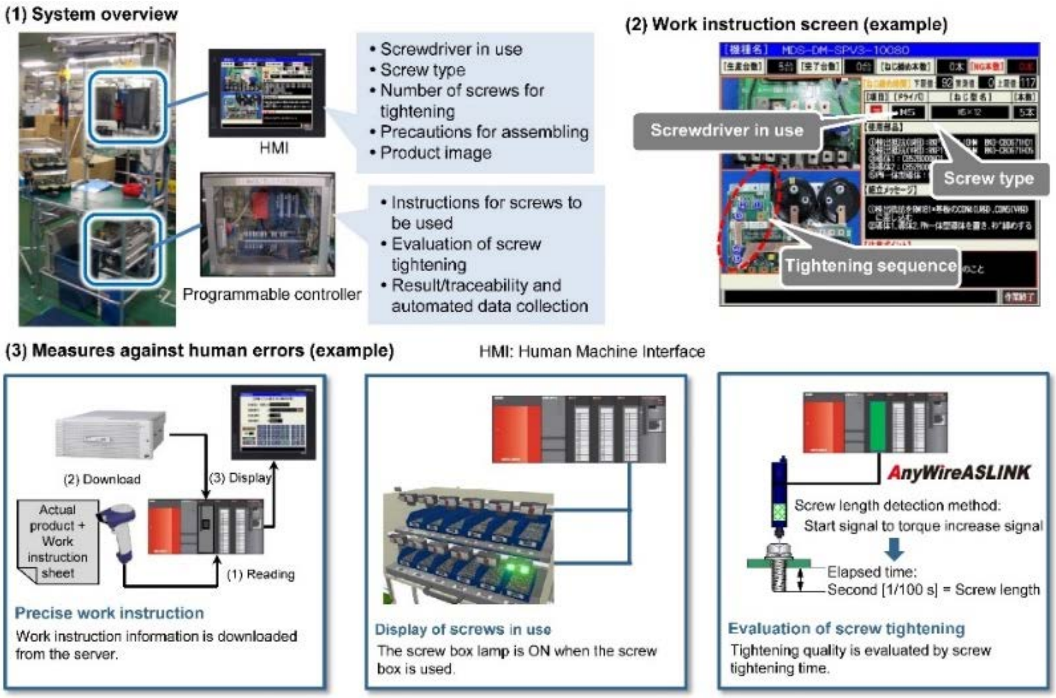

Fig. 5 Screw-tightening instruction system