Manufacturing Reform Utilizing IoT Technology

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ABSTRACT

In addition to the existing production innovation activities, Fuji Electric has developed its supply chain management (SCM) reform activity since FY2009 to build the system in which sales and manufacturing processes synchronize autonomously. We are committed to productivity and quality improvement, security and safety, labor saving, and energy saving. We also promote production innovation and the use of IoT according to each factory's manufactured items and business characteristics. Fuji Electric, an IoT solution vendor, proactively utilizes its own products and systems.

1. Introduction

In addition to conventional production innovation activities, Fuji Electric has been implementing supply chain management (SCM) reform activities throughout the entire supply chain from FY2009 and built a system in which sales and manufacturing processes synchronize autonomously.

We have been promoting manufacturing based Internet of things (IoT) through the use of large quantities of data utilizing dramatically improved information processing capabilities and artificial intelligence (AI). As a result, we are carrying out manufacturing reforms and aiming to achieve autonomously synchronized production, which we also refer to as the Fuji Electric Production System (FePS) (see Fig. 1).

2. Manufacturing Based IoT Concepts

Figure 2 shows Fuji Electric's manufacturing based IoT concepts. We are promoting IoT along 2 axes, namely SCM and product lifecycle management (PLM), to achieve productivity and quality improvement; safety, security and labor savings; and energy savings. By doing this, we aim to achieve a "connected smart factory" in expectation that it will optimize the entire factory including energy savings.

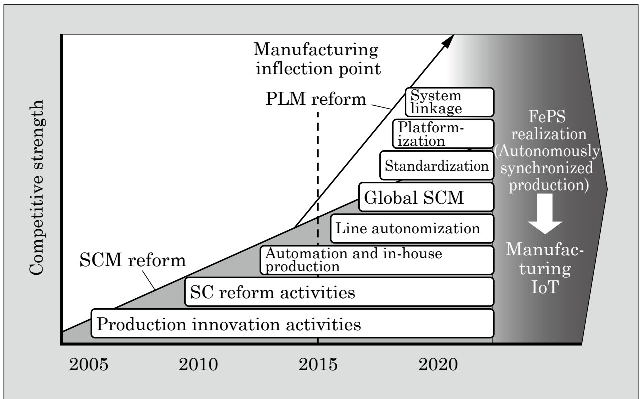

Fig.1 History of Fuji Electric's production innovation

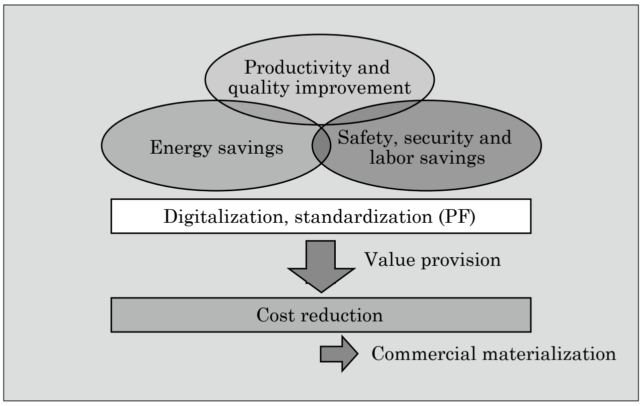

Fig.2 Manufacturing based IoT concepts

From the SCM axis, we are promoting the automation of production equipment and lines that utilize IoT. From the PLM axis, promoting standardization, digitization, and utilization of cyber physical systems (CPS).

IoT based manufacturing reforms aim to use data obtained from the field to simulate manufacturing via computers in order to achieve optimization by reflecting the results back into the field. To begin with, we established sensing technologies, information collection technologies and connection technologies, while developing a "Factory Visualization Dashboard" (see Section 3.2 below) that we have deployed at each factory.

Currently, in addition to standardizing manufacturing, we are promoting productivity and quality im-

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provements through the use of data.

3. Examples of Initiatives

Fuji Electric has been active in a wide range of manufacturing fields from electronic devices and components to plant equipment. Therefore, we are promoting production innovation and IoT advancement on the basis of the characteristics of the products and businesses of each factory.

Fuji Electric, also an IoT solutions vendor, actively utilizes its own products and systems in the development of IoT.

3.1 Production preparation utilizing CPS

Product functions are becoming increasingly sophisticated and diversified, and there has been increased demand to shorten the time required for market launch. It is against this backdrop that Fuji Electric is optimizing manufacturing processes through CPS, while shortening the time required to prepare production processes for mass production activities (see Fig. 3).

(1) Process design enhancement and increased efficiency through use of design information

In the process design, we decide manufacturing methods, personnel, amount of labor, equipment and tools while verifying manufacturability according to the product design. Therefore, process design is an extremely important work that has decisive influence on the QCD of products. To do this work, it has been necessary to spend a lot of time creating forms such as QC process charts and work instructions.

Therefore, we have built systems that can reduce the number of prototypes by extracting optimum manufacturing procedures while verifying manufacturability via computer with product design data, as well as create forms semi-automatically.

As a result, product design and process design can now be performed simultaneously while reflecting the results back into the product design, with the effect that preparation time for production is shortened and process design is simplified.

(2) Enhancement and efficiency increase in production line design

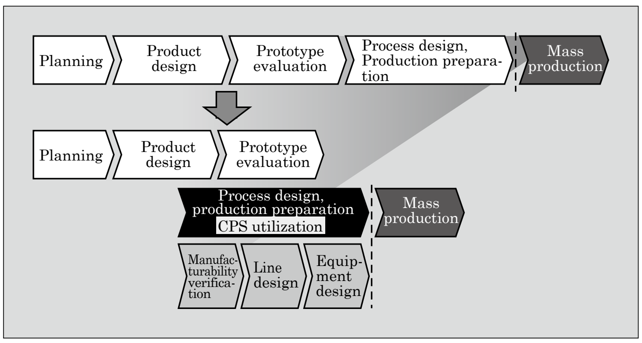

Fig.3 Improved production preparation efficiency via CPS

Fuji Electric has also developed a system that uses a computer to simulate the movement of people, things and equipment to build a more efficient production line. The system makes it possible to simulate takt time, line capacity and labor-hours using the line design tool that utilizes the manufacturability verification information mentioned above. Furthermore, by simulating the operations of workers, it is possible to pre-examine difficult-to-implement processes and processes that influence product quality while eliminating any issues that may occur. In this way, we are working to stabilize work quality and shorten line start-up time.

(3) Improving the design quality of automated equipment and shortening the verification period

After completing facility design, such as mechanical design, electrical design and software design, prototypes, are created and evaluated with the actual facility.

Therefore, prototyping and evaluation not only takes time, but also requires multiple prototypes to be created because this work is carried out by using real machines.

In order to reduce rework, improve design quality and reduce equipment development time by 20%, we have constructed an environment that uses 3D-CAD data to conduct prototyping and evaluation similar to that of real machines but using a computer instead.

Even when constructing a production line that uses several robots, interference between robots or a robot and human can be verified beforehand, thus making it possible to secure safety at time of actual machine verification.

Another benefit is that it becomes possible to evaluate operations at the time of mass production at facilities of remote sites, including those overseas, while also enabling operators to update software on the computers remotely.

3.2 Factory visualization dashboard

Manufacturing sites have conventionally made use of production progress management boards and Andon (a manufacturing status display system) to share on-site information and speed up countermeasures.

To achieve even better response, we developed and are installing "factory visualization dashboards" to achieve centralized monitoring of manufacturing key performance indicators (KPI) by collecting real-time 4M (man, machines, materials, methods) data at manufacturing sites and integrating various types of on-site information through the use of IoT (see Fig. 4).

By using factory visualization dashboards, various levels of management ranging from administrators and factory managers to line supervisors can ascertain quantitatively and in real-time KPI indicators necessary for daily management. This facilitates accurate and speedy response and overall optimization.

The dashboard is configured on a web screen so

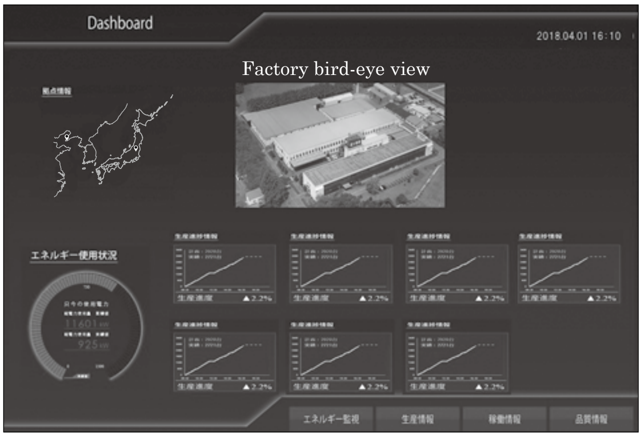

Fig.4 Factory visualization dashboard

that the display contents can be easily edited to correspond to changes in the process and line configuration. In addition, the network is configured taking into account security and access load distribution.

For older equipment that cannot output operation information, it is common to collect operation information based on operating status indicator signals. However, this only allows for limited types of information such as indicating normal operation, abnormal operation and stoppages. Therefore, we built a system for reading operation information from equipment control lines and displaying detailed operation states on a dashboard to visualize operation.

On integrated automation lines for mass produced products, the operation status and takt time of each piece of equipment are collectively displayed on the dashboard in real time as shown in Fig. 5. This makes it possible to quickly identify where takt disruptions occur. Furthermore, by using the video captured with web cameras, it becomes possible to investigate causes and take remedial measures.

In the future, we will continue to develop the dashboard and strengthen its analysis capabilities by combining analytics and AI.

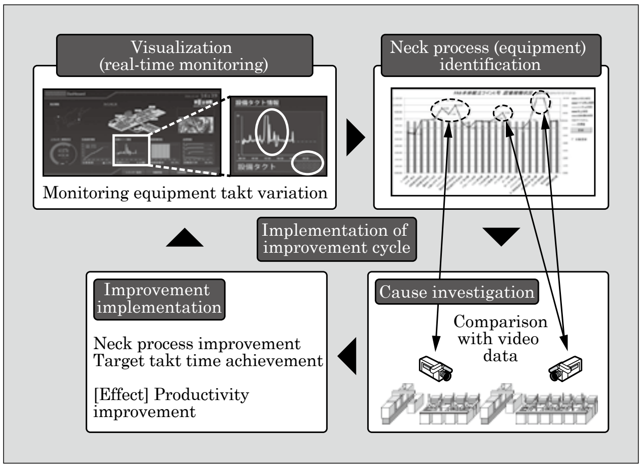

Fig.5 Examples of dashboard based improvements

3.3 Quality improvement and predictive maintenance through multivariate analysis

By using Fuji Electric's "MainGATE/MSPC" multivariate analysis tool, it is possible to detect abnormalities caused by multiple factors that cannot be monitored using individual data alone and extract optimum manufacturing conditions based on the relationship between quality and manufacturing factors. This tool is applied to manufacturing sites to improve quality and enhance equipment operation[1].

(1) Quality improvement in semiconductor manufacturing

Fuji Electric's pressure sensors are processed to extremely thin with a thickness of only several tens of micrometers by utilizing plasma etching for the back side of the Si wafer. Poor sensitivity will result if the thickness deviates from the specification range. Therefore, they must be processed with high precision (see Fig. 6).

To improve the quality, we investigated the cause of variation in thickness by applying MSPC for batch processes to manufacturing process data.

As a result, among the dozens of parameters, there were 2 specific parameters that highly contributed to the Q statistic (the degree of deviation from the normal model of the data being diagnosed) and were the main factors of variability.

By restricting these 2 parameters to within a certain range, it became possible to halve the variation in thickness.

(2) Predictive analysis of equipment abnormalities in press working

During press working, slug floats pose a big challenge. It is a situation in which scraps stick to the punch and come out of the die hole. Predictive detection has been difficult due to existence of various possible factors such as tool wear, clearance amount, processing oil viscosity, mold magnetization, and the attracting action between the punch and die (see Fig. 7).

Therefore, we implemented monitoring by mounting the press equipment with Fuji Electric's "Diagnostic Sensor Hub", a product that makes it possible to centrally manage measurement data by aligning the sampling cycles of various sensors such as temperature, current and voltage, 3-axis acceleration and

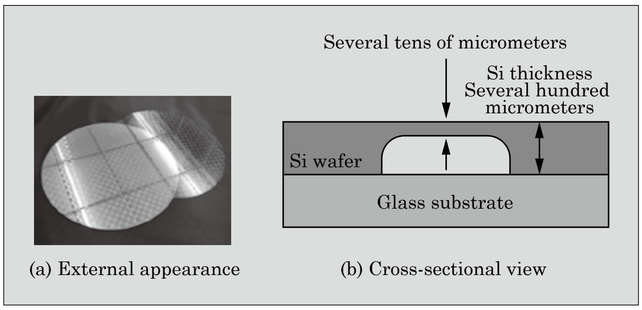

Fig.6 Wafer appearance and cross-sectional view

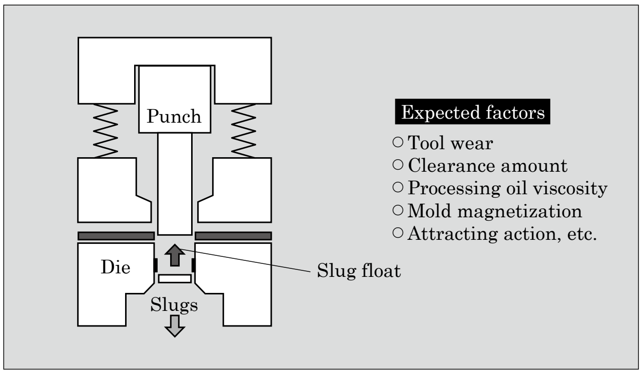

Fig.7 Occurrence of slug floats

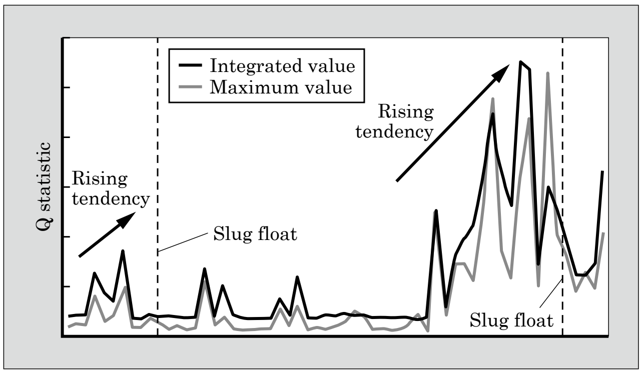

Fig.8 Signs of slug floats

strain sensors.

We created normal model based on data at normal operation and then analyzed the data before and after the occurrence of slug floats. As a result, we were able to achieve predictive detection by ascertaining rises in the Q statistic of sensing data before the occurrence of slug floats. We are currently accumulating data and carrying out detailed analysis in order to develop a method for preventing slug floats (see Fig. 8).

In the future, we plan to perform real-time analysis using MSPC to either stop equipment or set off an alarm upon signs of slug floats so that we can improve quality and increase the number of operating facilities.

3.4 Improving welding quality by digitizing skilled welding work

Welding work requires both the knack and know-how of highly skilled expert technicians and is susceptible to variations that greatly impact productivity and quality.

In recent years, the passing on of skills has become an issue as an increasing number of skilled technicians are retiring due to age. Furthermore, there is a shortage of skilled technicians who can guide others at overseas bases. It is often more difficult to train local technicians than technicians in Japan, while there also remains the challenge of developing an educational curriculum for the technicians.

Therefore, we are working to quantify welding processes through digitalization to facilitate the transfer of skills.

Moreover, in the future there is certain to be a labor shortage in Japan, and as such, the welding process also needs to be automated. In the next section, we will describe 3 steps for automating welding work and provide some examples along the way.

(1) Digitalization of the welding process

For welding quality, the strength of the welded part is important. To ensure the strength of the welded part, it is necessary to manage the penetration depth and penetration state.

Digitizing and quantifying the welding process and welding state is directly connected to maintaining and improving welding quality.

(2) Utilizing digitalization in technical education

Up until now, on the job training (OJT) has played a major role in training welding technicians because it endeavors to improve their skills through accumulated experience. However, a long period of time is required due to the sensory aspect of guidance and communication. Therefore, in order to facilitate early stage development, we have been developing and applying a skill diagnosis system that uses sensing technology to quantitatively evaluate skill levels (see Fig. 9).

When performing welding work, the worker judges the state of the work based on information received from the 5 senses, including seeing, hearing, touching. The worker controls the welding torch especially in response to changes in the melting state, such as relates to size and shape.

In addition to providing data such as welding current, voltage, feed rate and torch angle, the skill diagnosis system displays lists of the measurement results of the melting state obtained by the image sensor on the user's PC screen. After completing the welding, the worker himself can clarify the points of skill improvement by quantitatively examining the work.

In addition to the welding sites of each factory, we are promoting the use of the skill diagnosis system for training and educating new employees and are using it to maintain and improve quality through the use of a

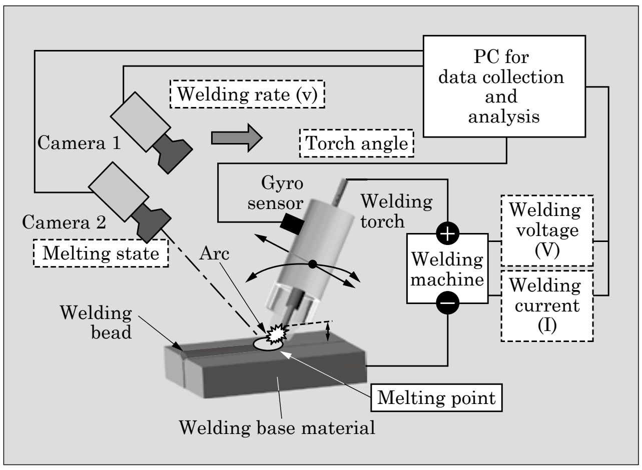

Fig.9 Welding work skill diagnosis system

certification program.

(3) Automation of difficult welding work through melting state sensing

For complex product structures, welding conditions must be established according to the structure. Therefore, welding is done manually because it is difficult to automate using robots. In particular, when dealing with structures that varying greatly in thickness, the technician must control the feeding operation of the welding torch while visually checking the melting state in order to ensure stable welding beads.

Fuji Electric is developing an automated welding technology for structures that are difficult to weld by using robot control that utilizes melting state sensing technology.

An image sensor mounted to the hand of the robot detects changes in the melting state and provides feedback for the operation of the robot. As a result, the feed rate of the welding torch is controlled to maintain a stable melting state at all times.

This technology will make it possible to automate the confirmation and judgment that are currently visually performed by skilled technicians, thereby enabling stable welding beads even for structures with a large variation of thickness.

In the future, Fuji Electric intends to apply automation to the welding work of all types of products in expectation that it will enhance maintainability and improve the quality of welding.

4. Postscript

In this paper, we described manufacturing reforms that apply IoT. To further advance this innovation, it will be important to integrate production technology with ICT technology, train IoT specialists such as data scientists and implement collaboration at the design stage that is the origin of this development. We plan to continue to actively utilize Fuji Electric's IoT products and systems, closely cooperate with related departments and promote further manufacturing reforms.

References

(1) Matsui, T. et al. Data Analysis Technology in Plant Control. FUJI ELECTRIC REVIEW. 2014, vol.60, no.1, p.21-26.

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