FA Solution That Applies IoT and Motion Control Technology

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ABSTRACT

The rapid development of smart manufacturing technologies has created the need to further improve productivity and create and maximize added values as FA solutions for the manufacturing industry. Fuji Electric has made use of IoT technologies to achieve quality traceability solutions, capable of improving productivity and reducing costs on automobile manufacturing assembly lines. In addition, we have also developed a motion control technology that makes use of high-performance controllers for the packaging lines of food factories. Those technologies make it possible to achieve stable sealing regardless of the packaging speed, as well as optimize control for packaging machine systems.

1. Introduction

In the current industrial world, there has been a rapid trend toward industrial transformation as seen in Industrie 4.0 in Germany and the Industrial Internet Consortium (IIC) in the United States as well as the establishment of the IoT Acceleration Consortium(1) in Japan. In this way, a movement toward smart manufacturing is being invigorated globally.

The backdrop to this situation is an accelerating development of technologies such as the Internet of Things (IoT), big data analysis and artificial intelligence (AI). While interest is significantly growing in the manufacturing industry, it is faced with new issues including how these technologies can be specifically utilized to lead to improvement of productivity and creation of added value.

As case examples of solutions to these issues, this paper presents a quality traceability solution for processing lines that makes use of the IoT technologies owned by Fuji Electric and describes the FA solutions based on the motion control technology with control performance that is among the highest in the industry.

2. Quality Traceability Solution for Automobile Manufacturing Assembly Lines

2.1 Background

The automobile industry is continuously growing on a global scale. Developing electric motorization and self-driving technology has been increasing person-hours for development, leading to frequent quality issues and labor shortages in Japan and overseas. To address these issues, productivity need to be further improved. Major challenges to increase productivity on automobile manufacturing shop floors are to eliminate defects and reduce costs. As shown in Table 1, there is an urgent need to meet requirements such as quality improvement to eliminate defects and the reduction of lead time to deal with defects.

To meet these requirements, an enormous amount of data is collected for production, operation, quality and maintenance. However, it is difficult for users themselves to effectively use and analyze the data, which results in an overflow of information that is not effectively utilized. Table 2 shows examples of the challenges to handle such big data.

To resolve those issues, Fuji Electric's quality traceability solution for assembly lines is equipped with functions of data collection during processing of individual products, data collection premised on data analysis and data maintenance that can be conducted by the user to contribute to the user's productivity improvement.

Table 1 Requirements for resolving challenges in automobile manufacturing shop floors

Item	Requirement
Requirement for eliminating defects	Quality improvement by grasping conditions of non-defective products and clarification of defect-generation mechanism
	Management of change points of 4 M's (man, machine, material, method)
Requirement for reducing costs	Reduction of person-hours for daily checks, maintenance and quality checks
	Reduction of short stops and stops due to sudden failure
	Improvement of tooling life
	Reduction of lead time to problem-solving

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Table 2 Major issues with handling big data

Issue	Details
Identification of necessary data	Data are collected in all time periods including processing, wait and maintenance, which increase the data to an enormous amount as they are accumulated, and makes searching for the necessary data time-consuming.
Processing of collected data	Methods of data utilization are often not clear and the formats and collection cycles of data are not standardized. Accordingly, data processing is required for analysis and processing the enormous amount of data accumulated imposes a heavy burden on the user.
Selection of collected data	To select the data collected, it is necessary to add data to or delete data from the collection device by trial and error. However, doing this is not easy and having the manufacturer carry it out incurs high costs.

2.2 Overview of solution

Figure 1 shows the quality traceability solution offered by Fuji Electric. It is composed of a databases server unit to accumulate these data and a data collection unit connecting manufacturing facilities and sensors via communication I/Os to collects raw data. It can collect necessary data specified by the user at required timings and easily trace the accumulated data by searching.

(1) Data collection unit

(a) Data collection function

Data collection unit collects data for one cycle (a cycle from the start to completion of processing of a target work piece) from computer numerical control (CNC) machines, programmable logic controllers (PLCs) and pressure, vibration and various other sensors in processing lines. It then combines the collected data into one package for each cycle as shown in Fig. 2.

The amount of collected data of this system, collecting necessary data at required timings, can be less than that of a system continuously collecting data. As a result, the trouble of data identification and processing for analysis is decreased, leading to a significant reduction in the burden on the user.

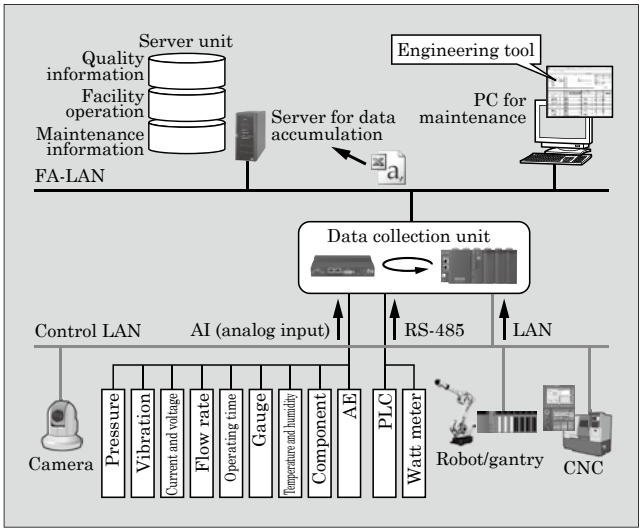

Fig.1 Overview of quality traceability solution

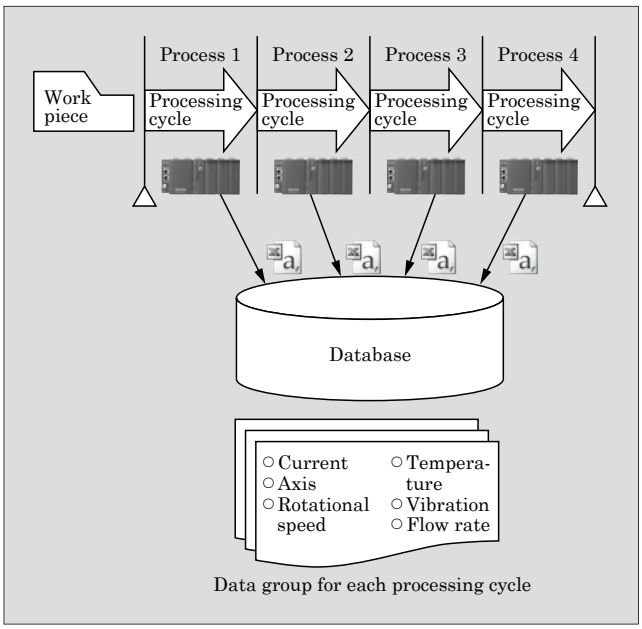

Fig.2 Image of data collection function

(b) Camera-server linking function

To control change points of 4 M's, namely man, machine, material and method, there is a need to have centralized control of videos shot using cameras together with analog data such as vibration and current. However, cameras are mainly controlled by a system for cameras, which is different from the control system for analog data collected from sensors, and this did not allow centralized control, posing an issue.

This solution provides a system of monitoring events on the shop floor while synchronizing recorded video image and changes in analog data as shown in Fig. 3. This system links data collection devices with a camera server.

(c) Engineering tool

An engineering tool is intended for system mas-

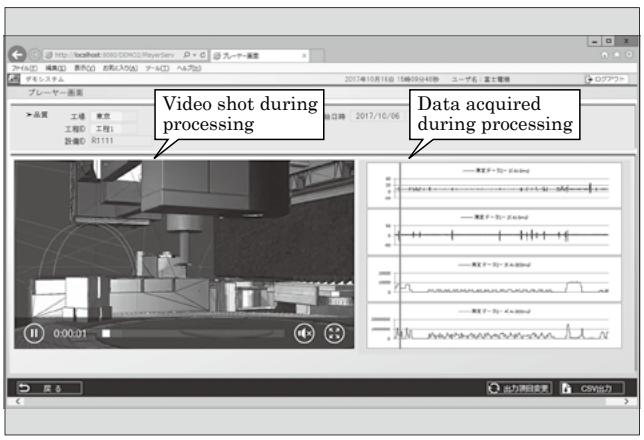

Fig.3 Sample screen of camera-server linking function

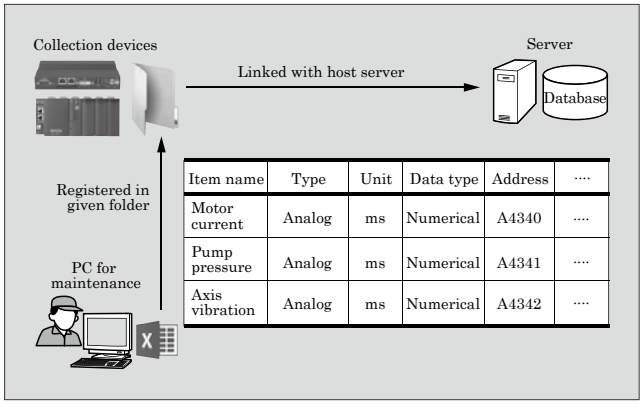

Fig.4 Overview of engineering tool

ter maintenance and data addition and deletion. This solution utilizes an engineering tool based on Excel*1, which is outlined in Fig. 4. With the engineering tool prepared on a PC for maintenance, users define item names, data types and storage addresses of data collected and register them in a given folder in the collection devices. This tool allows user to easily add and modify data to be collected.

(2) Server unit

(a) Traceability search function

Information on manufacturing facility operation is closely related to product quality information. Accordingly, when a problem occurs in the production line, users often check the operation information and quality information at the same time. However, searching for information was time-consuming because quality information is classified by product, whereas operation information, by facility. This solution offers a system that allows users to search either by operation or facility, which reduces the information search workload on them.

(b) Data summary function

It requires a long time to trace factors of abnormality from an enormous amount of data accumulated. This solution uses a server application to detect abnormalities with measured values exceeding the maintenance threshold and the maximum, minimum and average values of measurement items to display on the traceability search screen. This helps reduce the data check workload of the user.

2.3 Development of "MICREX-OnePack" equipment information collection system

To reduce the size and price of the data collection unit, Fuji Electric has been developing the "MICREX-OnePack" equipment information collection system that integrates the functions described in Section 2.2. As compared with the conventional collection unit of Fuji Electric, the volume is reduced by 95%. Table 3 shows outline specifications, and Fig. 5 shows the external appearance.

*1: Excel: Trademark or registered trademark of Microsoft Corporation

Table 3 Outline specifications of "MICREX-OnePack"

Item	Outline specifications
Power supply	Single-phase 100 to 240 V AC
Dimensions (mm)	W275 × D130 × T90 (Volume reduced by 95% from conventional products)
IO	AI*1 × 16 ch, DI*2 × 1 ch, DO*3 × 1 ch
Communication	Ethernet 100 Mbits/s 2 ch (host device, equipment) Ethernet 1 Gbits/s 1 ch (display) General-purpose communication (RS-232C 1 ch/422 2 ch/485 1 ch) Total 4-ch expansion port
Built-in protocol	Mitsubishi PLC, FOCAS II
Data storage	Supports SDHC standard cards (32 GB)

*1: AI: Analog input
*2: DI: Digital input
*3: DO: Digital output

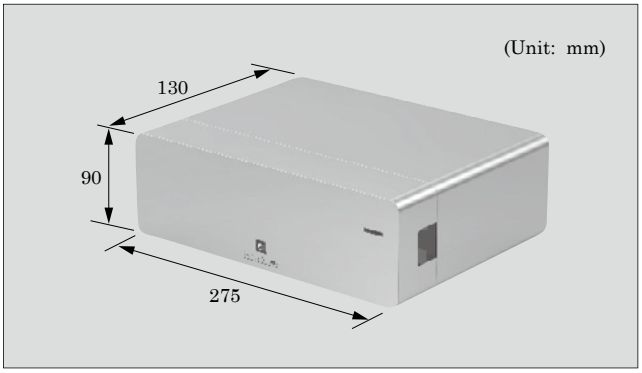

Fig.5 "MICREX-OnePack"

3. Packaging Machine Control by Motion Control Technology

3.1 Background

In the Asia region including China and India, demand for food is rising along with the population increase, and this trend has led to greater demand for machines for packaging food. In this region, package machine manufacturers are working on improving package performance per unit time, for instance, switching from a mechanical to a servo system.

3.2 Control of vertical packaging machines

(1) System configuration of vertical packaging machines

Figure 6 shows a basic system configuration of a vertical packaging machine. A vertical packaging machine uses a film feeding mechanism to vertically feed packaging film from the top downward. It then mainly uses gravity to insert package content into a bag of film and seals the opening of the bag using a heated sealer mechanism.

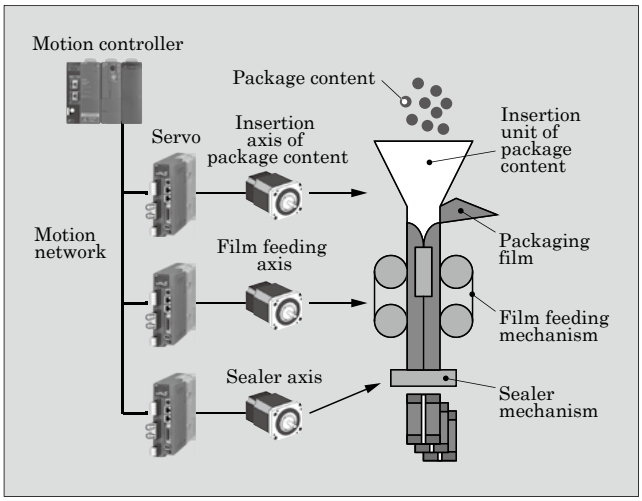

Fig.6 System configuration of vertical pillow packaging machine

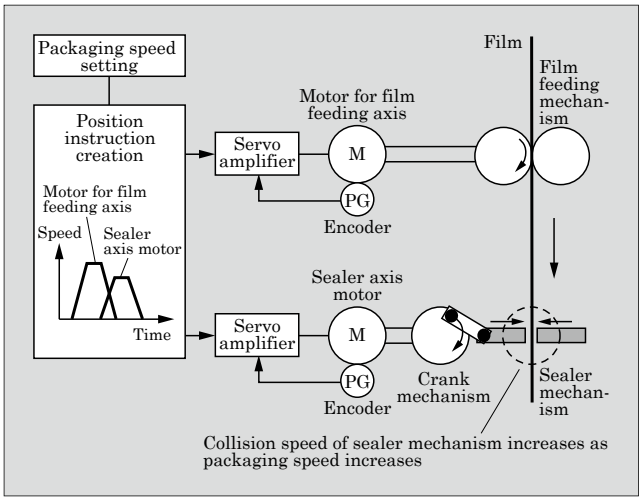

Fig.7 Overview of conventional control method

(2) Issue with conventional control method

Figure 7 outlines the conventional control method. The film feeding axis motor and sealer axis motor are position-controlled generally by trapezoidal acceleration and deceleration, and the rotational speeds of the respective axes are determined by the ratio according to the packaging speed. Increasing the packaging speed increases the collision speed of the sealer mechanism, causing a larger impact. For that reason, the vibration of the entire machine hindered stable quality sealing.

(3) Application of motion control

Figure 8 shows an example of packaging machine control that uses Fuji Electric's "SPH Series" PLC and "ALPHA5" servo systems.

In this motion control, the rotational speed of the sealer axis for sealing the film is maintained at a constant level, and the speeds in other sections are varied to change the packaging speed, and this has stabilized sealing regardless of the packaging speed.

By introducing this control, a packaging machine

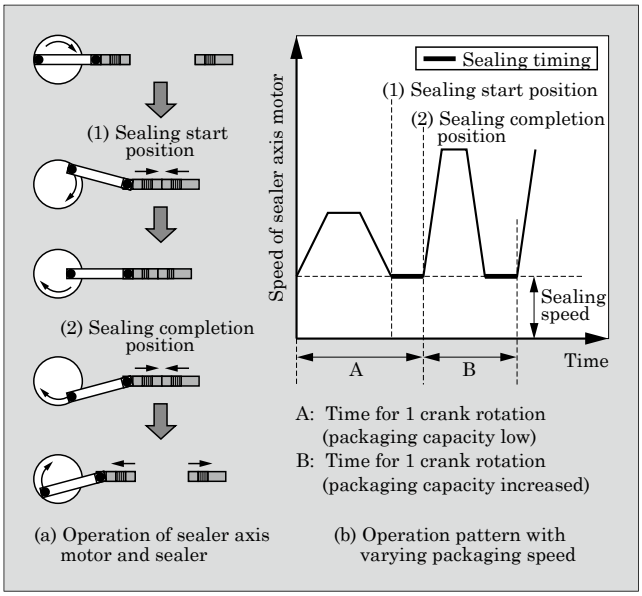

Fig.8 Overview of motion control

manufacturer in India has significantly improved the packaging speed compared with conventional systems.

3.3 Motion control function blocks and "SPH3000D"

(1) Motion control function blocks

Fuji Electric has developed function blocks (FBs) for the SPH Series and offered them mainly in the Asia region so that many customers can use the control programs as described earlier. Table 4 shows motion control FBs.

(2) SPH3000D

The latest CPU module of the SPH Series is equipped with FBs as system instructions, and this makes it possible to control a servo system without adding a special CPU for motion control. Figure 9

Table 4 List of motion control FBs

No.	FB name	Control details
1	VM00_VM	FB for virtual axis for synchronization control and external PG forecasting calculation
2	VM01_PTP	FB for general positioning (point-to-point control)
3	VM02_INTP	FB for 2-axis linear interpolation and 2-axis circular interpolation control
4	VM03_PSYNC	FB for ratio synchronization control
5	VM04_RSYNC	FB for synchronization control on rotational section Applied mainly to rotary shear control
6	VM05_FSYNC	FB for synchronization control on reciprocating section Applied mainly to flying shear control
7	VM06_CAM	FB for operation control on electronic cam
8	VM07_CAMPTN	FB for creating operation patterns of electronic cam
9	VM08_VEL	FB for speed control
10	VM09_TRQ	FB for torque control

Table 5 Outline specifications of “SPH3000D”

Type		NP1PU-048EZM	NP1PU-096EZM	NP1PU-128EZM	NP1PU-256EZM
Execution control system		Stored program, cyclic scanning system (default task), periodic task, event task			
I/O connection system		Direct connection I/O (SX bus) Remote I/O (DeviceNet, OPCN-1 and other remote I/O links)			
I/O control system		SX bus: Tact synchronization refresh			
		Remote I/O link: Refresh at fixed intervals by remote master (not synchronized with scan)			
CPU		32-bit RISC processor			
Programming language		IEC 61131-3 compliant Instruction List, Structured Text, Ladder Diagram, Function Block Diagram, Sequential Function Chart			
Instruction execution speed	Sequence instruction	9 ns or more/instruction			
	Applied instruction	8 ns or more/instruction			
No. of I/O points		8,192 (points)			
User memory		545 (Kwords)	1,409 (Kwords)	1,473 (Kwords)	2,753 (Kwords)
Program memory		98,304 (words)	196,608 (words)	262,144 (words)	524,288 (words)
		49,152 (steps)	98,304 (steps)	131,072 (steps)	262,144 (steps)
Data memory (High-speed space)		459,776 (words)	1,246,208 (words)	1,246,208 (words)	2,294,784 (words)
		229,376 (words)	229,376 (words)	229,376 (words)	229,376 (words)

Fig.9 “SPH3000D”

shows the external appearance of SPH3000D.

Conventionally, motion control FBs needed to be registered in the library as user FBs before being used. SPH3000D is equipped with the FBs as system instructions, which eliminates the need for registration and allows the user to easily build motion control systems.

In addition, the following improvements have been made with the SPH3000D to have faster control speed than that of conventional products.

(a) Program codes for motion control FBs have been made in the C language to minimize program sizes.

(b) Of the data memory area, the size of the high-speed area has been increased from 32 Kwords of the conventional models to 229 Kwords. Table 5 outlines the specifications of SPH3000D.

As a result, motion control executes at twice the speed of conventional models[2], which contributes to enhancing the performance of packaging machines.

4. Postscript

This paper has described FA solutions based on the IoT technology and motion control technology. These technologies, which are expected to further advance in the future, will make the needs of the manufacturing industry even more sophisticated and complicated. We intend to further develop our current approaches to create more added value and meet the needs of users.

References

(1) “IoT Acceleration Consortium”. IoT Acceleration Consortium. http://www.iotac.jp/en/, (accessed 2017-12-14).

(2) Fukushima, K. et al. “MICREX-SX Series” Motion Controller “SPH3000D”. FUJI ELECTRIC REVIEW. 2016, vol.62, no.4, p.280-282.

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