Manufacturing Execution Systems Encouraging DX on the Manufacturing Floor

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ABSTRACT

In recent years, the manufacturing industry has been accelerating the introduction of manufacturing execution systems (MES) to improve the efficiency of manufacturing processes and enhance productivity and quality through DX. MES can be interfaced with various systems to help improve product traceability and to quickly detect and solve problems in production processes. Fuji Electric has developed a MES that can be used for various applications such as food manufacturing by digitally twinning manufacturing floors as information models and systematically managing them. The MES can share information models among model users, use information identifiers, and link manufacturing information models with quality management information, allowing it to contribute to high productivity and quality.

1. Introduction

Digital Transformation (DX) refers to initiatives to drive the improvement of business processes and innovation by making advancements in information technology. In the manufacturing industry, DX is expected to make manufacturing processes more efficient and improve productivity and quality.

Among such initiatives, the adoption of manufacturing execution systems (MES) plays an essential role in DX. MESs are systems that collect and analyze data, as well as control and monitor production lines on the manufacturing floor. They are useful for increasing productivity and carrying out quality control and inventory management. For example, they can optimize the availability of production lines to increase production volume. In addition, an MES works with the core enterprise resource planning (ERP) system to enable visualization of not only the manufacturing floor but also entire supply chain, as well as data sharing and analysis. This improves the traceability of products and allows problems in the production process to be detected and solved at an early stage.

This paper describes manufacturing execution systems that contribute to DX on the manufacturing floor.

2. Overview of Manufacturing Execution Systems

2.1 What are manufacturing execution systems?

Manufacturing execution systems are information systems used to understand and control the manufacturing process, as well as to instruct and support workers. They are used in conjunction with each manufacturing process on the factory production line. The main functions include the 11 types[1] defined in the MESA-11 (Manufacturing Enterprise Solutions Association) model, such as work instruction management, shipment management, quality management, and maintenance management. This allows manufacturers to implement the necessary functions according to the line of business and purpose to which they are applying the system.

The applicable manufacturing industries can be

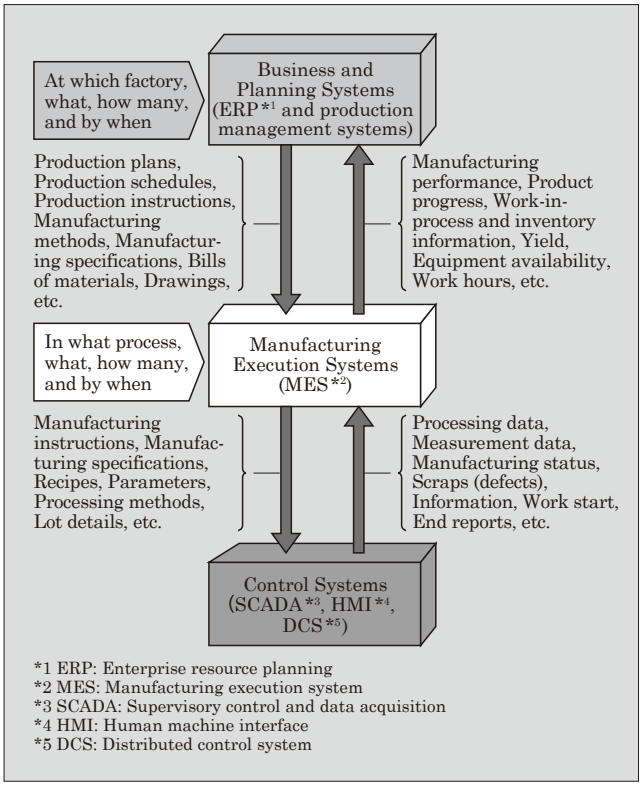

Fig.1 Roles and positioning of the MES

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roughly divided into two categories according to how the products are made: discrete manufacturing, in which raw materials and parts are processed and assembled into products, and process manufacturing, in which raw materials are sequentially input into manufacturing plants and other facilities. For example, the manufacture of automobiles, machines, and their parts falls under the discrete manufacturing category, while the manufacture of materials, food, and pharmaceuticals falls in the process manufacturing category. Fuji Electric offers two types of MES package solutions tailored to the characteristics of each category.

Figure 1 shows the roles and positioning of the MES. At the top are the ERP and production management systems, and at the bottom are control systems such as distributed control systems (DCSs) and programmable logic controllers (PLCs), which are used to manage manufacturing equipment. MES interconnects the data of the top systems and the bottom systems.

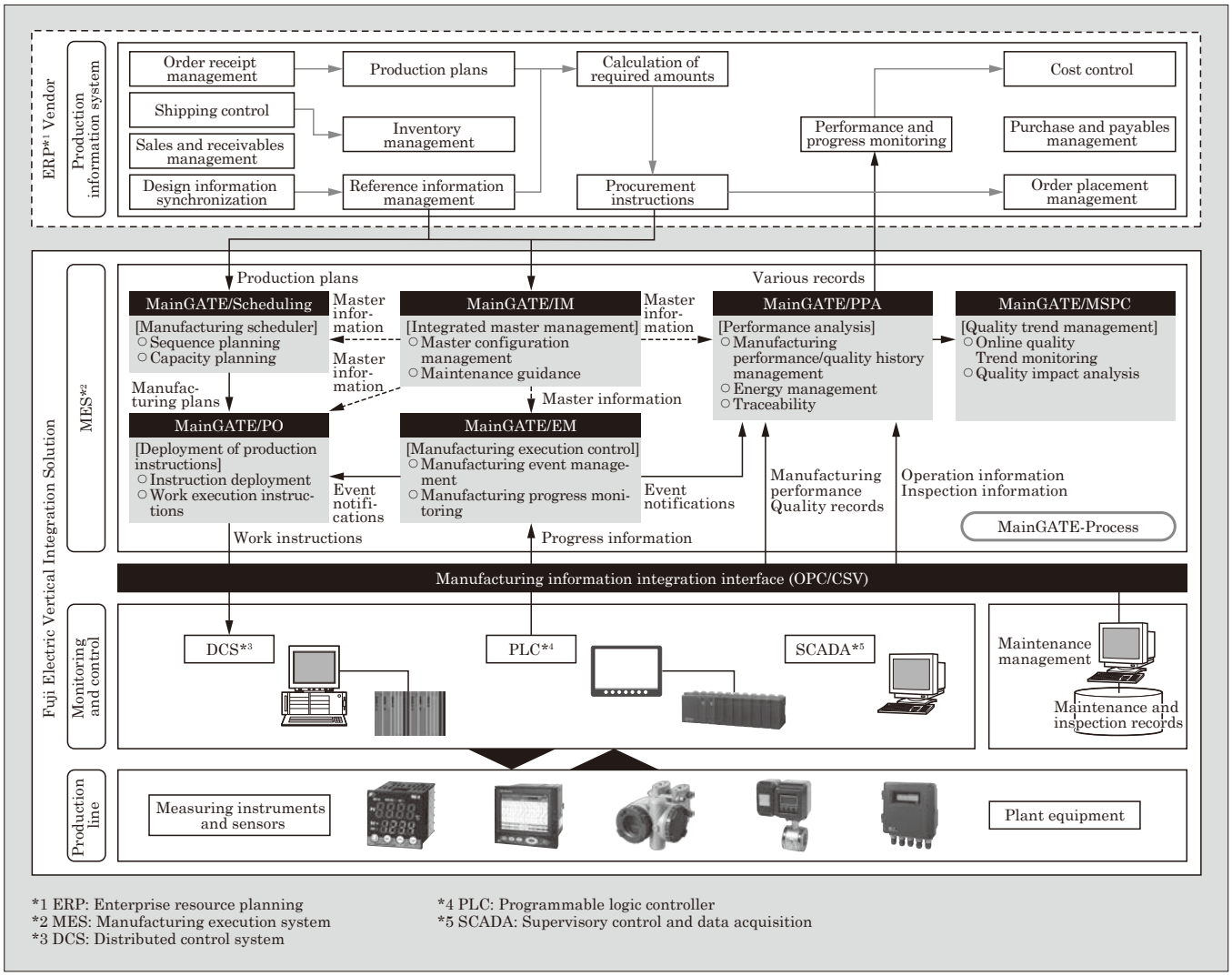
At Fuji Electric, we believe that the starting point of the manufacturing industry lies in the manufacturing activities performed at the worksite. As such, the MES is positioned to function as a bridge between the worksite and management.

2.2 Fuji Electric's manufacturing execution system

Fuji Electric has provided the "MainGATE Series" MES packages shown in Fig. 2 to a variety of customers in the food, chemical, and pharmaceutical industries, thereby contributing to the improvement of customer productivity and quality. Fuji Electric has also provided vertically integrated solutions by achieving seamless synchronization with its DCSs and PLCs.

The following products are available according to the function.

- ○MainGATE/PO: Production order deployment, production orders
- ○MainGATE/EM: Manufacturing event management, manufacturing progress monitoring
- ○MainGATE/IM: Master management
- ○MainGATE/PPA: Manufacturing performance management, traceability
- ○MainGATE/MSPC: Quality trend management



*1 ERP: Enterprise resource planning
*2 MES: Manufacturing execution system
*3 DCS: Distributed control system
*4 PLC: Programmable logic controller
*5 SCADA: Supervisory control and data acquisition

Fig.2 "MainGATE Series"

They include the following features.

(a) Provision of modules for each MES function
(b) Ability to systematically expand functions, including by partially introducing or switching functions, while maintaining data consistency
(c) Provision of high-efficiency engineering tools
(d) Easy follow-up for additional manufacturing items, changes in work procedures, addition of equipment, etc.
(e) Free extraction of data according to purpose of use

The most important feature is the availability of engineering tools. We built a flexible and versatile architecture for the engineering tools as the nature of manufacturing has been transitioning from low-mix, high-volume production to high-mix, low-volume production. Using the tools can make the change to the system in response to changes in procedures and the addition of control items in manufacturing equipment.

However, it has come to light that the current packages need to be improved in the following areas.

The database structure of the current packages use the lot number and the batch number as keys. It does not support data that is not linked to these keys, such as inventory.

In addition, raw material management and other work support functions that are positioned a level below on the management hierarchy were provided separately as add-on functions when requested individually by customers.

To utilize the accumulated data for various needs, such as operation, quality, and maintenance, employing highly flexible data structure is eligible, increasing the demand for the adoption of open architectures that facilitate data linkage. The current packages do not specifically support data management with a focus on equipment. Instead, each of them separately handles data management from multiple perspectives, including equipment.

3. New Manufacturing Execution System

A new MES package is under development to meet new needs while retaining the features of the current packages. The engineering functions of the present systems are efficient because they are specific to the implemented functions. However, it is difficult to change the functions or use them for other purposes. This new system uses a digital twin of the manufacturing floor as an OPC UA information model*1. In this way, the necessary information can be systematically managed for various applications.

3.1 Information models and information objects

The new system expresses information in terms of "information models" and the "information objects" that they represent (see Fig. 3).

An information model refers to a basic model that

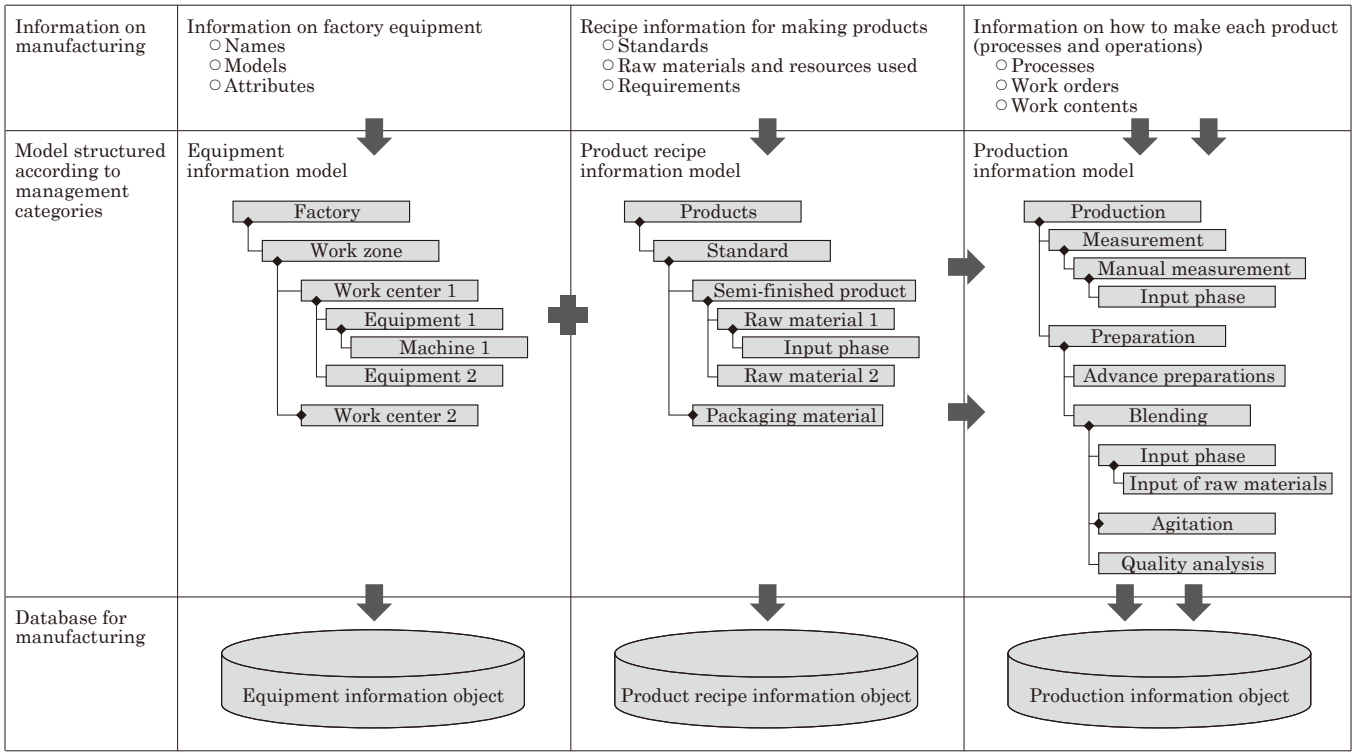


Fig.3 Overview of information models and information objects

*1 OPC UA is a trademark or registered trademark of OPC Foundation.

standardizes information. Information objects are tangible information related to equipment, products, and materials on the manufacturing floor that are represented by the information model.

By defining an information model, manufacturing standards for individual units such as companies and factories can also be defined, and manufacturing can be standardized that have been defined as individual work procedures for individual units such as factories and work zones. Standardization in manufacturing will facilitate management and improve production efficiency and quality.

Worksite information related to manufacturing execution can be classified into the following three types.

(1) Equipment information models and information objects

These are models that express the composition of production equipment segments on the manufacturing floor. They correspond to the "process segments" specified in ISA-95*[2]. To represent the physical configuration of the worksite, the structure is represented hierarchically. Generally, the hierarchy consists of the following seven hierarchical levels.

(a) Factories
Factories for producing products
(b) Work zones
Factory units divided according to function
(c) Work centers
Production control units into which work zones are further subdivided, used for issuing work orders
(d) Equipment types
Groups of equipment divided according to purpose of use
(e) Equipment
Equipment physically separated according to purpose of use
(f) Machinery
Units responsible for single control functions such as preparation, agitation or temperature control
(g) Instrumentation
Control of pumps, valves, flowmeters, and other instruments.

(2) Product recipe information models and information objects

These are models that represent the composition and attribute information of products, semi-finished products, and intermediate products, as well as a recipes (raw materials, packaging materials, and requirements) for production and quality control inspection items. These correspond to the "operation segments" specified in ISA-95. The structure for products is represented in the following hierarchy.

(a) Products
Mainly used in industry; refers to finished products resulting from the processing of raw materials
(b) Semi-finished products
Intermediate products that have not undergone all the steps necessary for completion. Semi-finished products are those that can be sold or at least stored outside of the process after undergoing certain processing.
(c) Intermediate products
Refers to products in intermediate manufacturing processes. Products at this stage are subject to sampling inspection to be checked for problems, and if no problems are found, the subsequent process is started. These are sometimes called intermediate manufacturing products. Intermediate products are half-finished products that will become completed products after undergoing the subsequent manufacturing processes.
(d) By-products
Products (recovered goods) necessarily obtained as a result of the processes used to produce something.
(e) Packing materials
Materials used in packaging. These materials include paper, plastic film, wooden boxes, and cardboard boxes.
(f) Raw materials
The basic materials used to manufacture and process products.

(3) Production information models and information objects

Production information models are generally structured according to the ISA-88*[3] procedure control model. Each piece of production procedure information in a production information model contains managed data related to manufacturing, such as instruction values, results values, and measurement values.

Since quality inspection is also one of the production procedures, quality inspection results are also managed in conjunction with the production information model.

3.2 Effects of information model application

(1) Advancing quality control efficiency

For products made in factories, quality control is indispensable. Many factories have quality checklists that are prepared and used manually. This new system uses production information models to manage not only production performance and measurement values but also quality inspection results together with production procedures. In this manner, it enables the required checklists to be easily prepared by simply ar-

*2 ISA-95 is a collection of standards for information systems related to the manufacture of goods specified by the ISA (International Society of Automation for automated equipment).

*3 ISA-88 is the international standard for batch processing, which suggests models for batch processing (including processes, equipment, control, and management).

ranging data for quality control.

(2) Utilization of accumulated data

(a) Utilization of information objects

The new system accumulates information about production processes in a form that is linked to each information object. As such, information can be obtained by accessing information at the necessary hierarchical level. When equipment is the focus, the information can be accessed through equipment information objects. Likewise, when raw materials are the focus, information can be accessed through product recipe information objects, and when production is the focus, information can be accessed through production information objects. As a result, necessary information can easily be synchronized between users who share information models, and the data can be utilized for operations such as analysis and evaluation of information.

(b) Use of information identifiers

Information models manage the state of the worksite in a hierarchical structure so that the necessary information can be accessed by tracing the hierarchy. However, when acquiring the production results of equipment used for the production of multiple products, the information models alone are not efficient because it is necessary to trace the production information model of each product one by one. To handle such applications, all information items should be assigned information identifiers. In doing so, the necessary information can be directly accessed by using the acquired information identifier as a key.

4. Postscript

This paper has described a manufacturing execution system that contributes to DX on the manufacturing floor.

Going forward, we will use information models to design systems that link together not only Fuji Electric products but also machinery and equipment made by other manufacturers in order to provide customers with solutions that implement our concept of connected factories, which we have adopted in our own operations. In doing so, we will continue to contribute to the improvement of the productivity and quality of the manufacturing operations of our customers.

References

(1) MESA International Whitepaper, https://www.mstc.or.jp/mfgx/spec/mesx-wp.pdf, (accessed 2023-03-24).

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