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A Real-time 4M Collecting Method for Production Information System

Seung Woo Lee, So Jeong Nam, Jai-Kyung Lee

Abstract—It can be said that the business sector is faced with a range of challenges—a rapidly changing business environment, an increase and diversification of customers' demands and the consequent need for quick response—for having in place flexible management and production info systems. As a matter of fact, many manufacturers have adopted production info management systems such as MES and ERP. Nevertheless, managers are having difficulties obtaining ever-changing production process information in real time, or responding quickly to any change in production related needs on the basis of such information. This is because they rely on poor production info systems which are not capable of providing real-time factory settings. If the manufacturer doesn't have a capacity for collecting or digitalizing the 4 Ms (Man, Machine, Material, Method), which are resources for production, on a real time basis, it might to difficult to effectively maintain the information on production process. In this regard, this paper will introduce some new alternatives to the existing methods of collecting the 4 Ms in real time, which are currently comprise the production field.

***Keywords*—**4M, Acquisition of Data on shop-floor, Real-time machine interface

I. Introduction

MES, one of the most commonly used production info management systems, is designed to optimize the production process from placing orders to shipping, which covers the scheduling of processes on the shop floor, instructions for each task, quality assurance activities, compilation of achievements, and all other tasks related with production. MES not only transfers the latest information on the production filed to the higher management group who plans each process of production through methods such as ERP, SCM and CRM, but also hands over the production information planned by the management to the production management organization. Like this, MES plays a fundamental and pivotal role in the management of information on the production process. Any company that does not have a production management system in place such as MES or POP may have to depend on manual labor in areas from planning the production process to giving instructions to workers, and cannot check the factory operation in real time.

Seung Woo Lee is with the Advanced Manufacturing Systems Research Division, Korea Institute of Machinery and Materials, Daejeon, Republic of Korea (phone: 82-42-868-7147; fax: 82-42-868-7431; e-mail: lsw673@kimm.re.kr).

So Jeong Nam is with the Advanced Manufacturing Systems Research Division, Korea Institute of Machinery and Materials, Daejeon, Republic of Korea (phone: 82-42-868-7242; fax: 82-42-868-7431; e-mail: minisso@kimm.re.kr).

Jai-Kyung Lee is with the Mechanical Systems Safety Research Division, Korea Institute of Machinery and Materials, Daejeon, Republic of Korea (phone: 82-42-868-7645; fax: 82-42-868-7477; e-mail:jkleece@kimm.re.kr)

The management will encounter a series of challenges if the production volume increases and the production process become more complex, such as failure to apply a transparent maintenance system to production and a correct production analysis result, resulting from production performance, irregularity in production equipment and other production statuses solely determined by the workers on the field. Even with a production management system in place, if the information on the 4 Ms, comprising the production field as fundamental resources, is not managed in a correct manner in real time, the system may not work effectively. A US consulting firm, Industry Direction, has introduced the following as requirements for a next-generation production management system [1].

The company has also emphasized the importance of the 4 Ms, the essential production resources.

● Support for more convenient restructuring of the 4 Ms, corresponding to requirements for reasonable management of orders and factories

● Real-time analysis of information on the 4 Ms aimed at improving productivity

● Management of multiple factories focused on QCD (Quality, Cost, and Delivery)

● Upgrading the reusability of service-oriented programs

● Unifying different higher-tier applications

● Capability of managing the production without the support of experts in related fields

This paper will introduce some alternatives to the existing methods of collecting the 4 Ms in real time that currently comprise the production field, for enhancement of the production info management system such as MES.

II. Methods of Collecting Information on the 4 Ms

The 4 Ms, the resources comprising the production process, include Man, Machine, Material and Method. Generally, in a 4M system, the data on production management are collected in real time, although the implementation may depend on the level of control instrument, given that the Machine element includes PLC—a digital control instrument, tools, FSM, and combination of automated systems. No matter how automated the production equipment is, each production process may require human labor. There will also invariably be activities in which the information cannot be collected by the automated equipment, and that workers should handle based on their own discretions in such events as a failure in equipment or quality assurance related service. Information for the 4 Ms can be collected in 3 types: Automated, Semi-auto and Manual.

A. Automated type

This type involves control instruments positioned between production equipment and the information system, which automatically collect the information from production equipment through standard protocols and programs such as TCP/IP or OPC (OLE for Process Control).

B. Semi-auto type

The semi-auto type can be divided largely into two sub-types that do not involve any control device; the first is using a sequential-type control system such as PLC (Programmable Logic Controller), which automatically collects data by means of I/O terminals. The second is using sensors attached to machinery systems with no control devices attached to them for collecting information on the operation and performance conditions.

C. Manual type

This type consists of manually typing in the data on production activities. It depends on the discretion of workers, and therefore does not guarantee that the information is timely. The efficiency of the info collecting method can be improved by using aids such as RFID and PDA. The data on the 4 Ms collected via these three methods can be converted to information that can be made useable for the production process and distributed throughout the organization for use as essential input to the production management system.

III. Design of Interfaces for Collection of Data on 4 Ms

This section will describe a device interface designed for flexible and independent real-time info collection for all types of different machinery systems, which is based on the 4M info collecting methods aforementioned.

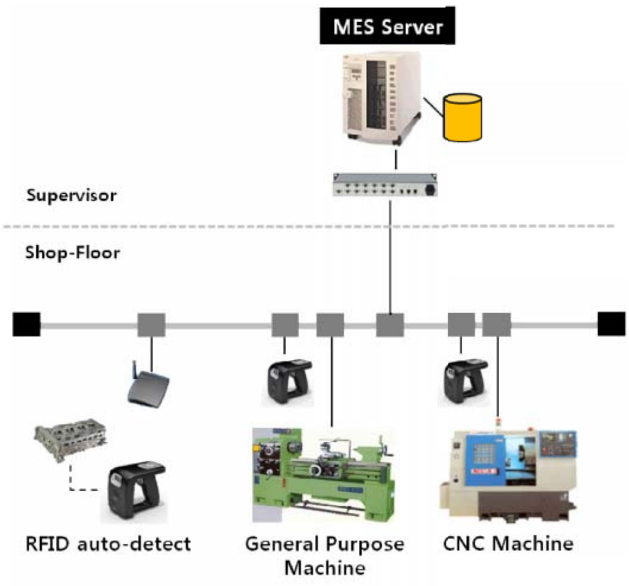

Fig. 1 Design of Interfaces

Since the Automated type involves control devices distributed around the equipment, which enables it to collect the data and is connected to the info system, the following sections will discuss only the Semi-Auto and Manual type; first, PLC based interfaces and sensor based interfaces in the Semi-Auto type, as shown in Fig. 1

A. PLC based interface

Since the CNC-based processing machines used on the field may have shielded structures, it is therefore difficult to implement external interfaces for them and send their data to the info management system. It may help to use API software provided by the CNC vendor, but it is costly and involves limitations in extracting required information. CNC-based equipment has I/O contacts called "PMC," which contain the status info of the equipment as contact signals. This study suggests a method using these I/O modules of PLC, and connecting the CNC equipment and PMC to collect data on the equipment status.

As shown in Fig. 2, the method works in a mechanism where the signals generated at the PMC contacts are connected to I/O modules, with those generated at CNC processed at PLC before being sent to the PC. Contact signals can be stand-alone or combined. For either type, processing the signals sent from a ladder program or PLC for processing the data in CNC equipment and PLC may require HMI or something similar. It is also possible to use different sensors and A/I modules of PLC to collect the status information required.

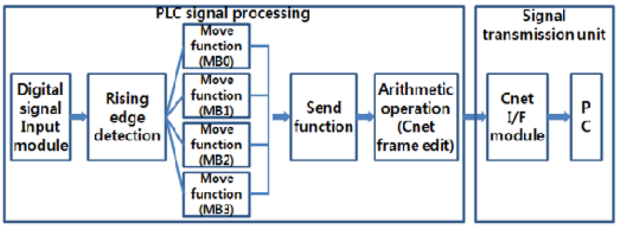

Fig. 2 Data processing using PLC

B. Sensor-based interface

This section will introduce a sensor-based interface board that can be used to collect the data on any piece of equipment with no attached controllers, as shown in Fig. 3.

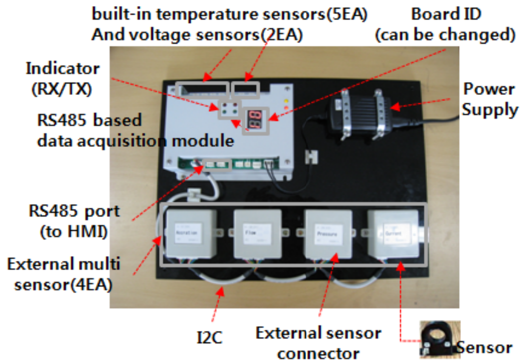

Fig. 3 Configuration of the Sensor-based interface board

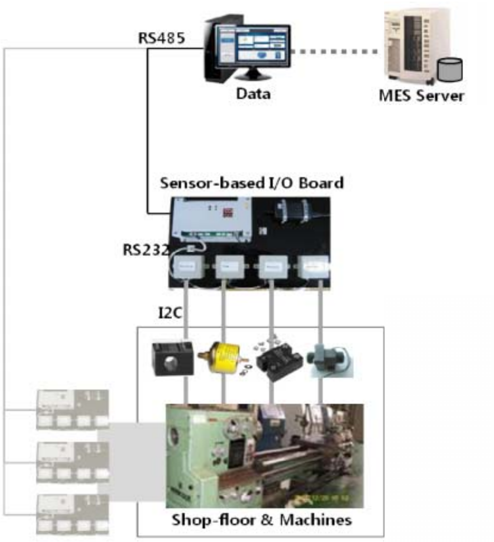

Fig. 4 Info collection using a sensor-based interface

Sensor-based I/O boards consist of a sensor unit for monitoring the temperature and pressure, a communication unit and an I/O unit. The board supports an input power between 7.5VDC~ 30VDC and RS232 communication can be connected to the PC or another external device. The temperature sensor is designed to detect a temperature between -19.9 ~99 , and the pressure sensor, a pressure between 0V and 36V. In addition, the external sensor extension terminals allow an extension of the number of sensors up to 256 to ensure the flexibility of the status info collecting process. In this study, the number of the total number of sensors that can be connected to the I/O board to ensure the reliability of the system. The data is collected through a total of 11 sensors including 7 temp/pressure sensors, one deployed to each I/O board, and 4 extended sensors, as shown in Fig. 4.The external sensor is connected to the I/O board via a sensor connector and is capable of sending collected data by using I2C (Inter-Integrated Circuit), a two-line serial communication standard, between the chip and the board. 12C is the mother board of the DC computer bus, which is usually used to connect embedded systems and low-speed peripheral devices.

This study has considered how the network protocol should be designed for effective communication between different control units on the field and the info management system, and to higher-level data management organizations, as shown in Fig. 5. The structure of the frame of the communication protocol is largely divided into Start of Text (STX), sensor I/O board identification bytes (Addr.), sensor data set (Dataset), End of Transmission Block (ETB), and check sum bytes (BCC). In the frame of the communication protocol, the Dataset has a specific structure for supporting the data transmission process at each sensor, which consists of positive response bytes (ACK, Acknowledgement) for data received, sensor identification bytes (SensorID), sensor measurement data bytes (Data), and End of Text bytes (ETX) indicating all sensors have finished uploading data.

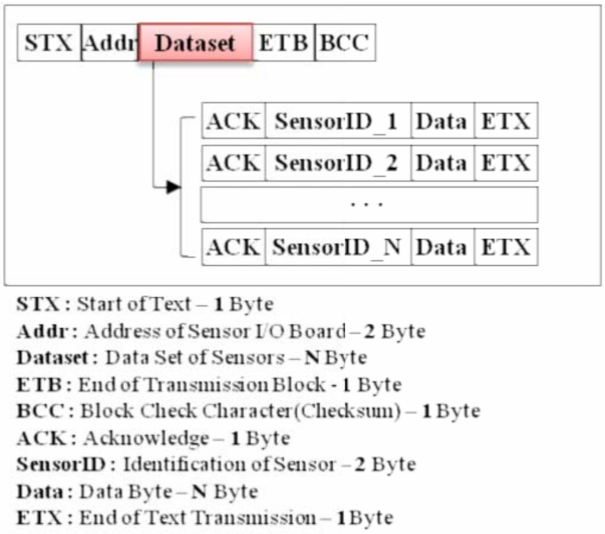

Fig. 5 Design of protocol

The Dataset can be deployed in multiple numbers depending on the number of sensors. Data bytes include Delimiters combined with the status info on micro machines sent by sensors. The bytes were defined in a way that they can deliver a FAIL message indicating communication failure upon no data sent by sensors and an N/A signal indicating no sensor is available.

This definition enables a judgment to be made on whether a transmission signal has arrived at the sensor I/O board and will improve the reliability of real time measurement through the "ALL" function which allows receiving all values measured by sensors upon [STX|Addr(N)|ENQ] request without repeating a communication with a [Request – Response] structure to receive sensor data from each equipment. This "ALL" function eliminates the need for the unnecessary task requesting already received sensor data that is attributed to an error in the network or data loss.

C. RFID-based Auto Detection Interface

Of all the 4M info collection methods, the Manual type has its limitations with respect to real time, punctual and accurate collection of data on the production line. This type cannot guarantee the accuracy and timeliness of data because it relies on the input by the field workers. For real-time, accurate data collection, the utilization of manpower should be minimized. To this end, this studied an RFID-based system, which consists of RFID Readers and antennas, designed to automatically detect work-pieces, work orders, workers, or machines that have RFID Tags attached on them.

The design of the ID Prefix is as follows:

- Equipment: EQ
- Operators: OP
- Products: PD
- Work Orders: WO

The system has its merits in that it minimizes the input by operators, helps to implement a paperless office environment and enables auto ID checking for auto data acquisition.

IV. Acquisition of Data on 4 Ms

The interface for collecting info on the 4 Ms in real time proposed in this study produces secondary field data on processing time, idle time, malfunctions, defectives, etc., on the basis of primary field data on the pressure, current, RPM, etc. These secondary data are mapped with the base information through the info collection system, and generate the tertiary information including daily production, average production cycle and operational performance.

TABLE I
Processing of Collected Primary Shop floor Data

Data	Description	Example
Primary Shop floor Data	Equipment interface or manual entry data	Voltage, RPM, On/Off, temperature, humidity, alarm, manual entry, CNC door open/close, CW/CCW of CNC spindle, etc.
Secondary Shop floor Data	Data generated after 1st processing	Operating time, idle time, malfunction time, equipment history, good product, defects, quantity, standby before the process, preparation time, standby after the process, etc.
Reference Data	System reference data	Worker data, product data, organization data, process data, equipment data, product order data, work order data, etc.
Tertiary Shop floor Data	Data generated after mapping of the primary and secondary data with the system reference data	Daily production by equipment, total daily production, average product production time by equipment, work output, work start time and end time, etc.

V. Conclusion

The paper introduced some alternatives for real-time collection of data on the 4 Ms, to help the managers boost the competitiveness of their production info management systems and effectively respond to the ever-changing production status.

Specifically, it has suggested a PLC-based interface for CNC equipment with sequential control devices attached, sensor-based interface for general-purpose equipment, and ID Auto Detection Interface using RFID for minimizing the data input by humans. The proposed 4M info collection methods have the properties of middleware positioned between the production equipment and info system, which can be used in a wide range of manufacturing settings and equipment as well as in a stand-alone architecture that does not require additional devices. The study has introduced some interfaces enabling real-time, automatic 4M data collection regarding the production performance, quality, equipment operation, failures, movement of products, etc. As a further step, we are planning to research an autonomous 4M reshuffling method for minimizing maintenance, without additional works or modification of production info management programs, in restructuring the 4 Ms.

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