Title:
An Architecture Design for Smart Manufacturing Execution System

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Keywords:
Manufacturing Execution System(MES), Data integration, System architecture, Collaboration

DOI: 10.14733/cadconfP.2016.342-347

Introduction:

Contemporary manufacturing companies have been confronting with various demands such as reducing time-to-market, flexibly changing operation schedule, which is hard to be satisfied concurrently [5]. Even though ERP(Enterprise Resource Planning) system supports information flow between enterprise and outside stakeholder, using ERP alone isn't enough because ERP mainly concentrates on managerial level issue[6]. To get around, the MES was introduced for managing shop floor activities based on production schedule and shop floor situation by collecting shop floor data and showing organized data to the operators [4].

However, many of current manufacturing companies have a difficulty in handling manufacturing management activities using MES mainly due to lack of infrastructure for data collection, analysis, integration of manufacturing data due to difficulty in integrating different protocols[1]. Even though many researches treat data collection, data analysis based on shop floor situation, action based on context in shop floor, little number of previous researches deals with collaboration among various functionalities provided by MES. Smart MES is the MES that can recognize and deal with shop floor situation in real-time manner with (1) infrastructure which can collect shop floor data overcoming various protocol, analyze data and extract some useful information, (2) various functions other than just operation scheduling, production control, part tracking, some function needs to be included such as quality management, maintenance management[2], (3) collaboration among various functions to optimize manufacturing management activity in shop floor, (4) data synchronization among various functions to optimize the effect of cooperation. These four properties are ones that derived from literature survey as implications.

This paper is organized as follows. Problem of current MES and design consideration for Smart MES are specified. Then, based on design consideration, architecture for Smart MES is derived. Finally, operation scenario based on architecture and advantages of the architecture are introduced.

Requirement analysis of current MES and Design consideration for Smart MES:

To design Smart MES, problem derived from current MES solution and previous research should be identified and should be reflected. Various problems can be derived depending on point of view the one focus on. In this paper, we analyze the problem from the perspective of data collection, analysis, and integration. We found problems based on literature review and some interview with shop floor workers, engineers in car door assembly company and refractory-brick making company. Problems derived are regarded as requirements. Design consideration is derived according to problems above. Problems and corresponding design considerations are organized in Tab. 1 and Tab. 2, respectively.

NO.	Problems of Current MES(PR)
1	Workers should record data by hand which coming from machine controller and type into MES or DB(DataBase).
2	Sensor technology is often used as a means for getting data from shop floor. However, since there're many existing communication standards on sensors[3] and the PLC(Programmable Logic Controller) supports different types of sensor depending on vendors, data integration is key issue.
3	Even though some companies invest money to extract data from facilities by utilizing controller protocol, it's hard to integrate data because of different protocol controller supports.
4	It's hard to modify operation schedule based on stakeholder requirement or shop floor situation once manufacturing schedule is initially determined.
5	It's difficult for MES operator to track the WIP(work-in-piece) in real-time.
6	Allocating right preventive maintenance schedule is challenging one since it should consider resource status and production operation schedule.
7	Generally, it's hard to recognize what kind of failure happened in machine. It mostly depends on workers' tacit knowledge to get around.
8	Comprehensive data analysis based on overall shop floor should be desired. Most of information processing in many manufacturing companies was conducted in narrow scope.
9	It's hard to figure out what kind of quality problem on product happened, what brought about that problem and when that problem started to happen.
10	Estimating material consumption for production is desired for association with SCM(supply chain management) so that production can be conducted seamlessly with minimizing production & inventory cost.
11	In manufacturing company, production performance analysis result is managed only the amount of production.
12	Data integration /synchronization between MES and Enterprise information system isn't established as one expects.
13	There is a lack of collaboration between MES functions.

Tab. 1: Problems of Current MES.

NO.	Design consideration (DC)	PR(s) reflected
1	Real-time data acquisition via sensor technology: To realize real-time data analysis and response, it's essential to gather shop floor data to recognize shop floor situation.	PR #1
2	Reliability of data generated from shop floor: Since analysis and judgement are based on shop floor data, it's crucial to ensure the reliability of data.	PR #1
3	Communication means for various sensors and controllers: Even though PLC can retrieve sensor data from sensor, controller and then send to MES, not all types of sensors are supported.	PR #1, #2, #3
4	Close connection with enterprise information system: Communication between enterprise information system and MES should be established.	PR #12
5	Determination of source of data: It's important to know where each datum comes from so that appropriate data set can be selected.	PR #4, #5, #9
6	Data storage in distributed database: When it comes to store shop floor data in MES, using relational database such as MySQL is not good option because manufacturing data is so huge that relational database can't deal with it efficiently.	PR #1, #5, #7, #8
7	Data analysis methodology: Some methodology like data mining is needed to extract some useful information.	PR #7, #8, #9
8	Visualization / Report for analysis result: Big data analysis result is needed to be organized so that Smart MES operator or other users can understand.	PR #7, #8, #9
9	Collaboration among MES functions: It's desired to be linked among MES functions to share data generated or stored in each function.	PR #4, #5, #6, #10,#11,#13
10	Pervasive access to shop floor and devices: Pervasive access to analysis result is a basis for accomplishing transfer visualization material.	PR #4, #5, #6, #7, #8, #9, #10,#13
11	Unified data model: Each facility, even though it supports same function, has different attributes set. That means that it requires unified data model to integrate data from shop floor.	PR #2, #3, #12
12	Data transformation between shop floor and Smart MES: For transforming data between Smart MES and shop floor using unified data model, there must exists	PR #1, #2, #3

	some means to deal with.	
13	Data transformation between Smart MES and Enterprise information system: For transforming data between Smart MES and enterprise information system using unified data model, there must exists some means to deal with.	PR #12

Tab. 2: Design Consideration for Smart MES.

Smart MES Architecture:

Before proposing architecture, system concepts which are applied in design of Smart MES architecture are defined. Details are presented below.

- [System Concept(SC) #1] Adoption of real-time communication environment. (Reflected DC #1,#2,#3,#4,#10)
- [SC #2] Data integration & transformation. (Reflected DC #2, #3, #5,#11,#12,#13)
- [SC #3] Adoption of Big data module. (Reflected DC #6,#7,#8)
- [SC #4] Smart MES functionality as applications (Reflected #9)

Based on above system concept and design consideration, we provide the architecture for Smart MES as shown in Fig 1. Modules consisting of Smart MES architecture are described below in brief manner. Details will be described in the full paper due to limitation on page number.

- Device middleware: Device middleware integrates different communication protocol existing in the shop floor.
- Enterprise information DB: Information coming from enterprise information system and information created from Smart MES application are stored and transformed.
- Data storage & integration: Data coming from shop floor needs to be transformed in unified format to be able to analyze efficiently.
- Data analysis Engine: After storage & integration, data is moved to data analysis engine to extract useful information for application. After analysis, visualization/report can be delivered to user for pervasive access. Analysis model can be modified and created based on shop floor situation or MES application configuration change.
- Smart MES application and its management module: Each function in this module utilizes result of data analysis to determine which action should be taken to shop floor and what kind of information should be delivered to enterprise information system. Function like operation detailed scheduling can also use information from enterprise information system. Data synchronization among applications and functional collaboration among various applications are also handled. Application can be added or modified. This'll not be discussed due to limitation of page number.
- Data transformation rule repository: This repository specifies rules that transform different data formats. The rule defines the transformation relationship among enterprise information system format from enterprise service bus, Smart MES application, Shop floor data in distributed database in data analysis engine, shop floor data format.

Operation scenario based on architecture:

Even though the best way to prove the validity of the architecture that suggested above section is implementation, we don't adopt that approach since MES itself consists of so many components that one can't handle all of them. Among various scenarios that can be proposed and derived, we choose a scenario on product quality diagnosing and adjusting a spot-welding robot in a car door assembly company. We presented As-Is and To-Be model of MES. As-Is MES model is assumed to be: (1) connected with many interfaces due to various protocols, (2) hard to figure out shop floor situation and take action in real-time manner based on analysis of data, lack of collaboration among various MES functions. As-Is and To-be model of MES, namely Smart MES, is presented in Fig.2.

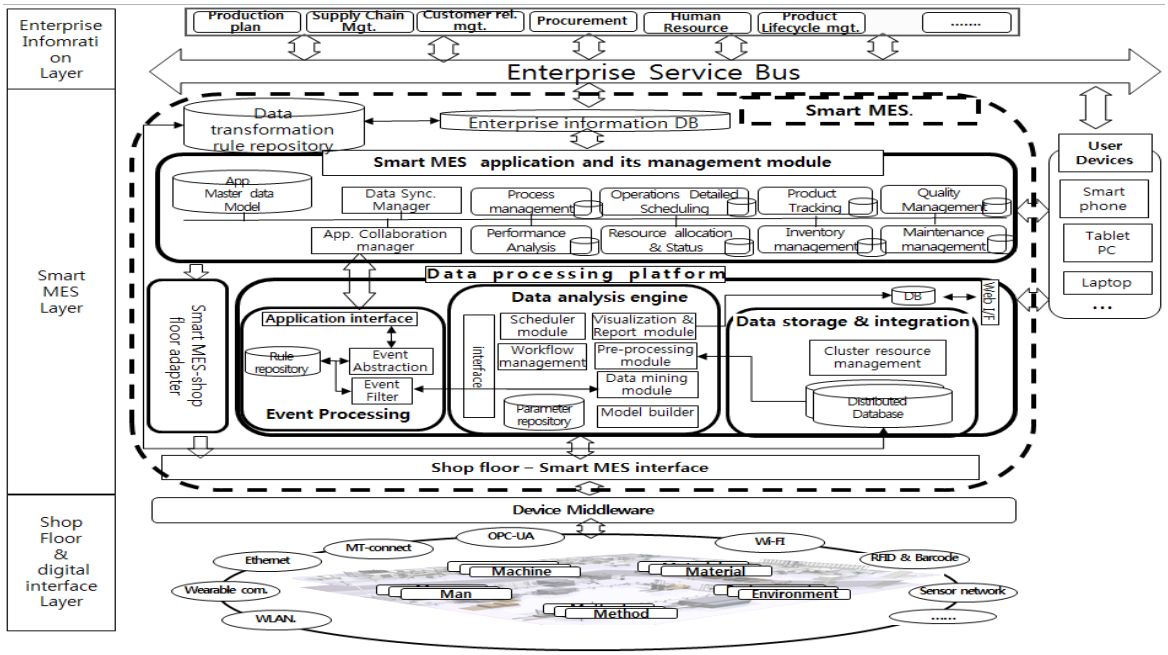

Fig. 1: Smart MES architecture.

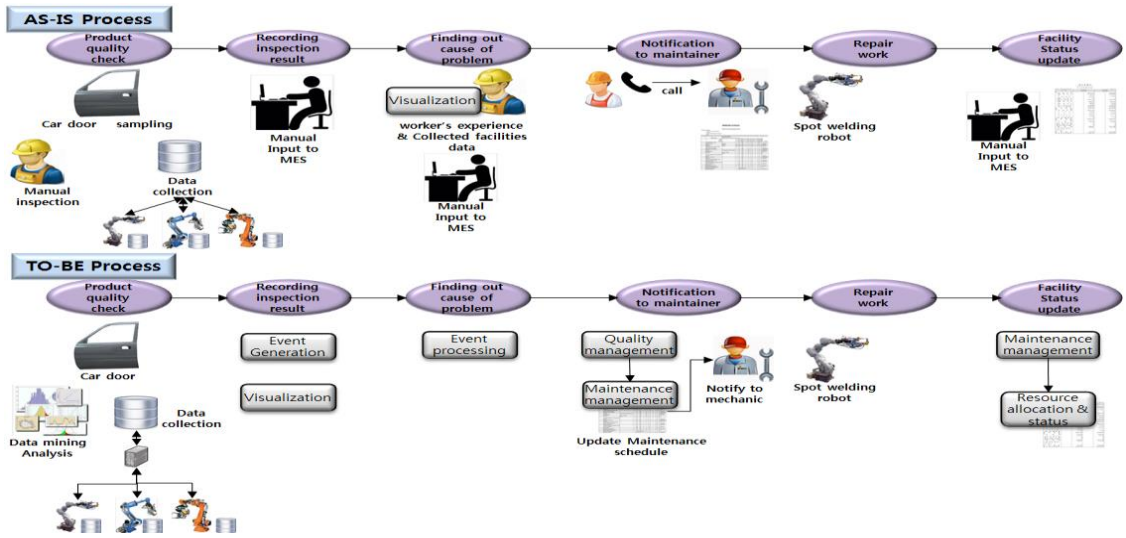

Fig. 2: Comparison of operation model.

We specify a common operation scenario applied in both models and then observe how this scenario is conducted in both models. The operation scenario is as follows. When a car door quality problem happens, then problem cause is to be found. If it's caused by just different machine parameters setting which should be adjusted against environment and WIP type etc., then machine parameter adjustment is done. If it's caused by failure of facility, then affected functionalities of MES are to be conducted such as maintenance management, process route change etc. Since functionalities of MES are related to

each other, it's important for each function to collaborate each other. We show that To-be model is advantageous for this scenario. Comparison with two models is presented in Tab.3.

Task	Current-MES(As-Is)	Smart MES(To-Be)	Advantages
Recording inspection result	Inspector records result by manually writing to database in MES.	Inspector doesn't have to manually write that result. If event happens, then that event is recorded by quality management service.	Recording work is automatically done by service in smart MES module. It means that MES can recognize the quality result faster.
Find out the cause of problem	Inspector relies on his/her expertise knowledge on product and collected data expressed by graph to find out problem on WIP.	Inspector doesn't have to rely only on his/her expertise knowledge. Data analysis can deal with it and give lots of help.	Even non-skilled inspector can handle a variety of WIP defect in real-time manner. It means the detection time is reduced.
Notify to Maintenance department	MES operator should give a call to maintenance worker to repair that machine. Usually, maintenance worker doesn't willing to change original schedule flexibly if it's not urgent such as facility failure.	Quality management service can deliver message to maintenance management service via application collaboration manager.	Notification to Maintenance management service is done automatic manner.
Notify to mechanic on change of maintenance schedule.	Since the contact for maintenance is usually done by call, so mechanic doesn't know unless it receives call.	Mechanics receive change of schedule generated from maintenance management service automatically.	Mechanics can receive necessary information in real-time. It implies that response time is reduced.
Facility status update	After repair work is done, resource status update is done by manual input.	After repair work is done, then it's not necessary to manually input because status update is done by data synchronization manager when repair work is done.	Status update is done automatic manner. So, corresponding facility can be reflected in next operation schedule faster than as-is model.

Tab. 3: Advantage of the Smart MES compared with current MES.

Conclusion:

In this paper, we described the problem for current MES system by pointing out lack of environment for analysing and interpreting, collecting shop floor data in real-time manner. Even though many researches try to solve these problems, they didn't deal with collaboration among various MES functions. To solve above issues, System of interest named Smart MES is defined and requirement and design consideration is defined for architecture design. Operation scenario making use of Smart MES is introduced to show the validity and usefulness of smart MES against current MES.

The developed works in this paper can be utilized as base framework for development. Further research is needed to establish and apply data model to the Smart MES architecture to ensure that data flow among various components can be shown. Detailed functions of smart MES can be elaborated by developing data model in Smart MES since data model itself represents physical entity, logical relationship among data, concept. Furthermore, since the Smart MES system is a huge system, full implementation of it will take time to realize. So, system for illustrating core functions of smart MES is under development.

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