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A Study on the Development and Effect of Smart Manufacturing System in PCB Line

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Abstract

A production system is a management system that supports all activities to perform production operations at the manufacturing site. From the point-of-view of a smart factory, smart manufacturing systems redesigned the concept of onsite production systems to fit the entire system and its necessary functional composition. In this study, we select the key functions needed to build a smart factory for a PCB line and propose a new six-step model for the deployment of a smart manufacturing system by integrating essential functions. The smart manufacturing system newly classified the production and operation tasks of PCB manufacturing and selected necessary functions through requirement analysis and benchmarking of advanced companies. The selected production operation tasks are mapped to the functions of the system and configured into seven modules, and the optimal deployment model is presented to allow flexible responses to the characteristics of the tasks. These methodologies are first presented in this study, and the proposed model was applied to the PCB line to confirm that they had significant changes in the work method, qualitative effects, and quantitative effects. Typically, lead time and WIP have reduced by about 50%.

Keywords

Effectiveness Evaluation, Key Function Extraction, Manufacturing Execution System, Smart Factory, Smart Manufacturing System, 4th Industrial Revolution

1. Introduction

A manufacturing execution system (MES) provides the required information to conduct the productive activities optimally until planned or until the production of the ordered products is completed, directs the factory activities with accurate real-time data, and supports decision-making in real time. Further, it gathers data from a series of products production processes, from the production plan of a field to shipment, and then monitors the productive activities. It can be defined as a system that traces and controls the processes through the advanced prevention approach and real-time collected data of possible problems [1]. As this study is about building of MES, it is presented the small and midsize manufacturing of simple building of MES using Excel VBA, the MES building strategy and effectiveness analysis of small and midsize manufacturing [2], and system building of manufacturing execution of digital factory based on PLM. Further, the contingency dispatching method of semiconductor processing line is also reported,

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capability comparison of management using the statistical process control (SPC) technique to monitor the change in production process, the study about sampling of main equipment factor to improve the product quality and maximize operating rate [3], and many studies related with printed circuit board (PCB) manufacturing are reported. However, these studies consist of only part functions of most manufacturing system or focus on the method of technical structure of the system, and mostly include the content about some part of module.

Moreover, it does not suggest how does it connect with the most important equipment of the field and collect the information, how does it control at a high level. Moreover, no prior research has been conducted on the required functionality and overall system architecture in a smart factory [4]. Additionally, no prior study has suggested how the necessary functions are defined in a real manufacturing field, how they are implemented, how the working process of the production line changes by implementing this system, and the types of qualitative and quantitative effects achieved.

Thus, this study suggests a six-step smart manufacturing system deployment model. The manufacturing model in this study comprises of systems that consist of seven modules that are required in PCB manufacturing and production control, and provides information about the product, equipment, material, and field operators that constitute important resources in real time. Section 1 examines the current status and problems of existing MES systems. In Section 2, the strategy and implementation process of smart manufacturing systems is divided into sections and divisions for the production operation of PCB manufacturing, and their requirements are analyzed and classified according to their importance. In addition, through the benchmarking of advanced companies, the current and target levels were set for each major task and for selected important tasks. In this way, the system was designed and deployed by mapping the selected and important tasks to its functions using seven distinct modules. Section 3 describes the improvements of the working methods that were changed at the manufacturing site after applying the smart manufacturing system, and their effects.

2. Implementation of Smart Manufacturing System

2.1 Implementation Strategy

The smart manufacturing system model is implemented in six steps, as shown in Fig. 1. At Step 1, the target products are chosen to build the smart manufacturing system at the field. Step 2 defines and analyzes the problems after their collection and identification of their requirements onsite. At Step 3, the collected requirement subdivides into large and middle-level classes, and then estimates A, B, C grade according to the importance. In addition, the target level is set by assessing the current level based on major business groups compared to advanced companies. As such, the selected A-level task and items with a large difference between the target level are selected as critical functions that are essential to the site. Step 4 defines the optimal process by analyzing the work processes at the site in detail for each of the key functions extracted earlier. In Step 5, the tasks extracted above are mapped to the functions of the system to form major modules and design systems. In this way, the standard architecture of smart manufacturing systems is configured, and modules that are essential to production target products are selected and implemented. At Step 6, the implemented changing aspect of manufacturing field measures to analyze the result of the developed smart manufacturing system, and examines the qualitative and quantitative effects.

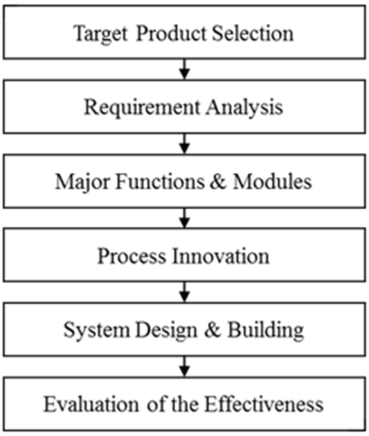

Fig. 1. Implementation strategy of smart manufacturing system.

2.2 Target Product Selection and Process Analysis

In this study, the competition among businesses of target product constructing smart manufacturing system is rapidly becoming fiercer, and it selects a PCB product progressing with high functionality.

A PCB consists of electronic components and is a circuit board that connects electrically through coppered circuit between components of single wires. The PCB process consists of copper clad laminate, drilling, copper planting, patterning, lamination, desmear, routing, bumping, and test process. At first, copper clad laminate is cut out by each product type and then is injected into process. Patterning is a process that forms a circuit that is needed on a substrate of raw materials. Copper plating is process of putting on conductor to attach with gap floors by process. Finally, electronic test process checks for circuit defects. It is currently on performance management in applying simple MES to all seven processes. About these processes, implementing the working equipment and input PC of MES are installed at the separate space, so operator fed the performance data into installed space of input PC after carrying out by each Lot working. Therefore, it is difficult to manage an accurate current status owing to the inconsistency between the recorded data of the process and the real products. It is placed in a difficult situation that per operator is in charge of many equipment which operate Lot return, working performance record of all sheets, PC data input of MES in field after working process and working complement. Thus, an analysis of problems and requirements at the site has resulted in many other problems in terms of manufacturing operation management, equipment engineering, quality control, raw material management, production planning, and master data management (MDM).

2.3 Requirements Analysis

About 90 items of requirement regarding production system of current many classes users are collected. Based on each task, they are divided into right high category (class 1) of manufacturing operating management, equipment engineering, quality control, subsidiary material management, production planning, MDM, and then they are classified into middle category (class 2) of 40. That is, we analyzed the tasks required to manufacture PCBs and the newly defined classification systems classified based on the majority of tasks and divisions. This classification establishes an operating system based on the activities required in the manufacturing of PCBs. That is, necessary functions of PCB manufacturing are defined as high and middle categories, and it suggested representative function among requirement of users of all 90, as presented in Table 1.

Table 1. Requirements analysis

Class 1	Class 2	No.	Function	Description	Rating
Manufacturing operation management	Lot management	1	Lot information	Automatic recognition of Lot input, start and end	A
	Lot traceability	2	Lot traceability	Lot progress history management	A
	:	:	:	:	:
Quality control	Process control	15	SPC	Detection and control of quality abnormalities	A
	Yield analysis	16	Detailed quality control	Monitoring and analyzing process critical factors	A
Material management	Material management	17	Raw material management	Raw materials inventory management	B
	Material performance	18	Materials usage performance	Management of raw materials usage performance	B
Production plan	Scheduling	19	Scheduler	Process and input scheduler	A
	Dispatching	20	Dispatcher	Dispatch of job priority by equipment	A

2.4 To-be Process Design

Ideal building of smart manufacturing system is most desirable to apply about all line process, but only positively necessary process can select with regard to achieving a maximum of effectiveness at a minimum cost. In this study, it selected 15 important processes in detail based on the requirement of user and the problem of analyzing field management in unit 2.3, as shown in Fig. 2. It is fundamentally designed to be entered as input and complement a significant amount of equipment information, used subsidiary material information, fair quality of product, and defect information automatically through bar cord scanning or equipment interface in selected process. These process equipment classify as all important, and implement state of equipment, equipment condition, and parameter through equipment on-line in real time. Further, it installs the input PC of operator at each equipment in process, so the operator enables easily to enter and check the information on touch screen.

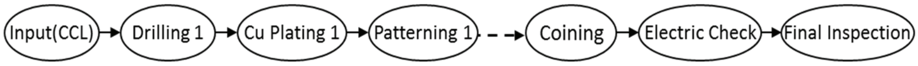

Fig. 2. To-be process.

2.5 Major Function Extraction and Process Innovation

To extract the important functions, the various functions, classified by medium level in 2.3, are rated by the degree of A, B, and C, based on the importance of manufacturing and effectiveness (Table 1). The rating evaluation criteria are based on whether the work is necessary or additional work is required to process products, and on whether the applied change of the work method is effective. That is, the function of A degree means it is essential in manufacturing the PCB products and effective in modifying the working method. Additionally, the B-level functions are essential for machining, however, when working methods are changed, they are less effective. Other additional functions are for C-level functions. In addition, from a system-by-system perspective, the target level to be achieved was newly set-up by diagnosing the current level of the company compared to advanced companies (refer Fig. 3).

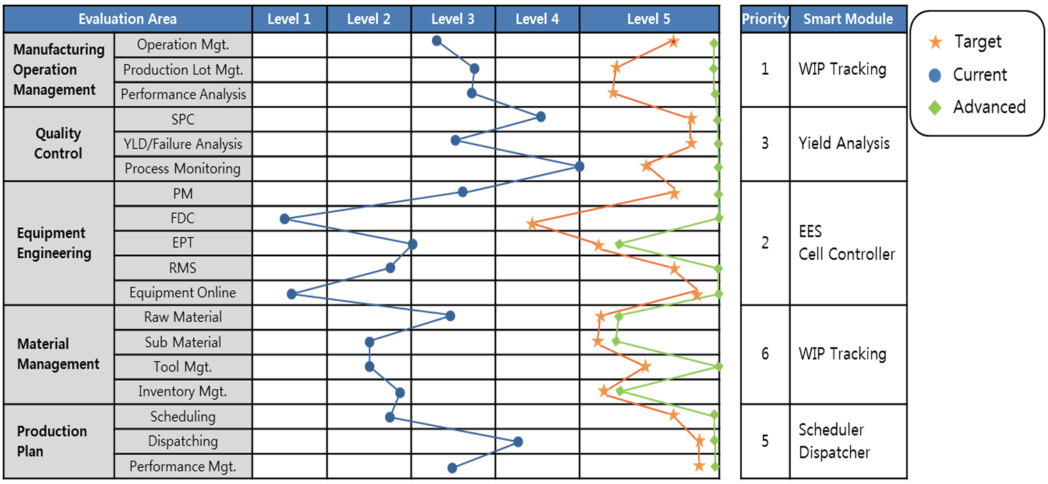

Fig. 3. Key function extraction of smart manufacturing system.

2.6 System Design and Implementation

Production systems are commercialized with products specialized many companies for each function, and most manufacturers use these commercial products. However, some companies have developed and operated their own necessary functions of the production system to maintain their production know-how. In any forms, it is true that there are many problems in terms of cost, performance, and field applicability in each industry. Functionality is also temporarily developed and applied in accordance to the needs of the site. Correspondingly, required functions from the perspective of the entire smart factory have not been properly developed. Thus, smart manufacturing systems consist of seven modules, which are selected throughout the process described in Section 2.5 (Fig. 4). Also each module uses commercial products that are most specialized for its own functions. Alternatively, the site-specific functions are developed on their own and the overall architecture is constructed to be compatible with each module. When using commercial products, the products are selected based on applicability of application offered, investment costs, verification on the field, and continuous development potential. Conversely, yield analysis (quality control), raw material management, and cell controller functions that are specialized for PCB processes, are developed separately to form the entire architecture, whereby each module is configured for compatibility. Equipment, material handling, and inspection/measurement control of the site shall be built as the characteristics of the line. The DBMS uses Oracle-Unix, institutional interception communication is RS-232C, and field equipment and server-to-server communication are applied by TCP/IP. Fig. 4 shows the final complete application architecture and its configuration is largely divided into three areas of production information management, production control, and equipment engineering. Modules developed by in-house system and the packages used by each module are expressed separately.

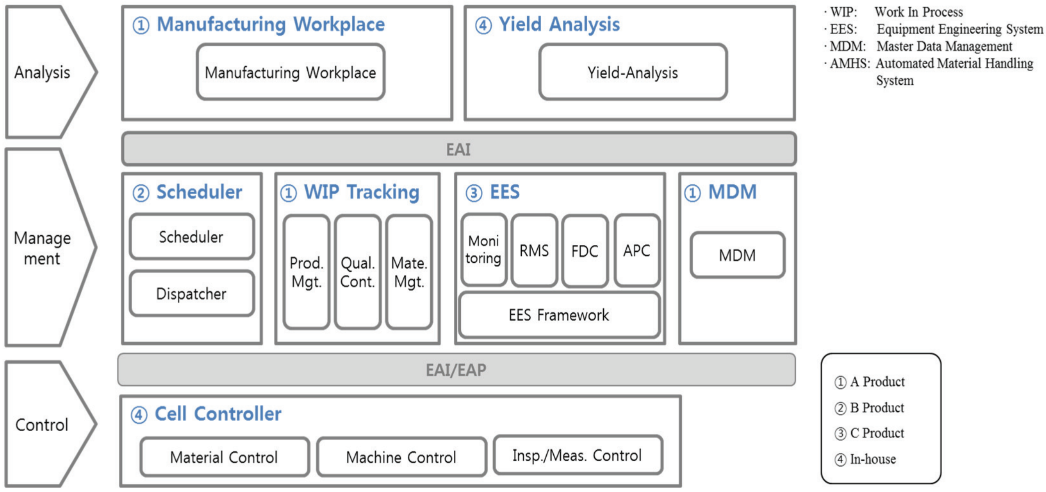

Fig. 4. Application architecture.

2.7 Implemented Appearance

Fig. 5 shows the implementation of the Scheduler (Dispatcher) module, one of the seven modules in a smart manufacturing system. Before the system was used, operators randomly decided to prioritize work and place product lots into the installation schedule. However, after applying the Dispatcher system, the work was executed according to the priority given by the system, thus displaying the overall operation status by equipment, waiting status, and task priority. It can also identify the operating Lot and the waiting Lot for each major equipment. Prior to the application of the dispatcher system, the operators prioritized and placed Lots randomly, which made it impossible to consider the balance of the before process and the after processes. The scheduler/dispatcher rule adjusts the priority according to the operation policies of the line, such as production volume, efficiency, and delivery time, and gives instructions for the work.

Main List | Dispatching List | Undispatching List | Loading Into

Red: Hot Lot		Yellow: Delay Lot		Blue: Reservation Lot		Bold: Change Conditions	
	Equipment	Working	Waiting 1	Waiting 2	Waiting 3	Waiting 4	Waiting 5
1	SHT M/C2	FK5E05A475	BK5705A475	IK5321A476	JK4L10X226	CK3831B475	HK1205X105
2	SHT M/C3	EK1405A475	BK5705A475	IK5321A476	JK4L10X226	CK3831B475	HK1205X105
3	SHT M/C5	HK1N10B105	CK3831B475	BK5705A476	JK5321A476	JK4L10X226	HK1205X105
4	SHT M/C6	MK9B03A104	BK5705A475	IK5321A476	JK4L10X226	CK3831B475	HK1205X105
5	SHT M/C7	K5T105A105	HK1205X105	BK5705A475	IK5321A476	JK4L10X226	CK3831B475

Fig. 5. Dispatcher user interface.

3. The Effects of Smart Manufacturing System

In this section, we analyze how the process of working at the manufacturing site improved after applying the smart manufacturing system, and discuss the performance by dividing it into qualitative and quantitative effects. The construction of smart manufacturing systems for one PCB line takes about 12 months, including the pre-analysis and stabilization period, and the input cost depends on the size of the line and the capabilities it implements. The changes at the manufacturing site before and after the introduction of a smart manufacturing system were compared in terms of production plan, manufacturing operation management, quality control, and equipment engineering management, based on the tasks performed on the site. We have identified that there are significant changes in the system's work done by people in each job. Thus, a smart manufacturing system has been established and applied to secure a foundation for increasing competitiveness in the production of highly value-added PCB products and manufacturing of PCBs. As presented in Fig. 6, the quantitative performance indicators were compliant with customer due dates, reduction of lead time and re-processing, reduction of manual sheet preparation and human error, and improvement in time to input data. In the case of manual sheets, the site has manually created hundreds of sheets for each process, including work log, quality card, Lot card, and raw material management log; however, this time, it saved about 50% of the sheets.

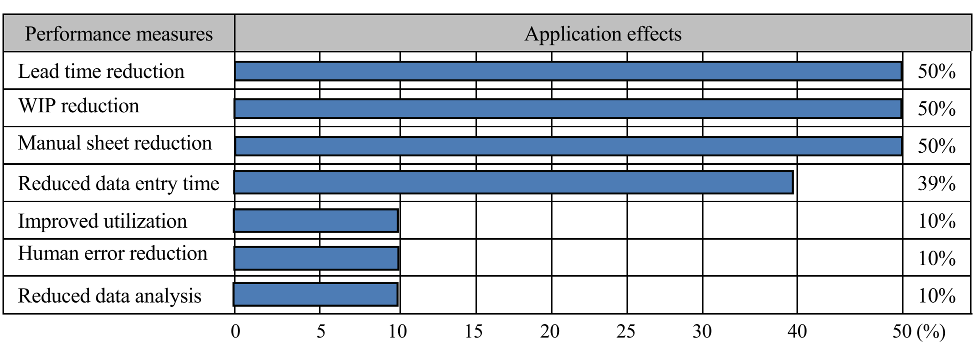

Fig. 6. Quantitative effects of applying a smart manufacturing system.

4. Conclusion

In this study, we have proposed a new six-step model for the deployment of a smart manufacturing system by selecting key functions and by integrating essential functions for a smart factory construction on a PCB line. The smart manufacturing system is defined by dividing the work of PCB manufacturing sites into sections, divisions, and by establishing the current and target levels through the benchmarking of the field/advanced companies. The selected functions were consisted of seven modules to present the optimal deployment methodology that can be flexibly responsive to the characteristics of the business.

The models proposed in this work were implemented and applied to PCB production lines to confirm that there were significant changes, qualitative and quantitative effects of working methods that were transferred from the actual equipment. Further research into smart equipment management systems and smart manufacturing systems should be conducted in order to implement custom manufacturing at the production site in line with the emerging fourth industrial revolution.

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