A STUDY ON E-ORIENTED ENTERPRISE MANUFACTURING EXECUTION SYSTEM BASED ON RFID AND INTERNET

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Abstract: The automation and integration in an enterprise has become more and more important, and radio frequency identification system (RFID) has caught great attention in this area. RFID system is not only on-site management tool, but it associates with manufacturing control system, material control system, warehousing management system and customer service management system. It can more accurately grasp manufacturing resource and the production line information. This study, from the manufacturer's view point, builds up a simulated e-factory containing three processing stations, one warehouse station, one packing station, and one transport station, with RFID using remote mechatronic control technology to collect manufacturing information. This e-factory utilizes distributed control technologies with the help of RFID to set up an internet-based real time monitoring system, including remote online user management interfaces, the internet-based manufacturing execution system, and database management of purchase order, material inventory, and manufacturing process. The developed system can be used as a reference for the industry to introduce RFID system.

Keywords: e-factory, radio frequency identification system.

I. INTRODUCTION

Twenty one century is an electronic century (e-century), from e-Commerce to e-Management; hence, the promotion of e-operation in an enterprise is a mainstream. Along with the progress of information technology and internet, the e-oriented concept in an enterprise has been widely applied to any corner of the enterprise. In an e-enterprise, the business operating person can communicate with customer and supplier through internet so as to complete online transaction and to share the information of all the partners within the supply chain. The internal side of the enterprise will coordinate and perform data sharing and cooperation through network and information system. Under such fast and correct environment of information propagation and application, all the industries have to seize effectively operation schedule and respond quickly to customer need so as to enhance enterprise's competitive advantages.

Moreover, due to the globalization trend of business operation, and to cope with the short delivery period, low price, high quality and small quantity and diversified product characteristics caused by short product's life cycle and low price trend, the on-site management of the supplier will have urgent need on information system to seize all the manufacturing dynamic information in time so as to enhance the manufacturing efficiency. However, before turning all the processes into electronic data in an enterprise, it is needed to turn the processes of a factory within the enterprise to electronic data, that is, the manufacturing information within the factory should be digitalized first in designing product, transferring the purchase order, purchasing the components, monitoring the process, performing remote repair, maintenance and diagnosis, etc. Meanwhile, the factory information is made more transparent so that the decision level of the company can fully seize the situation in the production line. In recent years, lots of enterprises have put their resources on the so-called B2B and B2C business models. The core "factory" that really manufactures the product, instead, is excluded from the network resource. However, if we take a look from business administration's viewpoint, in order to reinforce the competitiveness of an enterprise, mere B2B is not enough, B2B and F2B (factory to business) must go together, assist each other, and become indivisible.

The concept of e-factory is the association of automatic control of process with network, and it makes the factory information be able to be shared so as to achieve the goal of F2B [1]. Enterprise resource planning and integration usually has its focus on the construction of B2B and B2C. Although it can promote the communication and link of the downstream of the supply chain for enterprise to enterprise and enterprise to customer, and it can also reduce lots of unnecessary expenditure in order to reduce the cost and to increase the business opportunity [2], yet, without F2B link, product manufacturing information cannot be transferred to the hands of sale personnel quickly and correctly. Hence, the enterprise might make wrong judgment while they are getting the purchasing order.

In "U (Ubiquitous) Taiwan" plan [3], the most updated radio frequency identification system will be used. The application scope of RFID technology can be more extensive, and more ubiquitous. It can be further associated with digital family, internet, wireless network and equipment; hence, it can be used in new integrated technological applications such as remote medical care, safety surveillance, digital entertainment, vehicle navigation, electronic cargo, medical waste tracking, the customs clearance

of luggage in the airport, etc.. That is, it has unlimited business opportunities.The globalization era has come, and three flows of cash flow, logistics and information flow have become more important. In the logistics field, how to enhance the information integration capability of the supply chain so as to improve the logistics efficiency and to reduce the logistics cost is thus a very important topic. Hence, lots of new technologies have been developed to improve the efficiency of the supply chain. Market environment is changing quickly, information technology is under fast development, and manufacturing method and concept has to be updated constantly too. In order to use limited resource to enhance the competitiveness effectively, the automation and integration of enterprise is more and more important. Currently, in the field of factory automation, the use of RFID system has caught the attention especially. Under the allocation of RFID system, process can be appropriately planned, can be assisted by RFID, and then can be associated with constantly updated computer software application and management technology. Eventually, manufacturing and management function can be better exploited.

Currently, RFID system is not only the on-site management tool, but also is associated with manufacturing control system, material control system, warehousing management system and customer service management system. Through tight computer network connection, the rough traditional process flow card and barcode system is replaced, and lots of unnecessary labor, material and time are greatly saved and reduced. Hence, the manufacturing resource and the production line information can be grasped more accurately, and eventually the logistics and information flow within the factory can be associated. Since most domestic and foreign enterprises have the applications of the introduction of RFID system limited to the supply chain [4-5], logistics center, and retail suppliers, the application of RFID system to the setup of e-factory teaching system is introduced in this study, from the manufacturer's viewpoint. The setup method of RFID reader in the manufacturing process is introduced; meanwhile, real examples are used to describe the issues that might be faced during the reception, storage, and application of the manufacturing information. In other words, the application of RFID system in the manufacturing industry is studied, and it is hoped that the study result can be used as reference by the industry in the introduction of RFID system.

II. RFID

The development history of RFID technology can be dated back to airplane friend or foe identification system in World War II. Although it has several decades of development history, yet it has caught the attention of people only in recent years [6-7]. In one aspect, it originates from the breakthrough in RFID chip manufacturing technology, which makes RFID cost be able to reach the massive utilization scope; in another aspect, it is due to the pressure and demand to find new technology for the supply chain integration issue faced by the industry. However, to the supplier, the cost of RFID label is added, and if it cannot be associated effectively with its own logistics procedure, it could instead weaken its own competitiveness. Hence, for most American enterprises, in addition to the initial following of the trend and the formalized utilization of the RFID label, they start to think about, after the introduction of RFID technology, how to adjust themselves and take good use of the technology so as to create more benefits.

RFID is sort of wireless radio frequency identification technology. It is an architecture formed by the serial connection of Reader, Transponder or Label and Middleware & System Integration. In its action principle, Reader will emit first wireless wave of specific frequency to the label to drive the label circuit to send back the information within the chip, Reader can then receive the data [8]. The main objective of the system, in addition to transfer data through the label, is, at appropriate time and location, to use non-contact data transmission method to acquire data so as to satisfy the specific need of the product application. Moreover, the data stored in this label can be used to identify lots of objects, for example, objects that are still in production, merchandise in transport process, location, vehicle identification certificate, animal or even humans can all be identified through this label.

Through the attach of RFID label on the product, the enterprise can count the product in the warehouse or sale store through one set of Reader, inventory can be managed, and the expiration date of the product can also be checked; meanwhile, when it is attached on the money or bank card, it can prevent the counterfeit issue. Other applications include luggage, mail, package, medicine and valued financial bill, as long as RFID label is attached, its flow direction can then be well seized.

RFID label can be attached in all kinds of products, personnel and vehicles, the object status can be updated in real time, providing useful tracking and management function. In addition, in accordance with the positioning need, RFID can provide real time tracking usage according to the location record that is read. Some forms of RFID can be used for repeated reading and writing and utilization, and its memory can store the key data of the object. Then as the object moves, the data and information moves along too, which provides portability characteristic of the data. RFID has extensive application, and the most commonly seen ones are access control, property recycling, product management, material treatment, waste treatment, medical application management, traffic and transport application, security application,

animal monitoring, automatic control and the transportation ticket-card, etc.

Radio frequency identification system can realize the real time monitoring of all the processes of product from raw material, semi-product, transport, warehousing, distribution, rack-loading, final sale or even the product returning treatment. It not only provides automation on the manufacturing order, but also greatly reduce human error rate, and eventually product information transparency and management efficiency can be greatly enhanced. Wireless radio frequency identification technology can provide high efficiency in the raw material transport, can improve the production capacity planning and can reduce inventory loss and theft risk in the manufacturing industry. Meanwhile, it can also make the manufacturing process more efficient and flexible but the product quality is still ensured. The in-time and reliable enterprise information generated by wireless radio frequency identification technology can enhance the manufacturing capability of the manufacturer, it can process in time the continuous work flow, and it can also manage the inventory and distribute the resource so as to create a pull type manufacturing enterprise that is driven by the demand. RFID label can store lots of related information of the product, for example, A manufacturer at B day and C site manufactures F type of E piece of product by D shift. That is, the information is not only the B type product manufactured by A, as marked in the current barcode.

Radio frequency identification system plays key role, for all the manufacturing processes from the entrance of raw material into the factory to the leave of the product from the main gate of the factory, in the application in manufacturing industry. Its application fields include the following.

2.1. Raw material management

The raw materials and components needed for the production should be attached with RFID labels. No need to open the external package of the product, the system can identify the content in the product box, and the related information of the raw material can then be acquired accurately and in time, e.g. type, supplier, manufacturing time, manufacturing location, color and size, etc. In this way, automatic product receiving and classifying, warehouse tracking and supplementing (viewing board system), and batch control can be performed immediately. Warehousing operation can be done more efficiently. Especially for food and medicine industry, material could easily get rotten or has expiration period issue, it can thus improve the material tracking, the material loss rate or expiration rejection rate can be reduced, and eventually the material cost can be reduced. In the property aspect, when the material enters the factory, the payment process can be driven immediately after the information on the label is read, the cash flow management can then be speeded up, and the receiving operation can be promoted.

2.2. Manufacturing management (Just in time manufacturing and tracking)

Modern manufacturing methods such as Just-in-Time (JIT) have higher and higher requirements on the communication and coordination of each ring in the manufacturing process. The loss of any ring might lead to the paralysis of the entire production line or even the entire manufacturing process. Therefore, how to manage and find out accurately raw materials with complicated spec and send it just in time to the production line puzzles not only the manufacturer of complicated equipment but also enterprise adopting streamline operation. RFID plays an important role in controlling manufacturing elements and components [9]. It can ensure sufficient supply of correct materials or components, and the supply can satisfy the manufacturing need at correct time and in correct quantity. Through the help of RFID, the automation in product management can then be realized, not only the product location is clear, but its quantity is also under the full control of the system. When the inventory level at any site is reduced to below the specific value, the system will then issue a product supplement command automatically, and it will then command the automatic viewing board system to start the material supplemental signal.

RFID can confirm the location of the product in process automatically and in time, and it can enhance material's transparency in the manufacturing site so that the management person and production control person in the manufacturing site can correct operation data that are more in-time, more correct and more detailed. Using these data, the management person can integrate the enterprise resource planning, manufacturing execution, and the management maintenance system. This not only creates better demand forecast, but also enhances the efficiency of the personnel, material, and equipment.

2.3. Quality control

RFID label of the product in process can be performed with real time data collection so that the manufacturing industry can improve and implement stricter and more continuous quality control activity, and it can also enhance the promotion of six sigma activity. For industry with products such as food and medicine that are good for only limited time, according to the expiration date of the product, product automatic alarming system or push type/pull type strategy can be performed so as to reduce rejected product and profit loss.

2.4. Returned product recycling management

Returned product recycling management is mainly the repair service when a customer returns the defective product to the original manufacturer. It

includes the communication and coordination for the return of the product, the arrangement of the repair process, and the on-time return of the product to the customer's hand. The final goal is to satisfy the customer. Through the function of the connection of RFID label to the historical data of the database, we can seize securely all the information of the product in the manufacturing process so as to provide the related information for the returning of the product for repair, and finally, we can have the product returned to the customer.

2.5. Employee identification and safety management

RFID can also be used to verify and check the identity of a person or an object. Its significant advantage is that its wireless reading way can greatly enhance the effective identification distance, which enhances more effectively the way to handle the related data; or we can say that for the response to special condition, more time can be gained in such situation.

2.6. Asset management

Effective utilization of expensive asset, equipment and related documents for the operation is the key factor to gain high efficiency operation, and RFID technology can help the company to track the container, tray and cart. Meanwhile, it can also be pasted on the tool and spare component so as to enhance the efficiency of the maintenance, repair and rework operation of the equipment.

RFID technology applied by manufacturing industry in the above mentioned management job can obtain the following benefits: improving the demand planning and forecasting; shortening the capital turnover rate period and reducing business operation capital requirement; increasing the labor productivity in manufacturing and assembling operation; providing stricter quality control and improving product quality; reducing the loss, waste (materials), and the rework; having fast and correct product delivery process to improve the inventory and transport management of the supplier; getting more accurate production planning and forecasting results; improving the process transparency and reinforcing manufacturing flexibility; making the receiving and product delivering process more efficient; providing fast and correct service to acquire higher customer satisfaction; enhancing the tracking capability from the raw materials; providing fast and correct product recycling management; tracking and identifying parallel importing product and fake product.

III. E-FACTORY SYSTEM CONCEPT

Traditional information technologies have their applications in the manufacturing system focused on two stages of planning layer and control layer. The planning layer, formed by advanced planning and scheduling system (APS) and enterprise resource planning (ERP) system, is in charge of Master Production Scheduling (MPS), Material Requirements Planning (MRP), Capacity Requirement Planning (CRP) and production scheduling planning within the enterprise, and it arranges the processing order of sending the purchasing order to the manufacturing resource. The control layer is the control of the automatic manufacturing equipment in the control site through the computer and programmable control system in each plant as commanded by the manufacturing control system. Although two information systems of planning layer and control layer have mutually dependent relationship; however, if we take a look on the characteristic, we can see that planning layer has emphasis on customer satisfaction, but control layer emphasizes on the process performance. That is, the data characteristic is totally different to each other; hence, when the system is in real operation, they are mutually independent to each other. For the manufacturing process of products in the manufacturing site, the related personnel should follow the items in the production order, within the scheduled product delivery date of the purchase order, and use automatic manufacturing equipment, accompanied with the processing operation provided by appropriate equipment and personnel on the raw material, to produce product that meets the spec and quantity in time. The manufacturing information in each process is entered into the information system by hand or by report list; hence, there is no just-in-time communication channel between the planning layer and the on-site manufacturing control system. Since there is no on-site just-in-time feedback manufacturing information, the business operating personnel cannot fully seize the manufacturing activity in the manufacturing site; hence, to the manager, the on-site activity is like a black box operation. Moreover, the on-site manufacturing equipment, due to incompatibility of information format of different plant, cannot be integrated effectively.

In order to let the on-site manufacturing activity can be smoothly implemented by the control layer according to the plan, the MES (Manufacturing Execution System) in the implementation layer, in the information system of e-oriented enterprise, will play the key role to integrate the information flow and material flow [10], that is, it will be in charge of implementing and monitoring the manufacturing commands as generated by the upper layer planning system, Meanwhile, it will coordinate, control and monitor all the manufacturing equipment and activity in the control layer manufacturing site [11-12].An enterprise constructs Enterprise Resource Planning (ERP) system to be connected to other related information system to form a supply chain management information system. MES system seizes

real time manufacturing information. It provides manufacturing situation and quantity and information for ERP to calculate the manufacturing cost, and it is connected to customer relationship management system to provide information related to product warranty and customer service. To the external side, it uses EDI, WEB and B2B technology to connect the supplier and the customer system into a complete enterprise information platform. MES system is the core system of the e-factory, and it has functions such as manufacturing process control, process interlocking, just-in-time on-site management, on-site information tracking; meanwhile, it also provides related information to the customer. The e-factory system built in this study includes customer information management, purchase order management system, product data management, production scheduling, radio frequency identification system, raw material warehousing system, automatic transport system, manufacturing system, graphical process control, product-in-process tracking, quality inspection system, wireless network monitoring system, on-site information monitoring system, packaging system, and customer information system. The basis of the entire system is controlled by the RFID label attached on the work object and programmable logic controller (PLC) so as to achieve the functions of online real time information collection, arrangement, analysis, monitoring and tracking.

In this study, the above mentioned MES system of e-factory is used as an architecture, accompanied with information system and network monitoring technology, to develop e-factory teaching system that is based on portable device (PD) and internet. The system can feedback the on-site processing information to MES system, and these feedback information is used as initial information for implementing MES system, then through the use of advanced internet technology, different transmission information are sent to this module together, it let the user can, through the browser of a computer or PD, acquire the on-site processing information. Practically, manager, sale personnel, production control personnel and maintenance personnel can, at any time and any location, understand the manufacturing situation and product inventory quantity through the computer or PD in very quick way. It reduces the delay and barrier of layer and layer of communication, and the factory information can then be shared directly to the entire supply chain cluster. Meanwhile, it also provides fast response basis for the enterprise, and this information is connected to the enterprise network resource such as ERP and SCM software. It not only can reduce the enterprise operation and purchase cost, but also can feedback the market change to the manufacturing and production system so as to enhance the flexibility and competitiveness of the enterprise.

By extending the technology used in the Web-based PLC Lab [13] and integrating RFID system, we can build an e-manufacturing factory that performs e-commerce and manufacturing automation all together through networking. Figure 1 shows the miniature manufacturing system in our Lab [14]. that consists of three manufacturing stations (A/B/C), one storage station, one inspection/packing station, and one robot arm for conveying raw-materials/semi-products/ products.

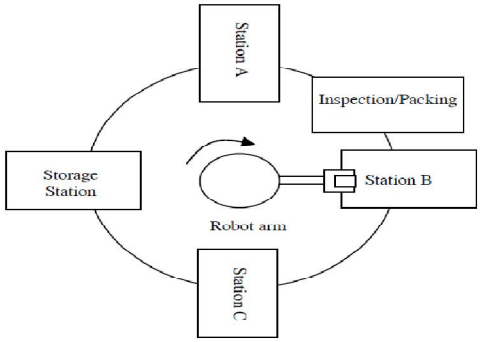


Fig. 1 Miniature e-manufacturing system

Figure 2 shows photos of those stations and robot arm in Fig. 1. These stations and robot arm are controlled by programmable logic controllers (PLC). The raw materials are stored in the storage station and conveyed one by one to one of the manufacturing stations (A, B, or C) according to the order determined by the scheduling program or by the user defined schedule. Different manufacturing station produces different semi-products or products. For instance, product type 1 can be made by station A, type 2 by station B, …, type 4 by stations A and B, etc. Therefore, with this system we can produce 7 different types of products. In order to keep tracks of all manufacturing information of each product, RFIDs are used. Shown in Fig. 3 are RFID tag and RFID reader. A RFID tag is attached to each raw material (object) and a RFID reader/writer is implemented on each station to read and process manufacturing data from the tag on the object, and record data back to the tag.

A software program is developed for users to place/manage orders, to alter the ingredient of products, and to specify manufacturing schedule through remote PCs or mobile devices. On site manufacturing data are collected by RFID and sent to the network via PLCs. Main controller/DDE server and other remote PCs/PDs can access these data through the network.

Figures 4-5 are the graphical user interface (GUI) on the PC developed for the presented e-factory. Figure 4 is the main GUI from which the user can access to any other sub-GUIs such as GUI for manufacturing station (A, B, or C) shown as Fig. 5. Figure 6 shows some e-factory GUIs on PD. The users can acquire the data of the e-factory and control it all through Internet.

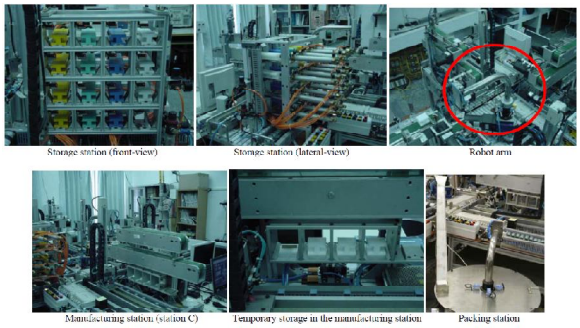


Fig. 2 Photos of stations in the miniature e-manufacturing system

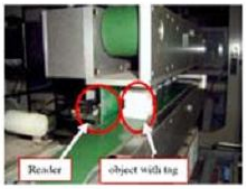


Fig. 3 Photos of RFID tag and reader



Fig. 4 GUI of e-factory



Fig. 5 manufacturing station



Fig. 6 GUIs on PD

CONCLUSIONS

This study applies RFID technology to unmanned e-factory, and the obtained actual benefits are as follows:

1. **The re-identification capability of the level of processing of the object to be processed.**
   Due to the data portability of RFID Tag, we can plan all the data of object to be processed and place them in the Tag, and the equipment then, through RFID Reader, reads the parameter data stored in the Tag so as to perform the related procedure.
2. **Independence of manufacturing equipment**
   In the past manufacturing identification system, no matter barcode or other method is used, the manufacturing equipment still has to be communication-connected and to communicate with the back end database because the identification unit provided only provides unique identification (UID), which does not have change function. When the database is in error or when the communication is interrupted, the manufacturing equipment will then be stopped, causing all the operation lines to stop. On the other hand, RFID Tag is a data unit itself and can store purchase order, product code, and related manufacturing parameter. Through the RFID reader, the equipment can get the related manufacturing parameters and perform the manufacturing. The manufacturing equipment thus has independent characteristic.
3. **The capability for semi-product to enter again into processing process**
   Since RFID Tag has the readability characteristic, when an object to be manufactured passes certain process, it can then record the manufacturing process in the Tag. This process can not only provide a reference for the quality inspection unit for quality control and inspection, but also be used as basis for lost semi-products caused by external factor or human factor to go back to the manufacturing process and to complete the process action.
4. **The increase of system stability**
   Before the introduction of RFID, the calculation and process judgment unit of the system is done by a computer. Data and command are sent through computer network. At the same time, this computer has to be in charge of all the control actions such as: warehousing, transporting, processing A/B/C stations, and the quality inspection station. When this host computer is paused due to all kinds of factors (machine stop or down, communication interruption, logic error, etc.), all the manufacturing equipment will stop accordingly. After adding the RFID mechanism, the original computer host function is simplified from the original monitoring/operation/judgment/ control to mere monitoring function, and the original operation/judgment and control will be handed over to the PLC of each station for independent handling; and the handling basis is to perform calculation and judgment according to the Tag content as read by RFID reader. Hence, the system and equipment stability is greatly enhanced, and each production line can operate independently and will not be influenced by other production line.

To sum up, this study, from the manufacturer's viewpoint, has introduced the application of RFID system in the setup of e-factory teaching system and the RFID Reader setup method in the manufacturing process, etc. In other words, this study has investigated the application situation of RFID system in e-factory, and it is hoped that the result can be used as reference by the industry for the introduction of RFID system into the company.

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