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RFID-Based Manufacturing Execution System for Mould Enterprises

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Abstract: According to the problem that it's difficult for mould enterprises to manage and control the production process accurately by using the current manufacturing execution system, the radio frequency identification (RFID) technology was introduced into the manufacturing execution system. In this paper, a RFID-based manufacturing execution system is proposed for tracing and managing the real-time manufacturing process of mould. The framework of RFID-based manufacturing execution system for mould enterprises was established, under this framework, the key technologies including RFID-based shop-floor model of mould enterprises, information fusion model for real-time monitoring, objective function of dynamic job shop scheduling were described respectively. Finally, through the research and application of the system, a novel mode was provided for manufacturing process management of mould enterprises. *Copyright © 2013 IFSA*

Keywords: Radio frequency identification (RFID), Active perception, Manufacturing execution system (MES), Mould enterprises.

1. Introduction

Global supply chains, market fragmentation, mass customization and shorter product life cycles have scaled up competition among enterprises. In such a situation, mould enterprises face both rare opportunities of development and grave challenges. Mould enterprises are typical one-of-a-kind and make-to-order enterprises [1], and its production process is hard to control and manage. In recent decades, Manufacturing Execution System (MES) was introduced to mould enterprises to control and manage mould manufacturing process. An MES is the main software production management tool between production planning at the company management level and control/automation systems at the shop-floor level [3]. MES mainly concentrates on managing shop-floor operations such as scheduling as well as its execution and control, timely informing shop-floor supervisors in terms of equipment status, material delivery and consumption as well as manufacturing progress [2].

Many mould enterprises have got certain achievements by implementing MES. However, there are still some problems exist in traditional MES: 1) since all the moulds are one-of-a-kind and their statuses must be uniquely tracked on manufacturing shop-floor, data collection is significant when such enterprises contemplate to implement MES [4]. Unfortunately, the paper-based data collection system dominates in their manufacturing sites. As a result, production data are often incomplete, inaccurate and untimely. The paper-based system forces employees to collect production data manually and cannot address the disturbances of human factors effectively. Furthermore, the visibility and traceability of manufacturing items are so weak that the manager couldn't get the real-time production information from shop-floor. 2) The production process for mould is hard to be controlled because the manufacturing process is unstable and orders are unpredictable. In this situation, the operation plans is very important for mould enterprises. Based on the accurate production information and characteristic of mould enterprises, how to make optimized production plan is a key problem for mould enterprises.

In recent years, RFID (radio frequency identification) has attracted more and more attention of many researchers [13-15]. RFID is an automatic object identification and data collection technology that utilizes radio waves [12]. An RFID system consists of hardware, such as RFID tags and readers, and software like RFID middleware. RFID technology has had a tremendous impact on education, healthcare, manufacturing, transportation, retailing, services, and even war. In the field of manufacturing, a number of researchers have utilized RFID to improve the core activities of the manufacturing supply chain including production, warehouse and inventory management, distribution, and product life cycle management.

2. Related Work

Recently, more and more attentions have been paid to the application of RFID. Chen [5] proposes research on building intelligent transportation system based on RFID technology, and the experimental results show that the system can effectively improve the traffic situation. Hu [6] focuses on how to storage and management of RFID data and proposes a cubing method to manage RFID data, whose efficiency depends only on the size of path database. Yang [7] propose a new RFID intrusion detection method that is based on fuzzy c-Means clustering and which can enhance the security and speed up the intrusion detection of RFID systems without amending the existing technical standards of RFID. Kohn et al. [11] is an early piece of precious work in addressing repair-control of manufacturing systems using real-time RFID information. Chen [12] proposed an enterprises application integration framework based on RFID technology. On the basis of this framework he also presents a RFID-based standard operation procedure to configure a prototype system for a particular shop floor operation and an operator orientation for performing the corresponding tasks. Zhang et al. [10] present an agent-based workflow management framework for RFID-enabled real-time reconfigurable manufacturing. Fang [9] present an event-driven shop floor work-in-progress management platform for creating a ubiquitous manufacturing environment. The platform aims to monitor and control dynamic production and material handling through RFID-enabled traceability and visibility of shop floor manufacturing processes. Xu [8] focuses on how to explore the potential benefits of a RFID system and reduce the expenditure of RFID application. They propose an optimization method which are applied and verified in a coil warehouse and the result shows that the hardware investment is cut down by reducing the number of RFID cards and the warehouse productivity is improved significantly.

Currently, few studies have considered the application of RFID to mould enterprises or the integration of applications. Therefore, in this paper, we propose a RFID-based MES for mould enterprises. In order to facilitate the real-time data collection, RFID has been used to capture manufacturing data, aiming at real-time synchronization of physical flow of materials and associated information flow. Through data processing and fusion, we can obtain the real-time information of mould manufacturing process. Based on the information, we use a dynamic job shop scheduling algorithm to optimize production plan. As a result, the production process of mould could be controlled and managed accurately by implementing the proposed RFID-based MES.

The remainder of this paper is organized as follows: In Section 3 we describe a RFID-based MES framework for mould enterprises. In Section 4 we introduce RFID-based shop-floor and smart resource. In Section 5 an information fusion model for real-time monitoring is discussed. In Section 6 we propose an objective function of dynamic job shop scheduling which is suitable for mould enterprises. In Section 7 we exemplify how implemented RFID-based MES facilitate the daily operations of mould production. Finally, the generalization is summarized in Section 8.

3. RFID-Based MES Framework

As shown in Fig. 1, the framework of RFID-based MES for mould enterprises include three core components, namely RFID-based mould shop-floor, real-time production information collection and monitoring, and dynamic job shop scheduling. According to the characteristic of mould enterprises, attaching different RFID devices to corresponding production resources. Through the technology of perception and network the traditional resource becomes smart resource, and then the mould shop-floor becomes RFID-based shop-floor. In the operation of RFID-based mould shop-floor, production information collection and monitoring is very important for the enterprises. We monitor the whole manufacturing process of mould by automatic collecting, processing, and mining the real-time production information from multi-sources. Based on the real-time information monitoring, a scheduling algorithm module which aim at minimizing total penalty cost of delayed moulds is used to optimize production plans for this system. We can see that the three modules constitute a self-adaptive and closed-loop system for mould manufacturing process, and this kind of system framework can effectively control and optimize the production process for mould enterprises.

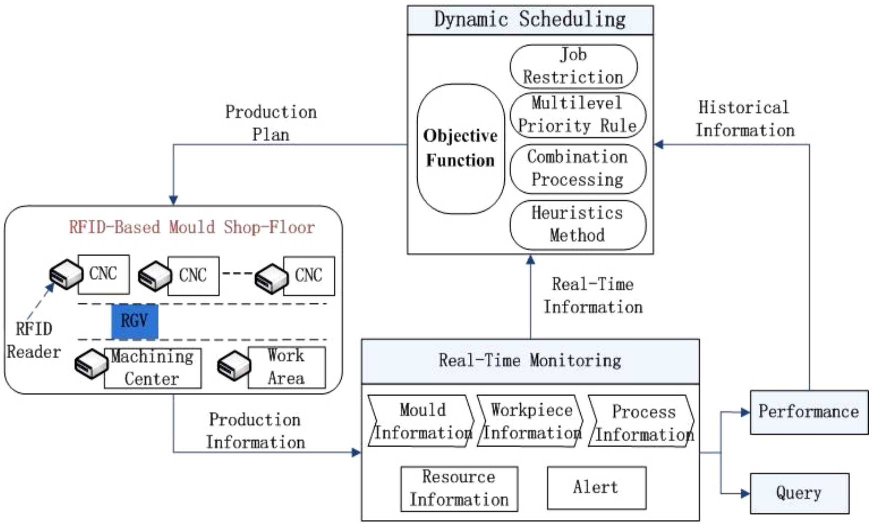

Fig. 1. Framework of RFID-based MES.

4. RFID-Based Shop-Floor of Mould Enterprises

The essential characteristic of RFID-based shop-floor is that manufacturing resources can interact and communicate with each other. Therefore, perception technology and intelligent devices are introduced to mould enterprises to make traditional resources become smart resources. Smart resources are able to contain detect, process and even reason with information about their statuses and movements, with the support of necessary back-end systems and infrastructure [14]. Typical manufacturing resources in shop-floor of mould enterprises include mobile and stationary assets (e.g. machines, conveyors), materials(e.g. finished products, workpieces, raw materials), spaces and location work areas(e.g. mould fitting area, mould assembly area), human resources (e.g. operators). In this research, when RFID devices (either readers or tags) are attached to these manufacturing resources, they become smart resources. As illustrated in Fig. 2, the smart resources in shop-floor and information systems have constituted enterprises level Internet of things (IoT) based on the RFID standards and perception technology. In other words, RFID-based shop-floor of mould enterprises has the ability to perceive manufacturing process and obtain the production information automatically.

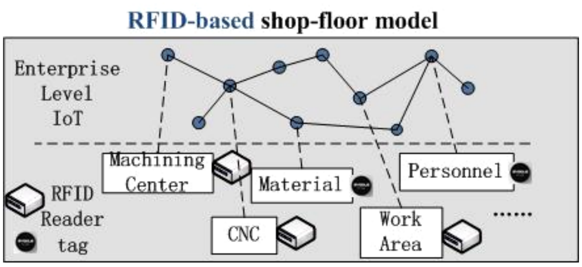

Fig. 2. RFID-based shop-floor model.

5. Information Fusion Model for Real-Time Monitoring

With the introduction of RFID and perception technology to mould enterprises, growing influx of RFID data will generated by active perception of smart resources. To cope with the real-time heterogeneous production data, we propose an information fusion model for handling, managing, and publishing the production information.

Raw event: In the environment of RFID-based shop-floor, when a RFID reader detects an entering tag, system will generate a raw event according to certain rules. In this research, the raw event is defined as:

<ID, EPC, Timestamp, RID, RSSI>,

ID means a 64 bit integer assigned by manager. EPC is a unique code of the RFID tag representing a physical object, and the coding can follow an industry standard (e.g. EPC Global). Timestamp is the time when the event happens. RID means the ID of the RFID reader which detects the tag. RSSI means the Received Signal Strength Indication of the tag when it is detected, and we can obtain the location information from RSSI. Raw event is the minimal granularity event in whole manufacturing process and other events are fused and transformed by it.

Key event: Through a series of data processing operations (e.g. filtering, smoothing), we can get the key node event which meet the requirement of the system.

Monitoring information: The monitoring information of production process of mould includes status of workpiece/mould, time node of key event, position of workpiece/mould, progress of workpiece/mould, etc. These kinds of information are generated by the key events through semantic transformation, information fusion, and event triggering.

The information fusion model based on the RFID is illustrated in Fig. 3, and the main roles of modules and other constitutes in the model are described in detail below:

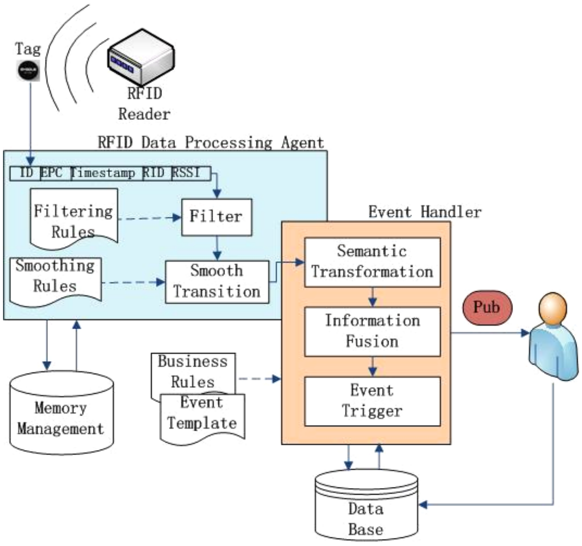

Fig. 3. Information fusion model.

Data processing agent: To reduce the hard-disk operations, we manage the raw events with a dynamic memory management method. Meanwhile, hash table data structure is used to store the huge amounts of data, and therefore performance of data insertion, updating, removal is enhanced. According to the defined rules of filtering and smoothing, the raw event becomes key event through RFID data processing agent.

Event handler: On the basis of event template and business rules, through semantic transformation and information fusion, the key event transforms into monitoring information and enterprises level event. When certain event is generated, the event trigger will traverse and match the multi-level information of the event and then update and release relevant information.

Information publishing: Through the real-time update of monitoring information by event trigger, the monitoring information is "pushed" to manager. Thus, we can monitor the production process of mould with the help of real-time production data.

6. Objective Function of Dynamic Job Shop Scheduling

Dynamic job shop scheduling plays an important role of MES for mould enterprises. The two existing problems in the traditional job shop scheduling are described as follows: 1) it can't guarantee accuracy and timeliness of production information collected by traditional MES, therefore the scheduling results don't coincide with the truth. 2) The objective function of scheduling algorithm can't meet the requirement of mould enterprises. On the basis of real-time production information collection and monitoring, an algorithm of dynamic job shop scheduling which aim at minimizing total penalty cost of delayed moulds is proposed.

Nowadays, with the improvement of technology and exacerbation of competition the production period of mould became shorter and shorter. Facing this kind of situation, mould enterprises must respond quickly to customer orders, and the key factor of response time is the delivery date of mould. Ideally, every mould should be delivered to customers in time. However, the enterprises can't meet the delivery date of all the moulds for various reasons. Thus, the objective of dynamic job shop scheduling for mould enterprises is minimizing total penalty cost of all the delayed moulds. Penalty cost incurred when planned finish date of a mould is later than its delivery date in agreement. And penalty cost usually depends on how much time you have delayed and the importance of the mould. For mould M_i, the delay time $TR(M_i)$ could be calculated as follows:

$$TR(M_i) = (PFT(M_i) - DT(M_i))^+ \qquad (1)$$

$PFT(M_i)$ means the planned finish date of mould M_i, and $DT(M_i)$ means delivery date of mould M_i. Delay time, $(X)^+ = \max\{0, X\}$ means if planned finish date is before or equal to delivery date, delay time is 0, otherwise delay time is the value between planned finish date and delivery date. The importance of the mould is expressed as penalty coefficient ω, and the penalty coefficient of M_i is ω_i, thus the penalty cost $PF(M_i)$ could be calculated as follows:

$$PF(M_i) = \omega_i \cdot TR(M_i) = \omega_i \cdot (PFT(M_i) - DT(M_i))^+ \qquad (2)$$

And the objective function of dynamic job shop scheduling could be expressed as follows:

$$\min : \sum_{i=1}^{N} \omega_i \cdot (PFT(M_i) - DT(M_i))^+ \qquad (3)$$

N means the total number of panned moulds.

7. Case Study

The development environment of the proposed system is briefly described below:

Operating Systems: server: Window XP, client: Window XP.

Database: SQL Server.

Programming language: Java2EE (Struts2, Spring, Hibernate).

Application Server: Tomcat.

RFID Tag: EPC Gen 2 passive RFID Tag.

RFID Reader: UHF RFID Reader.

Following the concepts and methodologies presented in the preceding sections, a demonstration system for managing and controlling the production process of mould enterprises is developed. The operation process of system is illustrated in Fig. 4:

Step 1: In the manufacturing environment of RFID-based shop-floor, the heterogeneous production data is collected by the RFID system automatically.

Step 2: Through the proposed information fusion model, the raw production data is transformed into the required monitoring information.

Step 3: Monitoring module can provide the full range and multi-level information of workpiece/mould, by which manager can control the whole production process of mould accurately.

Step 4: Based on not only a objective function which suitable for mould enterprises but also the real-time production information, the dynamic job shop scheduling module can make the optimum production plan for mould enterprises.

Step 5: The shop-floor begin a new task according to the plan made by the scheduling module. And the operation process returns to Step 1.

As shown in Fig. 4, the RFID-based MES is a self-adaptive and closed-loop system. With this operation process mould enterprises will effectively control and optimize the production process.

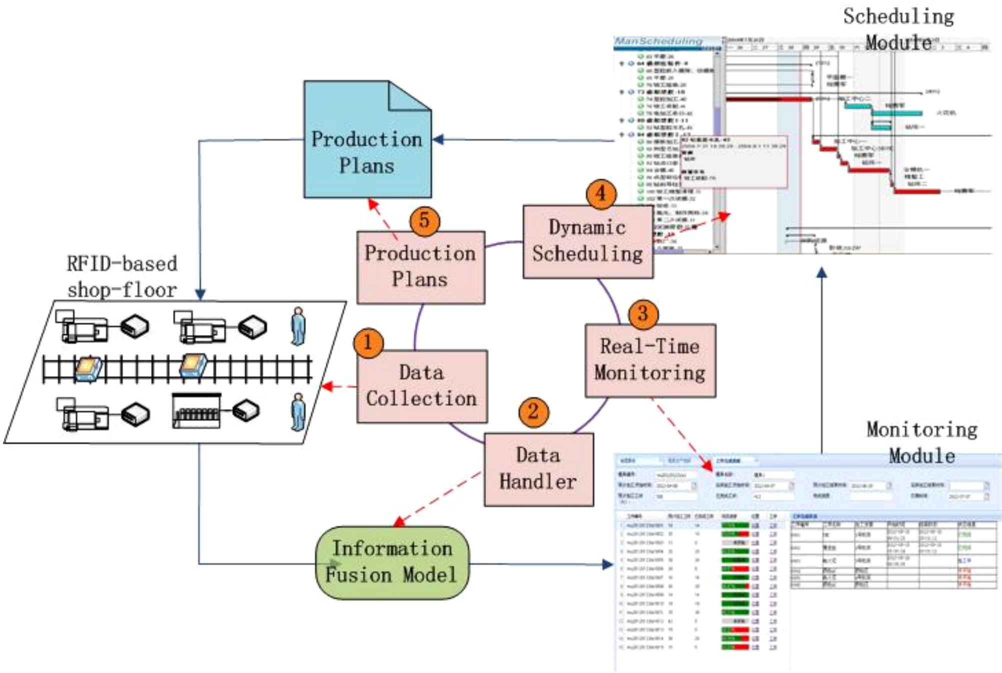

Fig. 4. Operation process of RFID-based MES.

8. Conclusions

This paper has presented a case study of applying RFID-based MES for managing and controlling the manufacturing process of mould. Based on the proposed framework of the system, we have introduced an information fusion model for real-time monitoring and Objective Function of Dynamic Job Shop Scheduling. Through the implementation of the proposed system, the enterprise achieved very good results in managing and controlling its production process. And the system also coincide the development direction of mould enterprises.

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