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RFID Integration for Material Management Considering Engineering Changes in ETO Industry

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Abstract. Radio Frequency Identification (RFID) is a type of auto-identification technique developed in 1950s. However, its wide applications in manufacturing industries does not start until early 2000s. Discussions about applications of RFID in Engineer to Order (ETO) industry have been raised since mid-2000s. Over a decade's technical development, it is becoming a common view that RFID is an important part of Cyber Physical Systems, Internet of Things, or Industry 4.0. Although researchers have started discussion about RFID applications in ETO industry, it is not well addressed that how RFID can be applied for the material management with respect to engineering changes (ECs), which has strong impacts on an ETO company. This paper reviews RFID applications in ETO industry and gives suggestions on how an RFID system can be integrated in an ETO company? How has RFID been utilized for material management under engineering changes? And what is the general framework of RFID in material management in ETO industry?

Keywords: RFID · ETO · Engineering changes · Material management

1 Introduction

Radio Frequency Identification (RFID) is one of auto-identification techniques developed in 1950s, which has increasing applications in manufacturing industries as a decisive data collection approach since 2000s [1]. Discussions about applications of RFID in Engineer to Order (ETO) industry have been raised since later-2000s [2], and still continue [3] partially because the benefits of applying RFID in ETO industry are obscured regarding higher initial investment than general barcode systems. Discussions on benefits of RFID application in supply chain started from mid 2000s [4-6]. As barcode technology is a well-accepted identification approach in manufacturing companies for quite a long time, it is not a one-step process to use RFID as a substitution. Concurrent operation for RFID and barcode has been systematically studied [7].

Furthermore, an RFID system is a front-end system for data accessing rather than an alternative of an ICT system for resource management. Thereby, RFID is often discussed with ICT system together [1, 8, 9]. It will not be economical and even feasible solution to use RFID without the integration with an ICT system. Additionally, it is quite often for an ETO company to have engineering changes due to high probability of design and production changes; while efficient material management can provide an

opportunity to increase competitiveness because materials account for 50-60 percent of total project costs [10]. This paper reviews applications of RFID in ETO industry, mainly focusing on material management and gives suggestions of utilizing RFID for material management under engineering changes, which provides a reference for ETO industry to implement RFID technique.

1.1 RFID technique and characteristics

RFID uses a wireless non-contact radio system to transfer data from a tag attached to an object, for the purposes of identification and tracking. In such a system, RFID tags are attached to physical objects, which are wirelessly interrogated by antennas powered by RFID readers. Tags respond with some identifying information that may be associated with arbitrary data records, which makes an RFID system as a type of auto-identification system. Multiple readers and antennas are commonly used to build an RFID system as shown in Fig. 1.

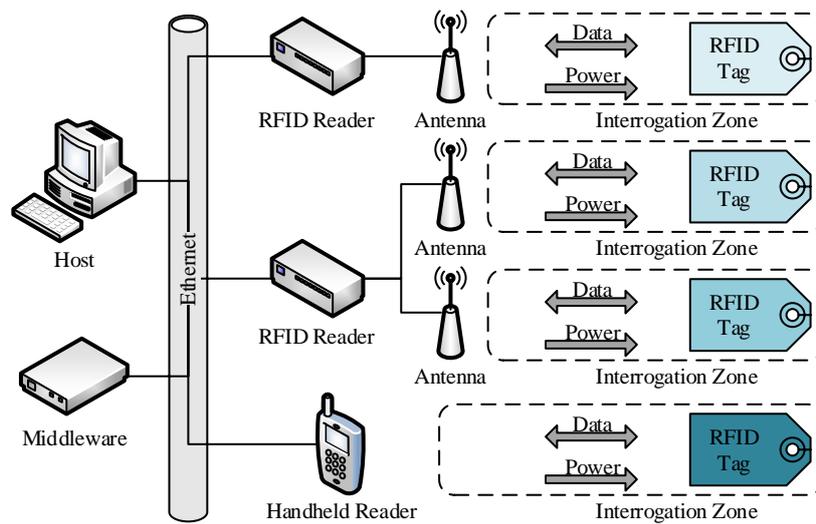


Fig. 1. A general RFID system

Main characteristics of RFID include non-line-of-sight data access and rewriteable on-chip data, which enable functionalities of remote and batch accessing, real-time accessing on-chip memory such as data retrieving, appending, erasing and protecting. In an RFID system, it is the RFID tag that is utilized as the data carrier, while other devices are used for accessing, transferring and managing the on-chip data. The working distance and the cost of an RFID tag depends on the working frequency and the additional power supply with the RFID tag. Characteristics can be compared as shown in Table 1.

Table 1. Characteristics of passive RFID systems working at different frequencies

Characteristics	Working frequency		
	Low	High	Ultra-high
Frequency	30-300KHz	3-30MHz	300-3000MHz
Reading distance	0.1m	1m	12m
Applications	Access control Livestock tracking	eTicket Payment	Inventory management Many others
Standards	ISO14223 ISO/IEC 18000-2	ISO 15693 ISO/IEC 18902 etc.	EPCglobal Gen2 (ISO 18000-6c)
Cost	High	Medium	Low
Sensitivity	Low	Medium	High

Potential applications at different decision levels based on these two characteristics are shown in Table 2.

Table 2. Applicability of RFID

Decision level	Applicability
Strategic level	Information sharing Increasing visibility
Tactical level	Tracing and tracking Decentralized data storage Life-cycle management Lead time reduction
Operational level	Far/near field identification Real-time locating system (RTLS) Processing history recording Automated item registration BOM recording Maintenance history recording

1.2 Material management under engineering changes in ETO

ETO is a strategy for manufacturing one-of-a-kind products (OKP) [11]. ETO companies are faced with the increasing complexity of products, production structures and processes [12]. ETO environment is characterized mostly by large and complex products which are designed and produced by customers' requirements. Products in this type of supply chain are required in low quantities and sometimes in medium volumes, but generally they contain a diversity of components in a complex combination. Each component should be assigned to specific operation in the production.

Engineering changes are considered as a major obstacle to the delivery of the product in ETO environment. Four main factors effecting engineering change are identified,

including unidentified change propagation, knowledge management, distributed environment and capacity and congestion [10].

Material planning which also named as material management concerns balancing supply and demand by initiating, controlling and monitoring of production and purchasing orders to allow the efficient material flow going without interruptions throughout the production. Overall task of material planning process is to ensure material availability at the right stage of production and at the right time. To do so material planning uses bill of materials, inventory data, and data from master production schedule in order to determine time-phased plans for all components and raw materials required for production. Material planning process includes broad set of tasks and activities like planning required materials, supplier selection, purchasing, inventory management and forecasting. Therefore, this process is not only simple computer calculations but also it includes an effective communication mechanisms, education activities and training programs. The material planning process starts when the order is received, materials specifications and materials coding systems are established and bill of materials is created. In order to link bill of materials with process structure, each component in the bill of materials should be assigned to specific operations in the production.

Having a supply chain with large number of suppliers creates even greater need for an effective and efficient management of material flow, as it is required to take into account deliveries of numerous components from different suppliers [13]. The material management starts when the order is received, materials specifications and materials coding systems are established and bill of materials is created. Material management uses bill of materials, inventory data, and data from master production schedule in order to determine time-phased plans for all components and raw materials required for production, including broad set of tasks and activities like planning required materials, supplier selection, purchasing, inventory management and forecasting.

2 Applications of RFID in ETO industry

The earliest application of RFID in ETO industry was component tracking, similar as in other industries. RFID was tested in construction industry for tracking components from a precast storage yard to a construction site [14] and providing a reference for maintenance service [2]. In addition, researchers used RFID for managing life-cycle data of ETO construction components [15]. Based on component tracking, main RFID applications occurred in ETO fields including item management [16], lead time estimation [17], and operation times estimation [18]. Shop floor monitoring was another commonly used in for manufacturing industries [19-21].

As mentioned above, processes integration has considerable potential to improve performance of an ETO company [9, 22]. An ICT system is vital to implement RFID in material management. Regarding this point, ubiquitous work systems [23] and current ERP system adaption [24] are studied by researchers to improve ETO production from the ICT perspective.

RFID is a decisive technique to enhance the performance of an MES/ERP. Regarding the integration of RFID with an MES/ERP, applications can generally cover identifying objects, realization of online interfaces, intra-enterprise logistics, quality management, access and attendance control and shop floor control [1, 9, 25]. ERP system has developed interface for RFID data transmission [8].

Ship building is another section where RFID is used for material management [16], ship block positioning during the assembly [26, 27] and safety management [28]. Besides implementation studies, researchers also focused on factor analysis in adoption process of vertical supply chains[29]. RFID also contributes in information sharing between different actors i.e. clients and suppliers within the supply chain [3].

3 RFID integration framework

To successfully implement RFID in an ETO environment, it is the first and foremost thing that integrating the RFID with the management system. Although standards are being established and interfaces are provided by commercial software, e.g. the Auto-ID infrastructure of SAP and BizTalk server for Microsoft Dynamics AX, they are relatively focused on business processes. Regarding complex requirements under high engineering changes probability, it is more important to embed the engineering related information in the RFID tag from the management system, other than the identification of the tracked item. However, this step is always performed by the RFID system provider without knowing well about the ETO process, which produces a large gap between a local test and the global feasibility. Performance indicators for Materials Management were proposed under engineering change [13] as shown in Fig. 2, providing a reference for the intervention of an RFID system.

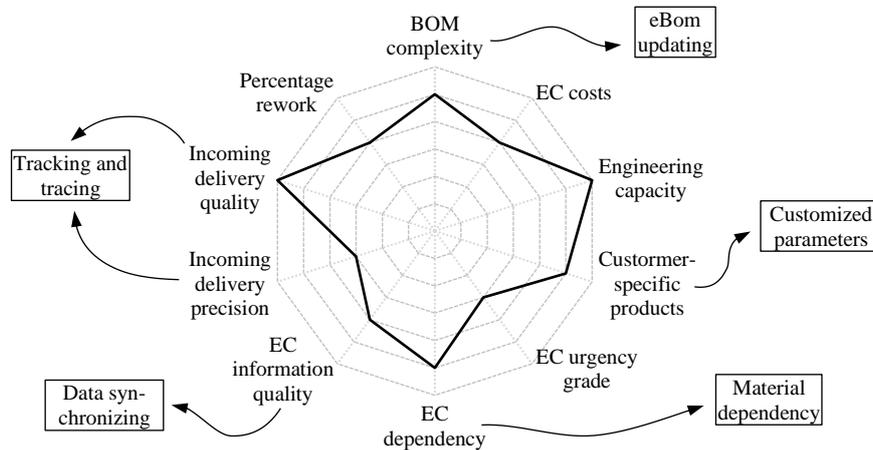


Fig. 2. Performance indicators for Materials Management under ECs (based on [13]) and relevant RFID modules

According to performance indicators in Fig. 2, five RFID modules are expected especially for material management considering ECs as described in Table 3.

Table 3. RFID modules for material management

Module	Description
eBOM updating	Designed for eBOM tag, which keeps detailed BOM and revision history
Customized parameters	Aim at special orders, which stores order specified engineering parameters, suppliers, customers, etc.
Material dependency	To record dependencies between orders/materials, for a quick lookup if ECs happen
Data synchronizing	To setup an error-free data updating mechanism, and ensure all confirmed changes are synchronized both in tag and database
Tracking and tracing (delivery reporting)	Especially for real-time delivery reporting, giving a clear picture of current state to decision makers

Among five modules above, data synchronizing needs more attention because it ensures the timely and accurate information before any decision is made. As distributed environment is one of the most important factors effecting EC [10], local ECs must be reported and updated in time for all relevant processes, so that misoperations can be avoided.

Hereby, RFID integration principles are proposed as a reference for designing an RFID system regarding engineering changes in ETO environment.

1. Evaluate components with high engineering changes probability.
2. Select suitable RFID devices according to characteristics of monitored components.
3. Main parameters related to engineering changes, suppliers and clients must be defined and pre-allocated in RFID tags referring performance indicators for Materials Management.
4. RFID data must be accessible both online and offline. Synchronization mechanism should be designed considering the network availability.
5. Authorize shared information in accordance with role of partners, i.e. suppliers and clients. On-chip data should be segmented so that they are visible to relevant partners.

4 Conclusions

RFID is becoming a promising technology and draws increasing attention with the improvement of technical performance and reliability. However, regarding complex engineering changes in ETO industry, material management always needs a tailor-made technical solution, so that RFID technique needs to be adapted and integrated to the ICT system to achieve the efficient management and maximum benefits. Current researches are still mainly focusing on components tracking and locating at the shop floor

level. To be noticed, it is a trend to involve information sharing via RFID system. However, it cannot be ignored that the engineering changes connect component monitoring and information sharing process, and related information must be reflected in the RFID tag via management system to improve the production performance.

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