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RFID-based wireless manufacturing for walking-worker assembly islands with fixed-position layouts

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Abstract

A walking-worker fixed-position flexible assembly line is a shop-floor where products are placed at work centres, the workers move from one work centre to another, and tools and components are brought to the work centre for assembly according to the process and production plan. Such assembly shop-floor configuration is not only suitable for producing large, bulky, heavy or fragile products, but also offers necessary flexibility and competitive operational efficiency for products of modest variety and production volumes. However, the shop-floor with a fixed-position assembly islands typically suffers from limited spaces at work centres and high dynamics of material and manpower flows in addition to common shop-floor problems. This paper presents an affordable solution to these problems by using wireless manufacturing (WM)–an emerging advanced manufacturing technology (AMT). WM relies substantially on wireless devices such as radio frequency identification(RFID) auto ID sensors and wireless information networks for the collection and synchronization of the real-time field data from manufacturing workshops. A simplified example is used to illustrate how to deploy WM technology for implementing the concept of Just-In-Time (JIT) manufacturing to reduce the shop-floor work-in-progress (WIP) inventories and smoothening their flows through real-time information visibility and traceability.

Keywords: RFID/auto ID; Wireless manufacturing; WIP; Assembly islands; Fixed-position layout

1. Introduction

The arrangement of machines, storage areas, and/or work areas usually within the confines of a physical structure of a manufacturing facility has significant impacts on shop-floor productivity. Facility layout is often determined by factors such as volume, weight of items to be produced, cost of the building to house the operation, the product mix that must have a facility, and the fragility of the product or component. Although not common, Fixed-Position layouts are normally used when products (e.g., ships and planes) are too fragile, large, bulky, or heavy to move. In such configuration, machines, material, and/or workers are moved to an assembly site (often called an assembly island) while products normally remain in one location for its entire manufacturing (assembly) period. Advantages of fixed-position layout include reduced movement of work items; minimized damage or cost of movement, and more continuity of the assigned work force since the item does not go from one department to another.

However, fixed position layouts have several disadvantages such as limited space at site and changing material needs. Since the product does not move while being produced, all movement of raw materials, personnel, components and equipment is from the supplier to the product. At different stages, different materials are needed, and therefore different items become critical as the assembly job develops. The volume and variety of materials needed are therefore highly dynamic. Movement of people and equipment to and from the work site may be expensive. In addition, the workers on work sites are highly skilled at performing the special operations that they are requested to do. Since the same workers are involved in more operations, skilled and versatile workers are required.

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The necessary combination of skills may be difficult to find and high pay levels may be necessary. Equipment utilization may be low if equipment is too expensive to move frequently and often left on-site. Duplication of the same the equipment at all assembly islands increases the fixed costs.

Other factors such as production volume and product variety also influence the decision if a fixed-position assembly shop should be best used. This is particularly true when the two options of fixed-position assembly and conventional assembly line are both feasible. Wang et al. [1] has conducted a comparative study on the system's performance based on the same assembly lines operated with fixed workers or with walking workers. The research was based on simulation models for the alternative systems. The results have shown that by using multiple-skilled walking-workers fixed-position system is advantageous over the conventional fixed-worker assembly line under similar conditions. In their study, however, work in progress (WIP) products move with the walking-workers. This is different from the situation in this paper where WIP products stay at assembly islands of fixed positions.

Fixed-position layouts have common shop-floor problems. The capturing and collection of information becomes a bottleneck while data processing is no longer an issue of concern with the rapid improvement in computational and communication power. Manual systems of data collection and capturing are time consuming, prone to errors, and tedious. It is a daunting task to trace and track WIP items in a large manufacturing plant. Manual identification sheets are frequently damaged, lost, or misplaced. Shop-floor operators are busy with operations that are supposed to add values to products. Operators are hardly motivated to type in the data about their operations because such data entry operations are non-value adding activities. As a result, the information does not accurately and promptly reflect the situations and changes of the situations due to disturbances. Without up-to-date information, it is impossible to make accurate shop-floor decisions, no matter how advanced enterprise resource planning (ERP) systems and manufacturing equipment are.

The need for automatic object identification (Auto ID) and "tracing and tracking" in manufacturing shop-floors has been long recognized in the field of computer integrated manufacturing (CIM). The limitation of using bar-coding based technology for this purpose was recognized and discussed as early as in early 1990s [2,3]. The dropping cost of radio frequency identification(RFID) technology (tags and readers) have motivated worldwide sporadic piloting efforts across different product sectors ranging from garment, electronic, mechanical, aerospace and automotive products. Early RFID manufacturing applications have been briefly quoted in [4] and further promoted in [5]. Johnson [6] presents a RFID application in a car production line. The website http://www.productivitybyrfid.com/ also provides a few links to real-life pilot cases. Chappell et al. [7] provides general overview on how Auto ID technology can be applied in manufacturing. Auto ID technology, whether deployed to individual product/part items [8–10] or their containers/pallets, is able to capture real-time field data from the workshops. However, most existing decision models and supports in production planning and control are not capable of dealing with such real-time data [11–13]. Kohn et al. [14] is an early piece of precious work in addressing repair-control of manufacturing systems using real-time RFID information.

This paper uses the term WM to describe a suite of emerging AMT relying substantially on wireless devices such RFID or Auto ID sensors and wireless information networks for the collection and synchronization of the real-time field data from manufacturing workshops. The authors have reported on their previous work on applying RFID technology in a typical product assembly flow line (Huang et al. [15]), and a typical shop-floor with a functional layout for part fabrication [16]. This paper uses a simplified example to illustrate how to deploy WM technology for implementing the concept of just-in-time (JIT) manufacturing in a typical fixed-position assembly shop-floor to reduce WIP inventories and smoothening their flows through real-time information visibility and traceability.

The rest of the paper is arranged as follows. Section 2 presents products and the corresponding assembly process chart together with the configuration of the fixed-position shop-floor. Section 3 discusses smart objects to be traced and tracked at shop-floors, and outlines the architecture of wireless information and communication infrastructure at shop-floors. Section 4 presents decision support systems and their integration with existing systems. Section 5 takes a snapshot of the product assembly execution in the fixed-position wireless manufacturing shop-floor.

2. Configuration of fixed-position assembly islands

For simplicity of discussion but without loosing generality, we have to consider a hypothetical product that represents those produced by some connecting companies. The hypothetical product consists of five modules. Modules A and D are commonly shared among the product family. Modules B and C have two and three options, respectively, for configuring six different product variants, as shown in Fig. 1(a). Module E has six options, and each corresponds to one product variant. This hypothetical product is a meaningful representative of simplified products such as automatic teller cash machines, drink/snack vending machines, plastic moulding machines, telecommunication equipment, and other types of machines tools. These products are not too bulky, nor too large. Both fixed-position assembly islands and conventional assembly lines are feasible. The use of RFID technology is able to increase the efficiency of the former to the competitive level to that of the latter while maintaining the flexibility.