A System using RFID Tags designated for Intelligent Manufacturing Process

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Abstract: The need for quality improvement, along with the possibility of disassembling products for environmental protection implies storing of a product history, starting from development and manufacturing phase until it reaches the end of its lifecycle. Based on possibility of a smart tag attachment to a product and going along with the idea of decentralizing an assembly line, the paper herein proposes a system which can be implemented at every operational point within an assembly line.

Keywords: Traceability, Automated Assembly Line, Smart tag, RFID, Assembly, Disassembly, Expert System

1. Introduction

Traceability is agreed to be essential but it is avoided in many industrial projects because of both unfamiliarity and difficulty of implementation. Semi-automatic traceability tools promise the beginnings of a solution to these twin problems.

Traceability is essential for many purposes, including assurance that systems conform to their requirements, that terms are defined and used consistently, and that the structures of models correspond to requirements.

Carrying out a simple analysis of manufacturing evolution we can distinguish: Mass Production Era (1910-1980), Quality Management Era (1980-2000) and E-manufacturing Era (after 2000), as is shown in Table 1.

1910-1980	1980-2000	2000-future
Mass Production Era	**Quality Management Era**	**E-manufacturing Era**
• standard processes • design and delivery at the producer choice • vertical orientation	• horizontal orientation • reliability • competitiveness • global approach • centralized control architectures	• design and delivery at the customer choice • hierarchical control • increased speed • global approach

Table 1 : The evolution of the production environment

During the Quality Management Era, the control of the manufacturing processes, especially the one related to the Flexible manufacturing Systems was connected to the CIM (Computer Integrated Manufacturing) philosophy and to the CIM-OSA paradigm (Fischer, 1999). The OSA (Open System Architecture) concept provides an architecture to describe the real world of the manufacturing enterprise by providing a unique set of advanced features to model functionality and behaviour of CIM systems at three distinct levels – requirements definition, design specification and implementation description. This description is used to control the enterprise operation and to plan, design and optimise updates of the real operation environment.

Today, manufacturers face a more complex set of challenges than ever before, trying to provide the supply chain visibility that the customers want, to meet increasingly aggressive deadlines, to improve the production planning process. The responses to these challenges are comprehensive solutions that provide an unprecedented level of visibility and give instant access to the necessary information (Lee, 2000).

The constant shortening of product life cycles as well as a flexible usage of existing process equipment are major reasons for the increasing demands on advanced manufacturing systems (AMS). Several adjustments in the ways of working are required to be able to constantly accommodate to the AMS characterized by ongoing changes. This requires rapid product and process development, efficient changeovers between products, user-oriented support during various work tasks, a well-functioning work organization, and skilled personnel with competence and ability to handle the system. The role of the Information Technology (IT) becomes decisive and the step to the E–manufacturing paradigm appears as necessary (Bajic, 2002). By ensuring that the physical implementation model is directly processed by the information technology components of the system, the control of the operation of the CIM system at runtime may be achieved in congruence with the specified behaviour of the enterprise. The key to reach the necessary flexibility is the control of the information flow. In today's complex business environment of high-speed continuous change, the use of latest information technology such as E-Manufacturing, Collaborative Manufacturing Execution (CME), Enterprise Production Management (EPM) and Manufacturing Execution Systems (MES), is required because it enables business agility by accommodating unforeseen changes and automating the information flow (Wong, 2002).

2. The Concept of Traceability in the E-Manufacturing Context

The E-manufacturing paradigm was generated at the end of quality era, as a sub-class of the more large concept of E-business – a moment of structural transformation of the manufacturing enterprise, associated with increasing quantity of information contained in products and services. Its keywords are: flexibility, efficiency, and responsiveness to customer. Talking about e-manufacturing, we cannot omit customer driven design and delivery, flat informational corporate structure, partnership virtual network, speed and agility, global orientation. So, in today's intense competitive e-business environment the mission for manufacturing businesses is to do more with less and to do it faster, better and cheaper. To accomplish this, manufacturers need real-time information management tools for continuous improvement and decision support. Timely and accurate information is the key to operating a competitive business and achieving a world-class business model. An integrated manufacturing execution information system can streamline operations dramatically improving throughput, automate the collection of data, improve efficiency and quality, and automatically provide the extensive documentation required by today's rigorous quality programs.

Increased emphasis on Quality Assurance, product liability, legislation, and the establishment of national and international manufacturing standards (e.g. ISO 9000) has created a need for "products traceability". Traceability is the main property of a MES, because it provides the real-time visibility and dissemination of all plant data so that scheduling and planning software can then best perform their optimisation functions.

MES systems provide a meaningful relationship between business data with factory data by correlating product information with process and quality information in an on-line relational database. Basically, they provide the right information to the right people, at the right time, in an actionable format, in order for them to make timely and well informed decisions.

3. Framework Concept

The research team considered a redundant assembly line, designated for automatic manufacturing of a product. Onto this line, every point in which a component is added to the minimal assembly is called a *zone* (Vlad, *et al.*, 2003).

The redundant line, also referred as the return line has two major objectives:

- return of fault products where the error can be corrected
- components disassembly from the fault units, as long as this step is necessary for remedy of the deficiencies.

Zones can be divided into two types, considering the places where they are found:

- assembly zones
- disassembly zones, which made inverse operations to the product, with the purpose of retrieving the components. The components obtained in this way will be reused in the production process.

The concept is a standard one of traceability in the manufacturing phase; its novelty consists of the possibility to disassembly a product, which allows the recovery of good components and the correction of failures. An immediate consequence would be reduction of rejected products, an activity that can be traced throughout the manufacturing process.

The entire process – assembling/disassembly, is based on possibility to implement tags, such as RFID tags, at minimal assembly level. The tags' role is to store data, their advantage consisting of the fact that data may be rewritten depending on one's needs.

Thus, minimal assemblies arrive to the assembly line and, following some tests, components are added to them. Information about the successful path is written on the tag attached to the product.

However, in case a product is found non-conforming, the system can send specific information which will be stored onto the faulty product's tag; this information will later on be used to disassembly the product once it arrives back to the return line.

For economic reasons, a product is placed in a different line, (from the assembly line to the disassembly line, in case of a faulty product) using a time sharing algorithm. This ensures that the arrival of a product on a line is coordinated by a minimal lead system, without the necessity to implement a tag reader for this particular action.

Using tag attachment to the product allows decentralization of the assembly line, (Vlad, 2003) so that there will not be a need for concurrent links to a database located on central server or on a mainframe; thus it is possible to use the tag in order to store data about the product to which it is attached. A model of decentralized assembly line is shown in Fig. 1.

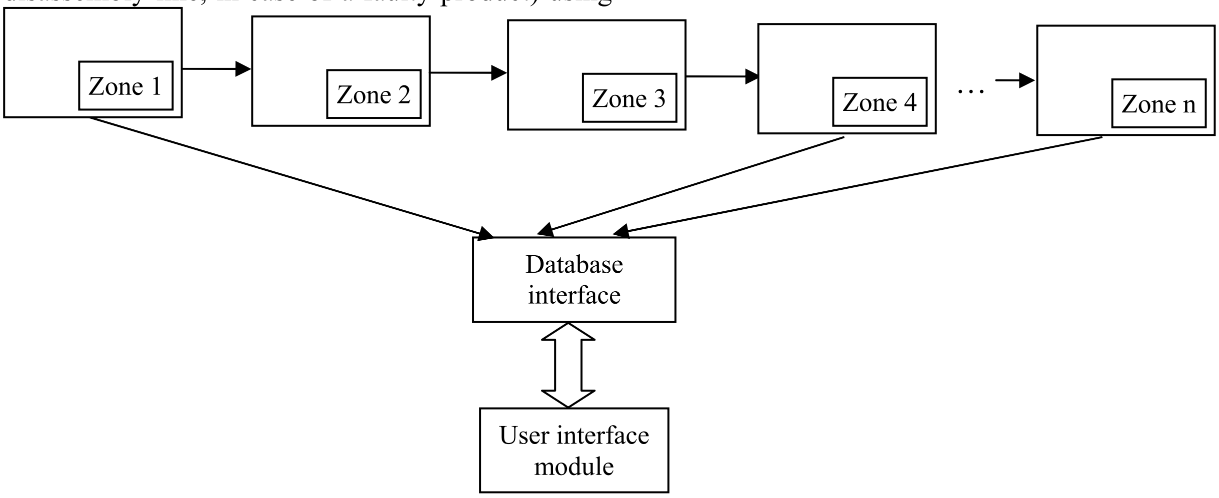

Fig.1. A model of a decentralized assembly line

This approach comes closer to current industrial application as in Toyota assembly and painting line, where tag is associated to a trolley carrying the vehicle to be assembled and painted with more than 703 dollies in operation (Philips 2003)

4. Zones Within an Assembly Line

At zone level, several specific operations take place, either for assembly or for disassembly of a unit. For unit testing it is necessary to use an expert system, with decision mechanisms. The four expert systems are coordinated by a local information system, which also assures availability of the reader for exchanging information in and from the tag.

A unit enters on an assembly line, and the first step is the adding of the tag. A unit follows a normal path, from the first zone to the last one, where the unit becomes a final product. In case of disassembling, the product is routed on a reverse path, through the disassembly line. The path of a unit is defined within the tag information structure, and also, based on the structure, the history of each product can be determined at the end of manufacturing phase.

Into each zone several operations are carried out:

- initial testing
- adding the component to the unit
- final testing

There is a difference between the zones on the assembly line and the ones on the return line. While the first one adds a component to the product, the second one removes the part from the unit; the removed part goes into a testing system. If this component is found conforming, it will be redirected to the assembly line, and then attached to other products coming on the assembly line.

The systems which are implemented in a zone are expert systems; they have a number of specific functions: testing the product, either when it enters the zone or when it exits the zone, making decisions whether a component should or should not be added within the zone, transmitting to the reader information that can be written on a tag, stopping the component feed line. In addition, the systems can communicate with each other.

The initial testing process is designed to detect the conformity of the unit resulted from the precursor phases of production. Although, as mentioned before, a final testing phase takes place in every phase, an item can be damaged in another zone, by modifying its properties due to a partial or momentary system error. This is not identified in the final test of the damaging zone, because it may happen that a certain component of the product, which was faulted, has no direct connection with the part that was added, part that is tested in the final test.

Initial testing is carried out by expert system IN. The tests' role is to stop a component to be added within a zone, in case of a faulty product.

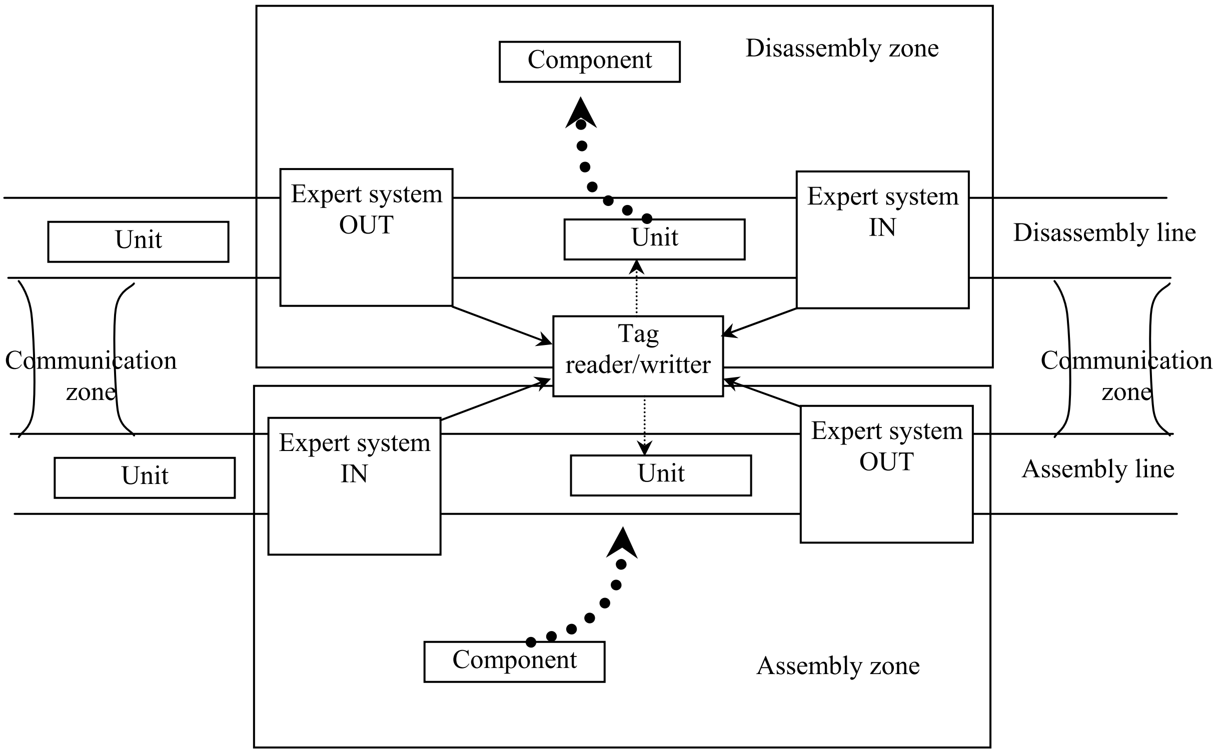

Fig.2. Systems integrated within a zone

If after the tests, the product is not considered faulty, it will take the normal path. The component will be added and then the product will go into the final testing session.

Should a faulty product be found, the expert system does not allow the component to be added within the zone, and communicates to the reader the information needed to disassembly the product. In addition, in this particular phase, information about the product's status within the respective zone is sent to the expert system OUT.

A key element is the reader, which can read and write data on the tags attached to the products. The reader receives information from the expert systems; this information relates to the status of a particular product. The reader is coordinated by the local information system. In order to reduce costs, one single reader was chosen; this reader is to function for all the four expert systems. Nevertheless, the reader can be simultaneously called only by two systems, because there are maximum two products, one in the assembly line and one in the return line. Priority in taking order can be set by a queuing mechanism.

The first step when entering a zone is reading the information on the tag, which reflects the history of the developed product.

Regarding the disassembly, a very important aspect is that the expert system will transmit to the tag precise information about the zones where the product is to be disassembled. For example, in order to repair a fault on a product, it is necessary to disassemble the product only in two zones out of ten, on the return line. The information stored on the tag are the results of application of ground rules for each expert system in each zone; these rules are implemented in the very beginning of the automated system development

The expert systems OUT have two main functions:

- testing the product
- establishing the path through the product development process.

In case a product complies with the testing specifications and the expert system IN has not recorded faults, the reader will store on the tag the code matching the path and the product will be forwarded to the assembly line.

If, however, in the initial testing, the system has received information that the unit is out of order, then the product will be returned to the assembly line. The disassembly code has been written on the tag since system IN, including information on the disassembling. As far as the current zone is concerned, there is no information stored on the tag relating to the disassembling process, because no component has been added to the product. In this particular case, system OUT will only coordinate the product, in order for the latter to enter the disassembling line.

Another situation is when faults have been discovered following the component adding process, faults which have been noticed by the system during the final testing. In this case, the reader stores on the tag information for disassembling, but the entire correction process will consist only in returning the product to the disassembly line in the same zone in order to be added a new component. In the disassembly line the faulty component will be removed and then the product's conformity will be tested; later, the product will return to the assembly line.

There are differences found in the expert systems on the disassembly line. The expert system IN will require data from the tag in order to determine whether the product should be disassembled in the very zone and, in case of a positive answer, the system will order the removal of the component.

On the other hand, in system OUT, specific tests will be carried out to determine whether the product can be reused after the disassembling or whether the fault is very serious, in which case the entire unit should be thrown away.

5. Information on the Tag

At tag level, one should find a number of specific information that makes it possible to uniquely identify the product and to find its manufacturing history. Regarding the unit's history, the tag will store information written in each zone, as well as information related to the product disassembly.

Field	Data type
Identification No.	Integer
Zone 1	True/False
Zone 1 entrance times	Integer
…	…
Zone n	True/False
Zone n entrance times	Integer
Return times	Integer
Current return	Byte

Table 2 Information stored at tag level

The path of the product is determined by the following of the zones, from the first to the last one. In case the number of times of entrance at every zone is found to be one at the end of the manufacturing process, then the product was developed with no errors. Based on the number of entrances in each zone, the product's history can be determined with a simple algorithm at final quality check.

The return times counter monitors the number of times a unit is moved on the disassembly line in order to correct different parts from it. If the return times value exceeds a certain limit, the product will be considered impossible to repair and will be removed from the line.

Final testing into a zone is done in order to check the quality of the operations taken towards the item into the respective zone. Therefore, a current return switch was added to the information structure on the tag, in order for the expert system OUT to make a decision regarding the path of the product. In case the operation was unsuccessful, the product is returned so that operation can be redone.

6. Modules at Zone Level

The zone is considered to consist of an assembling zone and a disassembling zone. In this sense, there is a structure gathered around a local information system, to which all the four expert systems are connected, as well as the smart tag reader.

The general model is presented below:

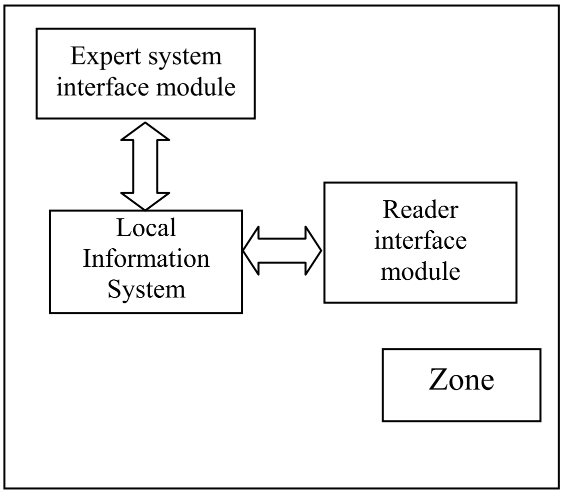

Fig. 3.The model of a decentralized automated assembly line

As we noticed in the figure, there are three main modules:

The expert system interface module

Expert system interface module carries out data exchange with the local information system. At expert system level there is a data acquisition process, data that results following the unit testing. The data, which is the effect, is sent to the local information system, which contains the rules base for all the four expert systems found in a zone. After the effect was identified in the local information system, and the cause was found, the expert system receives the decision to be applied, decision which can be: movement of a product from one line to another, start or stop component feed line, etc.

Local Information System

This module is found on the system that coordinates all the processes within a zone. The local information system serves for storing different sets of rules for every expert system, and it is also responsible for identifying the effects received from the systems with the one in its tables, in order to find the cause that generates the specified effect. The local information system module establishes the strategy for the next path of a product: whether it will move on the assembly line or it will be returned. The local information system module communicates to the reader information that will be stored on the tag of the product.

Reader interface module

Reader interface module ensures the communication between the reader and the local information system. It reads information on the card and converts it so that it can be used by the local information system. This module is responsible of the reverse process, in order to write data from the local information system.

7. Conclusions

The presented system develops the concept of decentralization of a disassembling line by using intelligent tags attached to the product. In addition, the research team propose a framework for cutting down the number of rejected products within automated manufacturing systems, by returning the faulty products on a redundant line, in order for them to be repaired or to retrieve a large number of parts from this kind of products.

Considering the tag implementation within the incipient phases of manufacturing, one can foreseen the decentralizing of an assembly line. If before anything was centralized, along with the fact that there were many concurrent data links to a server which hosts the database, the server was to be capable to take several decisions in real time, otherwise there was the risk that the assembly line was getting blocked.

Thus, the manufacturing history of the product is stored on the tag attached to the product. Tags can be recovered at the end of the production phase and they can be reused, which leads to production costs reduction. Also, the tag may stay on the product even after the manufacturing process is over, and, in this case, it can be used in several applications, such as monitoring or, at the end of product life, it can be disassembled, based on the information stored on the tag.

The next steps regarding the research activity at this project will be the simulation of a zone, which will consist of implementing the expert systems, the local information system and the procedures for communication between the tag and the reader.

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