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RFID Technology Use in Assembly and Disassembly Processes

Gordana OSTOJIĆ, Milovan LAZAREVIĆ, Vukica JOVANOVIĆ, Stevan STANKOVSKI, Ilija ĆOSIĆ

Abstract: Modern production conditions demand the application of the concept of distributed production. Today companies are specialized for partial technology processes. Hundreds, sometimes even thousands, of collaborative processes depend on workers' interaction and communication in product assembly and disassembly phases. RFID technologies can be really helpful in identifying objects in terms of sustainable development, regarding disassembly, recycling and reuse. In this paper we presented VCDE system architecture and the realization method of RFID technology as well as the data acquisition using RFID technology during the product lifecycle from the design process, production, assembly, usage, and an special example is given regarding disassembly and recycling process.

Key words: RFID technology, collaborative design, assembly process, disassembly process,

1 Introduction

Contemporary production conditions demand the application of distributed production concept. Changes on the factory floor are taking place on a daily basis. Besides, the expansion of enterprises through geographically distributed factory plants, administrative facilities, and sales offices, have led to the concept of distributed production systems. Virtual Collaborative Designing and Gathering Information Environment (VCDE) using RFID (Radio frequency identification) technology is an idea for the collaborative design in the product development and assembly and disassembly phases.

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RFID technology is suggested for the implementation because of the advantages comparing with other technologies for identification (e.g. barcode).

To carry out with WEEE (Waste Electrical and Electronic Equipment) Directive there has to be Take-back programs which give manufacturers the physical responsibility for products and/or packaging at the end of their useful lives. By accepting used products, manufacturers can acquire low-cost feedstock for new manufacture or remanufacture and recycling. Disassembly process has a key role in implementation of WEEE Directive and Take-back programs. Information gathered from the disassembly process can be very important through the whole supply chain (e.g. manufacturing, remanufacturing, service and recycling) including VCDE.

Suggestions for EOL (End of Life) strategies are given in [3]. Modeling of disassembly system and proposed selection of components after the completed disassembly is accomplished by using EOL strategies as starting point.

2 Collaborative Design

Recent trends in computing environments and engineering methodologies indicate that the future engineering infrastructure will be distributed and collaborative, where designers, process planners, manufacturers, clients, and other related domain personnel communicate and coordinate their activities using a global web-like network. The designers use heterogeneous systems, data structures, or information models, whose form and content may be not the same across all domains. Hence, appropriate standard exchange mechanisms are needed for realizing the full potential of sharing information models.

2.1 VCDE System Architecture

Collaborative web design can be either a client-server based suite of tools to facilitate design activities and capture design rationale or e.g. the use of the VRML as a communication and visualization medium for evaluation of detailed designs [1].

Some of the problems which may arise in the application of the distributed collaborative design are related to the heterogeneity, trust, awareness, interaction, and overload management, determination of access rights, system maintenance, and mutual understanding.

The concept presented in this work is a starting point of a future research project conceived at the Institute for Industrial Systems in Novi Sad (Serbia). Virtual Collaborative Designing and Gathering Information Environment Using RFID Technology (VCDE, see *Figure 1*) is an idea for the collaborative design in the product development and assembly and disassembly phases.

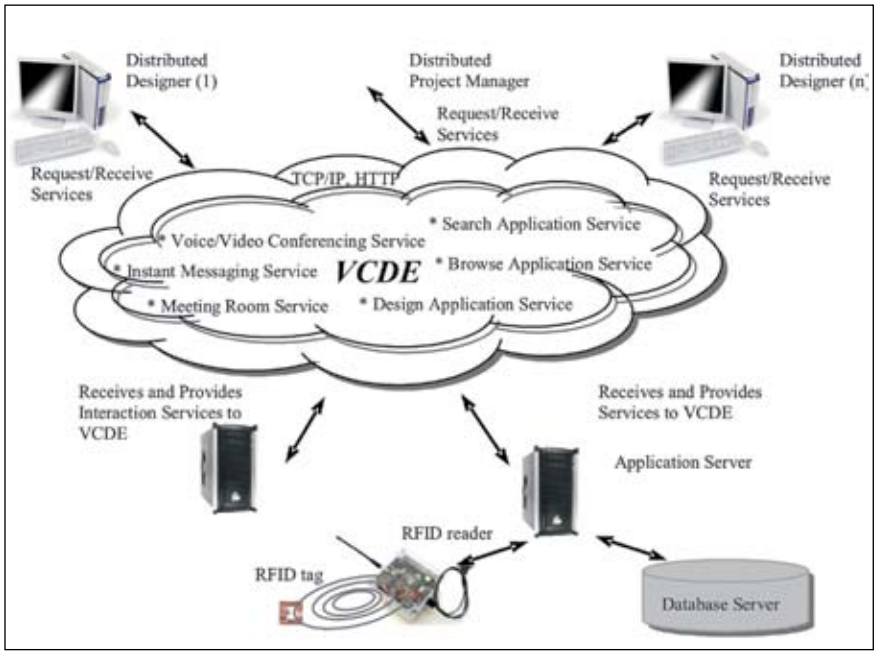

Figure 1. *VCDE System architecture*

The VCDE is a core of an information system which should provide data structure for the dislocated project manager and dislocated designers and engineers in the assembly and disassembly phases. There are many different ways of sharing information. It can be either through instant messaging service, meeting room service or voice/video conferencing service. It is very important to enable the manager and the designers to share the data accurately and in real time. Any change in the product design, production and assembly/disassembly can lead to a completely different working procedure. The server which receives and provides interaction services to the VCDE must be able to support communication, even if the manager and the designers and engineers are on different locations, or they are working on different operational systems or have different connection speeds.

The other part of the VCDE provides the application services. These services are meant to function as a search application service, browse application service, and design application service. The Application Server has to operate both with the RFID reader and the Database Server. The RFID reader obtains data from a RFID tag which is placed on a product and the application server has to make an inquiry to the database server. The database server stores all the information needed for a product assembly or disassembly.

2.2 RFID Technology

In the process of assembly or disassembly, one of the most important things is the graphical presentation of the exploded state of a product. The other issue is the assembly process itself, a sequence of assembly operations and tasks needed to make the product from the base parts. Sometimes such necessary information is not available, so that the product has to be disassembled to its subassemblies. Nowadays, when a sustainable development is getting more and more important, every company must take care of its products at the end of their life cycle. It is very difficult to create a disassembly system for any kind of a product. It would be better if every company could trace its products and find out where they are at the end of their life cycle and gather them at the own collection centers, to disassemble them. Later, the company can also reuse these assembly parts as spare parts or as recycle materials. The exploded state and assembly sequence can be stored in the server database and, using RFID technology, obtain the data needed for the disassembly management.

RFID is a generic term for technologies that use radio waves to automatically identify objects. There are several methods of identification, but the most common is to store a serial number that identifies the object and perhaps other information, on a microchip attached to an antenna (the chip and the antenna together are called an RFID transponder or an RFID tag). The antenna enables the chip to transmit the identification information to a reader. The reader converts the radio waves reflected back from the RFID tag into digital information that can then be passed on to computers to make use of it.

The basic hardware for the RFID includes RFID tags and RFID readers. There are two basic types of tags, passive and active (see *Figure 2*) [2].

– Passive RFID tags have no battery. They draw power from the RFID reader which emits electromagnetic waves that induce a current in the tag's antenna. Semi-passive tags use a battery to run the chip's circuitry but communicate by drawing power from the RFID reader.
– Active RFID tags have a battery which is used to run the microchip's

circuitry and broadcast a signal to a reader, similar to the way a cell phone transmits signals to a base station.

Active and semi-passive tags are useful for tracking high-value goods that need to be scanned over long ranges, such as railway cars on a track, but they cost a dollar or more - making them too expensive to put on low-cost items. Passive UHF tags cost today less than 50 cents each - in volumes of about a million tags. Their read range is not as far - typically less than 20 feet versus 100 feet or more for active tags - but they are far less expensive than active tags.

Figure 2. *RFID readers and tags [2]*

RFID tags can be read-only or read-writable. Read-writable tags allow the information stored on and emitted by the tag to be modified or re-written during the use. Passive read-only tags are the most affordable tag option available. They are also most limiting, because their signal reach and data use are constrained. An important variant of RFID tags is the Auto-ID tag, which is encoded with an electronic product code (EPC), a 96-bit unique naming scheme that can provide vast product details. The EPC is currently a most common encoding scheme for warehouse and distribution applications.

With readers strategically placed throughout a warehouse, a distribution center or an assembly system, the tag on the respective product or item, is followed along its journey through the supply chain. RFID tags (transponders) - affixed to cases, pallets, cartons, products or their parts - begin to transmit radio frequency signals when in the read zone of a stationary or mobile reader (interrogator). The reader picks up the signal and decodes the unique EPC that identifies the name, class and serial number of the product. This information is then matched with the record data in the host computer system and database application.

2.3 The Realization Method of RFID Technology

Studies related to the strategies of the end of life cycle of a product are very numerous. The most acceptable, and in its character comprehensive, classification of the end of product life cycle is [3]:

- Reuse of used products;
- Reconstruction of used products;
- Use of used products for spare parts;
- Recycling with disassembly;
- Recycling without disassembly;
- Disposal of the used products.

Reuse of the already used products is a strategy which organizes the return of discarded products that are still in function. If such an interest exists, the already used products are sold in the market.

Reconstruction of the used products is applied in the processes of modernization or upgrading their performance. The purpose of this strategy is to attain the product quality which is more or less similar to the quality of the new product. The quality of the reconstructed products depends on the predetermined depth of disassembly. If a product is disassembled to the level of parts and the control and replacement of all the parts is conducted, the used products are brought to a high level of quality, required for the new products. Also, it is possible to conduct the modernization of products by replacing certain modules with contemporary ones (product upgrade), after applying the disassembly.

Using the already used products for spare parts is being a frequent practice. In certain companies, outdated products are being collected in an organized manner. The purpose of this strategy is to take a relatively small amount of parts/subassemblies from a used product and use them for the above strategy, or for another purpose, the rest being used for material recycling.

Recycling with disassembly is a strategy used for separating different parts made of different materials, before their conversion in the process of disassembly. The purpose of this strategy is to use the materials from the used products and parts, by separating them in the procedure of disassembly into the component parts and with appropriate selection, depending on the given type of material. These materials can then be used in the production of original or some other products.

Recycling without disassembly is a procedure which is used to compact and compress a product and then perform attrition and sorting out by the type of material.

From the environmental point of view, product disposal as a waste is the most inconvenient strategy for managing products at the end of their useful life. Having the above strategies in mind it is necessary to design an appropriate production system in accord with them.

Systems for the refinement planned in a way to consider the EOL strategies in the work give very complex information regarding the selection of proper components after the completion of the disassembly process.

After choosing the appropriate strategy for a given product and a sequential execution of certain operations of disassembly it is necessary to conduct sorting of the disassembled components (parts/substructures). Basically, we can suggest the following possibilities for selection of components after the completed disassembly:
- Hazardous materials (components) (H);
- Material recycling (R);
- Reuse (P);
- Finishing, (D);
- Incineration (I);
- Waste disposal (W).

Components disassembled from a product are identified, measured and sorted in the different phases of the process. During the disassembly process it is necessary to place the appropriate RFID tags on the disassembled components or containers for identification of the disassembled components.

A reader placed on the disassembly line is used for identification. Information gathered on the disassembly line imply, for example, groups of products, producers, date of production, disassembled materials, disassembled parts, weight, disassembly instructions, etc. Disassembled components are stored in the warehouses or proper containers, and RFID infrastructure is well suited for the applications where:
- A large number of items is to be identified individually;
- Additional data about the item need to be managed.

The advantages of RFID technology in handling of certain parts and materials are [4]:
- Product information on spare parts;
- Product identification and connection with the producer in any phase of the life cycle of a product;
- The possibility of automatic sorting of products;
- More efficient use of resources:
- More accurate and faster flow of parts;
- Decentralization of Information and Intelligence;
- A list with hazardous materials which are contained in the product;
- Automation and increased efficiency of information management, etc.

The application of RFID technology in the course of the life cycle of a product is shown in Figure 3 [5], with a special emphasis on the production system for the disassembly of products at the end of the life cycle (EOL products) – systems for disassembly.

2.4 Product Database for Assembly/Disassembly

To establish the data source for a collaborative design in the phases of designing, assembly and disassembly of a product in its life cycle we need to create a database. Since this is not a complicated database, we use Microsoft Access to create it.

When planning a database, the first thing is to realize which data are needed for the process of collaborative design. These data can be organized in a number of tables and connected via primary keys. For each part we need to know: EPC, Part code, Material, Is the part base or not, Assembly sequence, Constraints – Align, Mate, or Insert, Part life cycle, Manufacturing date, Manufacturer.

For the materials we need information about the ID of material and its name. For the manufacturer of a part we can use information about its name, address, phone number, email address and contact person.

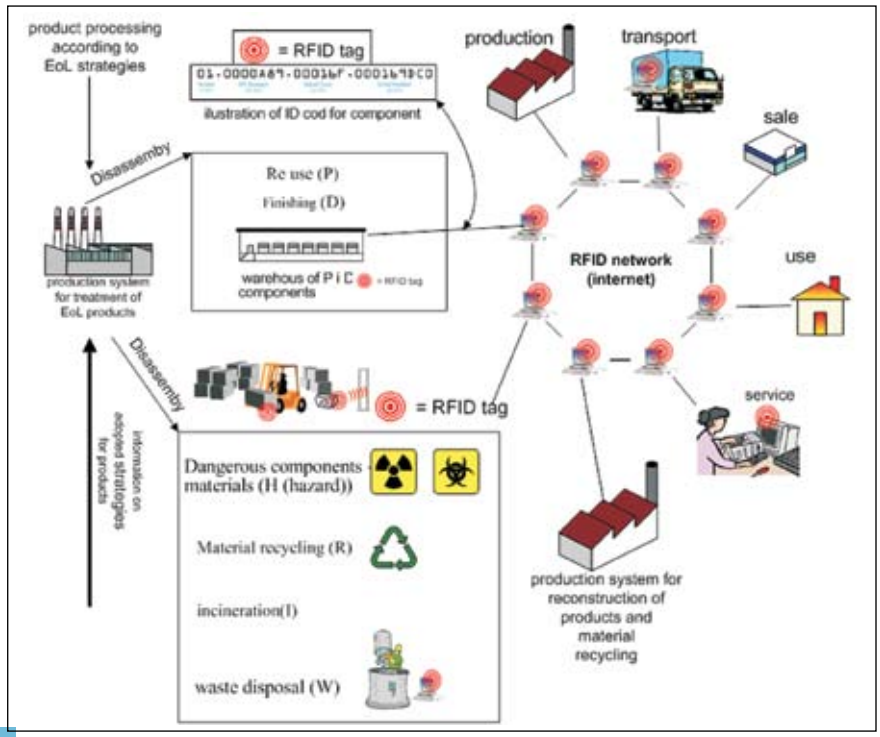

Figure 3. *Data acquisition using RFID technology [5]*

Following the previously made plan about data needed, we have to construct three tables in Microsoft Access: Table of Parts, Table of Materials, and Table of Manufacturers. Foreign keys in Table Parts are Manufacturer and Material. We used them to create the relationship between the tables (see *Figure 4*).

Once the database is constructed we can use it over the web via Macromedia Cold Fusion Application server.
For a collaborative design we can use data by developing Cold Fusion application which can access the database server and use data from the existing database or any other data source (in our case an RFID reader) and send it to the web server as an HTML document which is then presented to the dislocated manager who originally made request for the data. To do this we configure our database as a data source for a Cold Fusion application. For a Microsoft Access database we can use either ODBC or OLE/DB drivers, to make connection.

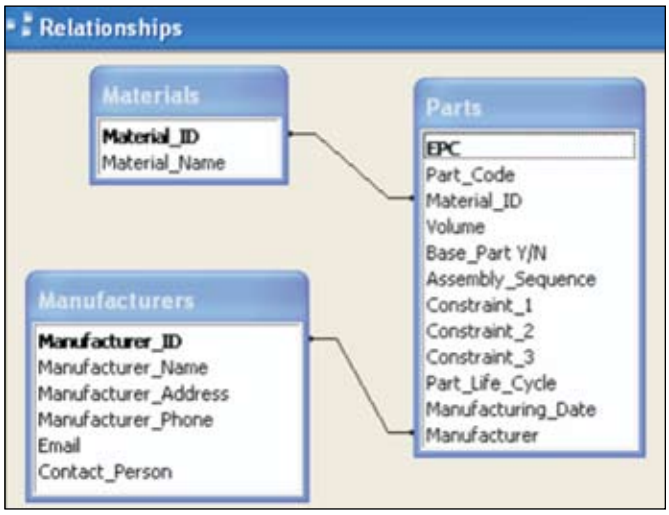

Figure 4. *Relationships between the tables*

3 Conclusion

Modern production management is crucially dependent on the information technology and more than ever they rely on the web usage. Collaborative web enabled environment can be used on a daily basis for communication between product designers and engineers in the disassembly process. This is getting more important in view of frequent changes in the global market. RFID technologies can be really helpful in terms of a sustainable development, regarding disassembly, recycling and re-use. According to the WEEE Directive, certain measures must be undertaken in order to prevent waste, e.g. electrical and electronic equipment. All manufacturers should take care of the recycling of such equipment and reuse of its components by applying the RFID technology to trace a product in all the phases of its life cycle.

Advantages of using RFID technology through the whole supply chain are: effective, contact less and reliable way of gathering information, with the possibility of not only reading but writing data from/to a RFID tags (especially important in disassembly process). There are different reasons why RFID technology has not been in wider use during the life cycle of a product. Some of them are: the widespread use of barcode, higher expenses due to RFID tags, privacy and security measures, lack of the consensus on standards and other reasons. Next step in our research will be to determine weak points in VCDE system, possibility of system interruption by unauthorized personnel and defining criteria's for component or part selection on which the RFID tags will be placed.

The RFID technologies in the disassembly and recycling will be easily used in the next period, when certain producers start incorporating RFID tags with unique EPC code in their products during the assembly phase.

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Uporaba tehnologije RFID v procesu montaže in demontaže

Razširjeni povzetek

V razpršenih procesih, kot so izdelava, montaža in demontaža, je mogoče koristno uporabljati tako imenovano tehnologijo frekvenčne radioidentifikacije – RFID – za prenos informacij. Tehnologija RFID je uporabna tako za identifikacijo objektov v času montaže kakor pri demontaži in recikliranju. V ta namen je bil razvit koncept virtualnega sodelujočega razvoja izdelkov (VCDE) in ustreznega okolja za prenos informacij s tehnologijo RDFI za identifikacijo objektov.

VCDE je ogrodje informacijskega sistema, ki omogoča izmenjavo podatkov med vodjem projekta in oddaljenimi konstruktorji, planerji montaže in demontaže ter samo montažo in demontažo. Ti si med seboj izmenjujejo podatke in informacije na različne načine: samo z elektronsko pošto, s sodelovanjem na glasovnih ali videokonferencah. Zelo pomembno je, da je izmenjava točna in v realnem času. Z vsemi spremembami pri razvoju izdelka, v proizvodnji, v montaži/demontaži morajo biti seznanjeni vsi (*slika 1*). Uporabniški server v sistemu VCDE mora omogočati povezavo z RFID, ta pa branje informacij z nosilca na izdelku in prenos v podatkovni strežnik.

RFID je generični izraz za tehnologijo, ki uporablja radijske valove za avtomatično identifikacijo objektov. Najpogosteje je v mikročipu, ki je povezan z anteno (RFID tag - oddajnik), spravljena serijska številka objekta, lahko pa so dodane še druge informacije. Oddajniki so lahko pasivni, če dobivajo napajanje od čitalnika, in aktivni, če imajo lastno napajanje. Uporaba aktivnih oddajnikov je omejena na primer na vlake ali tovornjake, kjer se informacije prenašajo v daljšem intervalu. Pasivni oddajniki, ki stanejo le nekaj centov, so primerni tam, kjer je potrebno veliko število oddajnikov, na primer za identifikacijo izdelkov, palet, kartonov in podobno.

V procesu montaže in demontaže je pomembna grafična predstavitev trenutnega stanja objekta montaže in demontaže. Prav tako so nujne informacije o zaporedju operacij in poteku samih montažnih/demontažnih operacij. Demontažo in predelavo izdelkov ob koncu življenjske dobe otežuje prav pomanjkanje informacij o zgradbi izdelka. Vgraditev nosilcev informacij, npr. chipov, na objekte bi olajšala razpoznavanje izdelkov prav v demontaži.

Skupaj z razvojem sistema za spremljanje izdelkov v času demontaže je treba ustrezno oblikovati informacije o materialih, ki so potrebni za odstranitev, so nevarni, se bodo ponovno uporabili ali gredo na smetišče. Prav tehnologija RFID omogoča povezavo s proizvajalcem izdelka in neposredni prenos podatkov za vrstni red demontaže in za vse aktivnosti, povezane z demontažo. Razen pri demontaži je tehnologija RFID uporabna kot informacija za rezervne dele pri vzdrževanju ter v distribuciji izdelkov. V ta namen je izdelana ustrezna podatkovna baza, ki vključuje ustrezno zgradbo in je avtomatično generirana pri razvoju izdelkov.

Izvleček: Moderna proizvodnja zahteva distribuirano proizvodnjo. Danes so podjetja specializirana za posamezne tehnološke procese. Sodelovanje pri procesih je odvisno od neštetih stikov med delavci in izmenjave informacij tako v fazi montaže kot v fazi demontaže. Tehnologije RFID so lahko resnično v pomoč pri identifikaciji objektov v smislu stalnega razvoja izdelkov glede na demontažo, recikliranje in ponovno uporabo. V tem prispevku so predstavljeni tudi arhitektura sistema VCDE in realizacija tehnologije RFID kakor tudi obvladovanje podatkov v času celotne življenjske dobe izdelka, to je od razvoja, izdelave, montaže in uporabe izdelka. Poseben poudarek je na uporabi tehnologije RFID pri demontaži in recikliranju.

Ključne besede: tehnologija RFID, sodelujoče načrtovanje, montaža, demontaža,