Strojniški vestnik - Journal of Mechanical Engineering 54(2008)11, 759-767
UDC 658.5

Paper received: 17.10.2007
Paper accepted: 25.09.2008

Radio Frequency Identification Technology Application in Disassembly Systems

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This paper presents the results of developing a model of RFID technology application in disassembly systems as a solution for a problem of rapid arrival of numerous products at a waste dump. During the process of disassembly and dismantling the basic components, they should be redirected to the disassembly systems for renewal, reprocessing and recycling. An integral part of the WEEE (Waste Electrical and Electronic Equipment) directive is the product take back strategy, which supports the endeavor to recycling as efficient as possible. System processes, like disassembly, make it possible to selectively separate the renewable, non-recycling and dangerous components from those which are recyclable. Appropriately planned process of disassembly, together with recycling and waste disposal, can help to efficiently manage the products during their life cycle. In order for something to be achieved, proper strategies should be considered. The collection of data about all kinds of flows of products, materials, parts/subassemblies and dangerous components/materials are necessary at the end of the life cycle. By applying RFID (Radio Frequency Identification) technologies to the systems for refining the outdated product, the management of all the above mentioned flows can be improved. Information gathered in this way is reliable, precise and dynamic. They could provide optimum management with products that have come to the end of their work lifetime.

Keywords: radio frequency identification technology, end of life cycle, disassembly systems

0 INTRODUCTION

Contemporary production conditions demand the application of distributed production concept, because there is an enormous pressure on the manufacturers to comply with market changes and continuous shortening of the product life cycle [9]. Virtual Manufacturing Systems (VMS) are currently more and more indispensable for obtaining the information about future properties and the state of manufacturing in any production company [8], and a help for dealing with the problem of dynamic changes and shortening of the product life cycle. RFID technology could be appropriate solution for problems regarding automatic identification and data acquisition. Information gathered in this way could be crucial for designing and functioning of VMS and Virtual Disassembly System (VDS).

There is a need for finding a good solution for a problem of production of certain types of products and their disposal into the waste dumps, in order to reduce and control the quantity of such waste, because the waste is being made in ever-increasing quantities. According to some researches, quantity of electrical appliances being used in every household is about 3.3 tones for one citizen per life time of which: large household appliances 69%, small household appliances 8%, information technology and telecommunications equipment 7%, consumer equipment 13%, lighting equipment < 1%, electrical and electronic tools 2%, toys, leisure and sports equipment < 1%, monitoring and control instruments < 1% [7]. Having this in mind, production systems for the processing of such waste are designed and put into use.

Disassembly is just one of the processes in the life cycle of a product [8] and lately it has attracted a lot of attention, considering its key role in reassembling and recycling of products. This is due to ecological and economical reasons. The echological side of the problem is seen in ending numerous products at waste dumps and in depletion of non-renewable natural riches. The economical side of the problem of disassembly is seen in the need for a design of the disassembly system in a way that the value of the disassembly process result is grater then the resources invested for its proper functioning [4].

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The end result of the disassembly is frequently changing, depending on the state of the product, especially when we realize that we are talking about technologically outdated products.

Strategies for managing products at the end of their life cycles, the problem of shaping the production system to refine the products at the end of the life cycle and using of RFID technology are presented in this paper work. Other similar researches have been done in this field [10] and [11]. This approach of using RFID technology is rather new and it is a challenge for a research.

1 STRATEGIES FOR PRODUCTS AT THE END OF THE LIFE CYCLE

First step in designing disassembly system process is to consider possible end of life strategies for products. Strategies for products at the end of a life cycle represent methodes, which are used to conduct the general direction of products, and only suggestions are given for the management of a product at the end of a life cycle. Studies related with the strategies of the products end of a life cycle are numerous [4] and [5]. The most accepted, and in its character, the most comprehensive classification of the products end of a life cycle is [1]:

1. re-use of used products,
2. reconstruction of used products,
3. usage of already used products for spare parts,
4. recycling with disassembly,
5. recycling without disassembly,
6. dumping of the used products.

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

Reconstruction of used products is applied due to modernize or to upgrade their performances. The purpose of this strategy is to attain a product, which is in quality less or very similar to the quality of the new products. The quality of the reconstructed products depends on the determined depth of disassembly. If a product is disassembled to the level of parts and a control and a replacement of all 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, after applying the disassembly.

Appliance of already exploited products for spare parts is being frequently used. In certain companies, out of date products are being collected in an organized manner. The purpose of this strategy is to take a relatively small part of sub modules from a used product and use them for the above mentioned strategy, or for another purpose, and the rest will be used for material recycling.

Recycling with disassembly is a strategy used for separating parts made of different material, before its 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 determined 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 the product and then crush it and sort it by type of material.

Disposal is, from the ecological point of view, the most inconvenient strategy for disposing products on the waste dumps. Having the above mentioned strategies in mind, it is necessary to design an appropriate production system.

2 STRATEGY SELECTION FOR PRODUCT AT THE END OF THE LIFE CYCLE

The production system for product processing at the end of life cycle has a quite complex structure, since there is a need for more then one technologicaly different subsystem like [4]:

1. disassembly,
2. reassembly,
3. recycling,
4. waste incineration,
5. hazardous waste storage,
6. waste storage.

The choice of strategies for reconstruction of used products (2), usage of already used products for spare parts (3) and recycling with disassembly (4) are made according with the both momentary product condition and suggestions taken from the database for particular product. A production system for product processing, according with chosen strategies for product management at the end of the life cycle, is shown in the Figure 1. [4].

In the most general case, if for the given product (p_i), all three potential strategies are chosen as possible, which comprise the need for disassembly (strategies 2, 3 and 4), then the production system for processing of such products contains in itself all the elements as in the previous figure. In case we choose only the strategy number 4, then a subsystem for repair does not exist.

When choosing strategies 3 and 4, a subsystem for repair possibly exists. Depending on the type of product and the type of repair, the repair subsystem does not have to be specially separated. It is important to notice that in the procedure of the product disassembly, during the parts selection, a flow of materials must be planed for the parts that are headed for reassembly. In other words, it is often very possible to conduct, in a same place, within one subsystem where the disassembly is conducted, a second assembly of the product. A subsystem is being shaped for disassembly/reassembly, with a developed procedure for disassembly, selection of parts/subsystems and then, the reassembly of the required elements. In this case, a line for disassembly and a line for reassembly (assembly) are completely overlapping.

3 PRODUCT DISASSEMBLY PROCESS

Disassembly can be defined as a process of separating a product into its basic parts or subsystems, including the analysis on the condition of products and the selection of dismantled parts [4]. That is always an assembly of operations, which are conducted on technological systems for disassembly with the help of certain tools and fixtures.

In the disassembly, the operation procedure is accomplished according to an adequate technological procedure, which is designated for every work place in particular. The procedure implies, in the most general case, the following [4]:

- accomplishing operation with the help of appropriate tools and fixtures,
- analysis of the state and the diagnosis of the disassembled components (part/subsystem),
- selection of the disassembled components (part/subsystem) according to previously accomplished analysis of the condition and the diagnosis.

Basic problems in designing and working processes of disassembly systems are in a component selection phase. It is a result of a lack of information about products, and different product condition arrived in disassembly system. That is the reason for expansion of product design documentation with another document - scenario for component selection (Table 1).

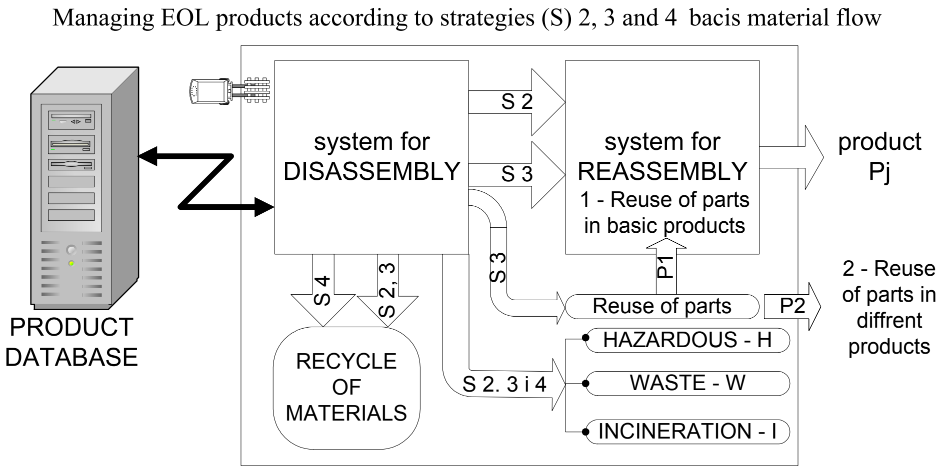

Fig. 1. *Production system for processing the products at the end of the life cycle*

In essence, we distinguish the next possibilities for the selection of components after the process of disassembly:

- dangerous components – materials (*H* (hazard)),
- material recycling (*R*),
- reusable (*P*),
- finishing (*D*),
- incinerate (*I* (incineration)),
- waste disposal (*W* (waste)).

Scenario for component selection is important document not only in designing disassembly system process, but later when system is functioning. It enables dynamic correction of variant component selection (parts/ subassemblies). There are many possible selection alternatives for some components (Table 1.). The reason is that products arrive in disassembly system in different conditions. It is important to emphasize that not all parts are necessary to pass through the phases of condition analysis and diagnosis. This can be applied in the case when in a selection scenario (procedure) for the disassembled part it is not foreseen to have more possible variants of selection, but only one (e.g. recycling). In this case, right after the process of disassembly, a selection of the components is accomplished according to the previously determined scenario.

4 IMPLEMENTATION OF RFID TECHNOLOGY IN A (SUB) SYSTEM FOR DISASSEMBLY

In the (sub) systems of disassembly, we often find obstacles for different reasons. One of them is a problem of a lack of any kind of information regarding the newly arrived products for processing (disassembly) and their distribution, after the operation, from specific work places [3]. Before and after conducting certain disassembly operations, information are crucial for efficient and effective decision making and for general management of the work processes.

Improvement of the quality of transferring information for conducting certain operations of disassembly, and then for the analysis of the state, diagnosis and selection of the disassembled components into appropriate flows, is one of the steps for general improvement of the processes for managing products at the end of the life cycle.

With the aim of faster distribution of real time information to according information flow nodes, it is necessary to use RFID technologies.

4.1. RFID Technologies

Radio Frequency IDentification (RFID) is a technology that enables automatic reading of multiple objects at the same time, without the need for individual scanning. The tag keeps in itself an Electronic Product Code (EPC) of every object that is read with the help of a remote reader.

EPC is a 96-bit numerical code written on a "smart tags" memory chip, which is fixed to individual products and physical objects. In this way, AUTO ID makes the dynamical acquisition of data possible, and products identification is located in every product with a unique print [2].

Table 1. *Component selection scenario*

Possible strategies for product:										
Part ID	Modul ID	Pcs	Disassem-bly level	......	Possible variants of selection after disassembly					
					H hazard	R recycle	P1/2 reuse	D remanuf.	I inciner.	W waste
				...						
				...						

In every mentioned phase of the work process it is possible to upgrade the process by applying the RFID technologies, because of the advantages compare to other identification technologies.

Tasks that needs to be performed in disassembly system are complex and they involve not only disassembly proces but later analysis and diagnosys of component condition and their selection in adequate material/component flows. Decision about material/component variant selection is made according to the established diagnosis and suggested component/material variant selection obtained form the disassembly documentation database accordig with the RFID product identification i.e. document named Component selection scenario (Fig 2.)

Problems are mostly noted in [4]:

- providing instructions for performing technological processes of disassembly,
- selection process of disassembled components (parts/ subsystems / materials),
- divergence – dissipation of the material flows is obvious and especially characteristic for the disassembly processes; controling the flows and the quantity in the material warehouse for disassembled components (parts / subsystems / materials).

In these parts of information flows it is possible to apply RFID technologies with the goal of: gathering real time data, improving the quality and the availability of certain types of information needed for not only disassembly process but also for the selection of disassembled parts and reassembly process.

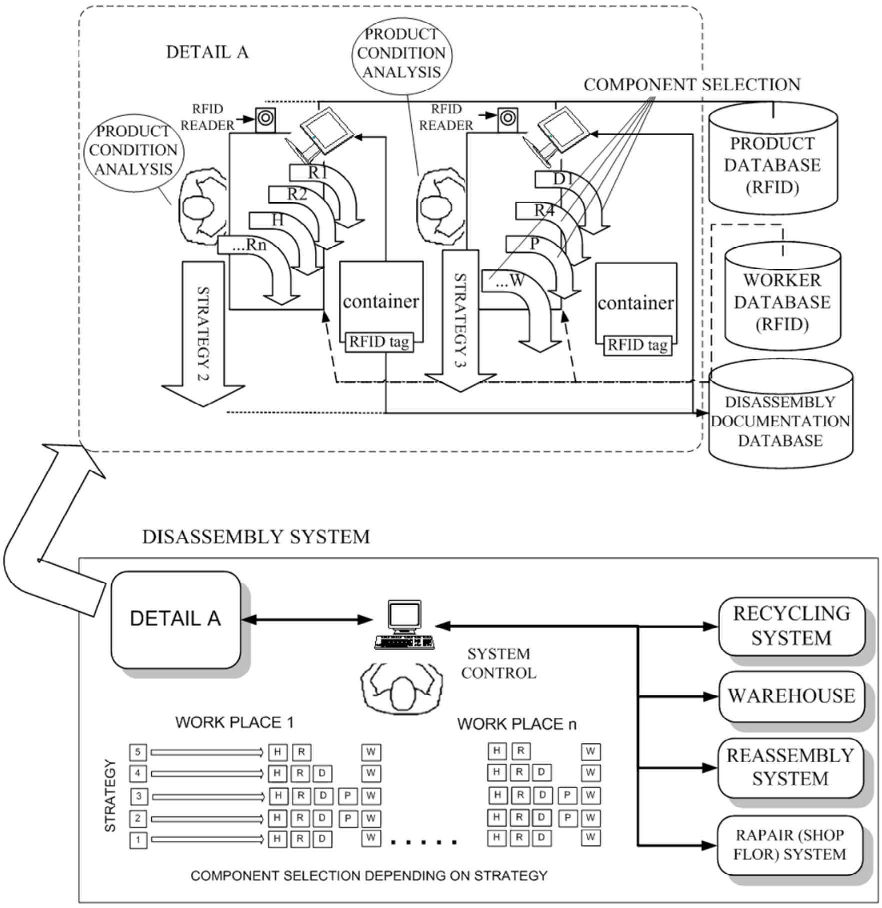

Fig. 2. *Material flows during the processing of an electric motor*

4.2. A Model of RFID Technology Application in the Disassembly Subsystem

When designing a disassembly system one of the problems arising is the way of gathering information from products meant to be disassembled. Various technologies for automatic identification can be applied like barcode and others but we have developed a model of RFID technology application in the disassembly subsystem.

The model presented in this paper is a starting point of a research project conceived at the Institute for Industrial Systems in Novi Sad (Republic of Serbia). The concept of implementation of RFID technology in a disassembly process, applied in Laboratory for Assembly and Disassembly Systems at the Institute for Industrial Systems, is shown in Fig. 3.

In the control station (1) one of the possible strategies (strategies for reconstruction of used products (2), usage of already used products for spare parts (3) and recycling with disassembly 4) is being selected for the product that has to be disassembled. After selection, RFID transponder (tag) is being put on the base part of the product (3) which corresponds to the class and type of the product, for which the strategy has been chosen, with its EPC. After that, the product is being put on the assembly line and then moves to the processing phase. In the work station, the RFID tag reader (2) reads an EPC and uploads set of instructions from the database for the technological procedure of disassembly, in the form of a visual presentation on the monitor in front of the worker. Instructions are in a step by step form. They are activated by taking appropriate types of tools, and after returning them to their station, the next step is activated.

Another possibility is putting tags on tools and checking usage of tools with the help of RFID reader (6). If the worker takes by mistake different tool the system alerts with the adequate massage. If a task is being executed without tools, initiation of the next instruction is done manually.

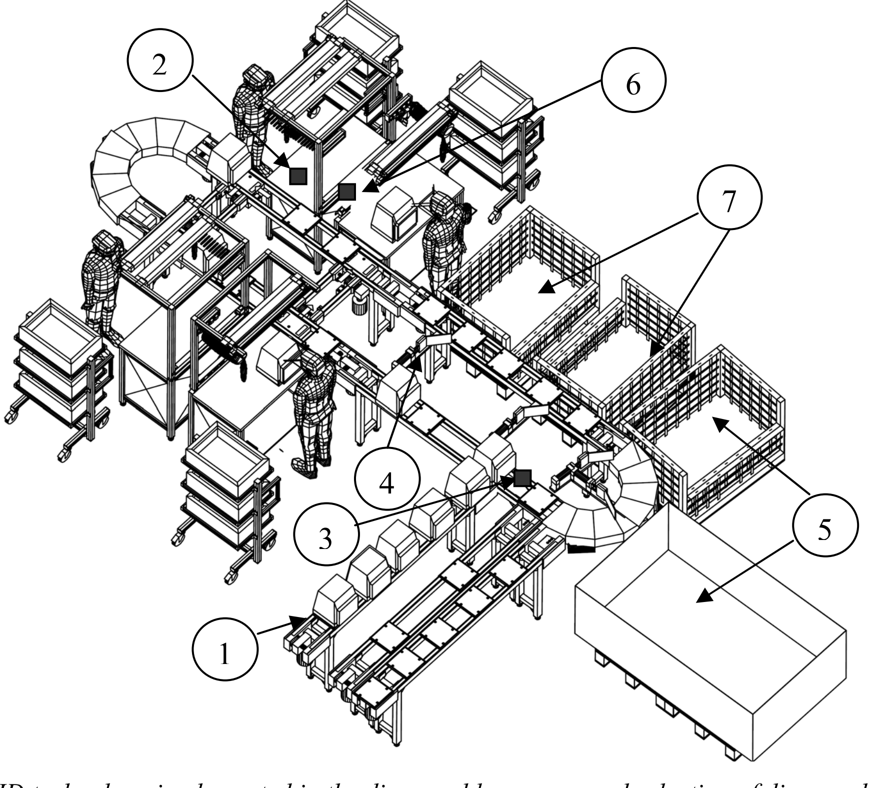

Fig. 3. *RFID technology implemented in the disassembly process and selection of disassembled parts of the products*

After the operation (set of operations) designated for that work station is completed, the set of instructions ends. The product is afterwards placed on the assembly line, and then on some of the other work stations. After reading its signal from the RFID tag, the identification of the object for that work place is being performed. If the object is supposed to be processed in that work station, the signal light flashes and the worker pick the object from the assembly line. After that the process is continued as in the previous operation with a set of instructions designed for that work place and for that product. If all the work stations are busy, the object is circling on the assembly line until the moment some of them are free. The tag has to be on the base part all the time. The base part is the last that leaves the disassembly process.

If some component (part or subassembly) can be used again according to strategy for usage of already used products for spare parts, after disassembly, then an appropriate tag is put on that component at momentary work station. The tag carries in itself an EPC that corresponds to the component on which it is being put. By placing the component with a tag on the assembly line, it is transported to the warehouse for later use.

Products, for which strategy for reconstruction of used products is selected, are moving all the time, from one phase to another, together with all the disassembled parts in the appropriate transport unit (e.g. a palette or a box – so-called kit). After completing all of the disassembly operations (required for executing reconstruction of the appropriate degree), the whole palette with all its disassembled components is being redirected to the overall subsystem, that is, toward the preparation warehouse for the product reconstruction.

Secondary materials, meaning materials that are going to be recycled, are being directed to adequate containers for the secondary material with the help of sensors which can recognize different types of materials, and the help of actuators (4), which push them into adequate containers. On each of the containers (5 for recycling, 7 for further disassembly processing) there is a tag-transponder, which corresponds to the type of material for which the container is designated.

Analyzing previous system with manual data acquisition and installed RFID system we came to the conclusion that overall time that product spends on disassembly line (from it's arrival to control station till putting it into containers) has been decreased for more than 17% (Table 2., Fig. 4.). It is important to mention that quantity of disassembled products is not big enough to provide fully valid statistically model of the impact of RFID technology on disassembly processes, since research was conducted in laboratory conditions.

This kind of concept enables a complete control of all material flows in the disassembly process. Also, it could be possible to track the number of parts in a warehouse and types of material and material quantity for recycling and for waste dumps.

One of the basic problems in the disassembly system is designing and organizing a disassembly system for different types of products.

Table 2. *Experimental results*

Average time for disassem. (min/ piece)	$\bar{t}_1$	$\bar{t}_2$	$\bar{t}_3$	$\bar{t}_4$	$\bar{t}_5$	$\bar{t}_6$	$\bar{t}_7$	$\bar{t}_8$	$\bar{t}_9$	$\bar{t}_{10}$	$\bar{t}_{11}$	$\bar{t}_{12}$	$\bar{t}_{13}$	$\bar{t}_{14}$	$\bar{t}_{15}$	$\bar{t}_{16}$	$\bar{t}_{17}$	$\bar{t}_{18}$	$\bar{t}_{19}$	$\bar{t}_{20}$	$\sum \bar{t}_{ii}$
Manual disassembly	5.5	5.2	6.5	6.9	7.5	6.2	8.2	9.7	8.0	7.8	5.1	5.3	9.5	9.0	8.4	8.2	5.0	5.3	7.0	9.0	143.3
Disassembly with RFID use	6.3	6.2	5.0	4.9	5.0	9.0	5.2	5.9	7.2	6.2	5.3	5.4	7.6	6.8	7.7	4.9	5.1	5.0	8.6	4.8	122.1
Model-type of monitor disassembled	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	
Σ t_{ii} (manual disassembly) > Σ t_{ii} (disassembly using RFID) (laboratory conditions conclusion: 17% shorter time - by using RFID)																					

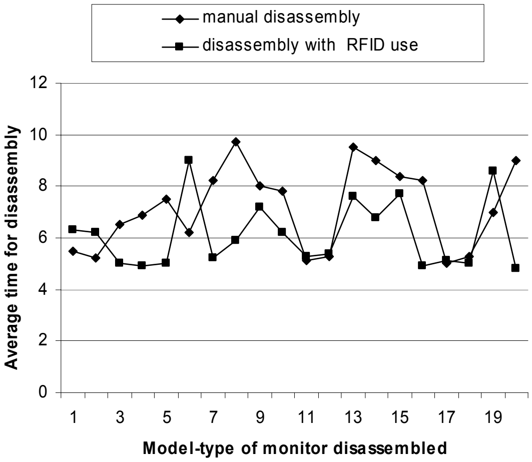

Fig. 4. *Average time for manual disassembly comparing to disassembly with RFID technology*

It is uncommon to organize a disassembly system for only one type of product, unless this way of the systems functioning is strategically planed.A suggested system design has a higher degree of flexibility in the sense of possibilities to process different types of products including different variants of the same product.

Savings in time and space required for the selection of components (parts / subsystems / materials) are also noticeable.

5 CONCLUSİON

The RFID technology has not been in wider usage in production, assembly and disassembly processes for various reasons. Some of them are: the popularity of the barcode, higher expenses due to RFID tags, privacy and security measures, lack of consensus on standards. However, some things are changing (e.g. the limited possibilities of barcodes in different conditions are being noticed, the tag prices are falling...) and slowly, the advantages of the RFID technology are being noticeable.

By implementing of RFID technology in the disassembly process it would be possible to quickly gather necessary information for the disassembly process, basically about the structure and the composition of the materials in the product. This information is necessary to define the technological procedure of disassembly completely and without any difficulties. Also, there can be integrated information about date of the production, so the system can be able to decide about later usage of the product in reassembling. All the products of the older generation, which currently arrive to the disassembly subsystems, carry with them exactly this problem – the lack of information.

The benefits arriving with the use of the RFID technologies are multiple. As stated above, the possibilities of supervision, control and data acquisition in real time for the whole process is upgraded by using the RFID technology.

The model of RFID technology in the disassembly process presented in this paper is a starting point of a research project conceived at the Institute for Industrial Systems in Novi Sad. It is important to mention that quantity of disassembled products used in this research is not big enough to provide fully valid statistically model of the impact of RFID technology on disassembly processes, since research was conducted in laboratory conditions. For a valid statistical model it would be necessary to implement it in manufacturing site. There is another challenge for overcoming problems with high level of electrical noise coming from many electrical devices in manufacturing site which interfere with the writing and reading of RFID tags that could be tested when the model is implemented in manufacturing site.

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