Proceedings in MANUFACTURING SYSTEMS
Proceedings in Manufacturing Systems, Volume 12, Issue 4, 2017, 155-160 ISSN 2067-9238

ARCHITECTURE OF THE RFID SYSTEMS USED IN PRODUCTION SYSTEMS

Adrian POPESCU[1,*], George ENCIU[2], Emilia POPESCU[3], Irina TACHE[4]

[1)] PhD, Lecturer, Machines and Production Systems Department, University “Politehnica” of Bucharest, Romania
[2)] PhD, Prof., Machines and Production Systems Department, University “Politehnica” of Bucharest, Romania
[3)] PhD, Assistant Professor, Machines and Production Systems Department, University “Politehnica” of Bucharest, Romania
[4)] PhD, Lecturer, Automatic Control and Systems Engineering Department, University “Politehnica” of Bucharest, Romania

Abstract: *This paper presents a case study which points out the way the radio frequency identification RFID systems are integrated into automated production flows from an information flow viewpoint. For the experimental research, we used an RFID system with a reader, a programmable logical controller for storing the data in a common database and a computer numerical control machine. Thus, two objectives were pursued: the presentation of the main types of architectures specific to radio frequency identification systems in terms of their performances and the way of storing the information specific to the processings performed by a computer numerical control machine for the workpieces or the workpieces to be processed. This was possible by attaching an RFID tag to each palette on which a workpiece to be processed was positioned. By means of the RFID system, we could identify the information on the processings to be performed or we could write information about the processings performed for each workpiece. In implementing and operating the radio frequency identification system, the positioning of RFID readers in relation to the tag palettes on the structure of the tool machine was taken into account to avoid potential interference.*

Key words: *radio-frequency, tag, reader, programmable logical controller, CNC.*

1. INTRODUCTION

RFID systems use radio frequency transmission to identify objects which have tags attached [1]. The simplest RFID system consists of a reader, a server, a database on which information is stored and tags, respectively (Fig. 1).

The reader contains electronic components which emit and receive a signal to and from the proximity tag, a microprocessor which checks and decodes the received data and a memory which records the data for a future transmission if necessary. The reader has an antenna connected so that data can be received and transmitted. The antenna can be integrated into the reader case or can be separated. A tag contains an electronic chip as the main element that controls the communication with the reader. This contains a memory section with the role of storing the identification codes or other data, which is activated when the communication is also activated [2].

RFID systems are used in many areas of activity. In the industry they can be used for production management. Wang et al. [3] used radio frequency identification to supervise and control production for a prototype manufacturing cell. The real-time data taken over from production through the RFID system could be stored by means of a programmable logical controller and used for real-time production planning.

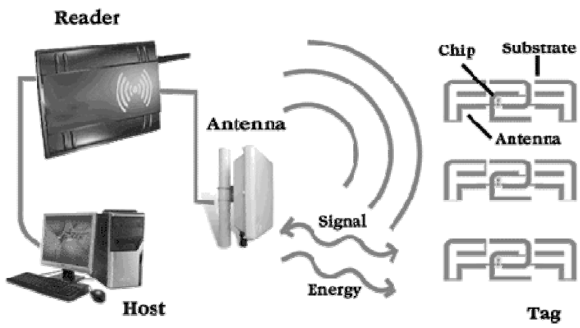


Fig. 1. General architecture of an RFID system.

Within flexible production systems, the use of the RFID technology has become essential for the proper operation and also without flow blocks. Barenji et al. [4] argue that the application of the RFID technology in manufacturing systems provides the basis for designing more flexible and agile systems through the use of real-time component information.

A major advantage of using the radio frequency identification technologies is presented by Sardroud in his paper [5] and consists of the possibility of integrating the latest innovations in communication technologies for real-time data collection. In this approach, the combination of the radio frequency identification technologies, the global positioning systems (GPS) and the General Packet Radio System (GPRS) technologies can facilitate extremely inexpensive solutions without a

* Corresponding author: Splaiul Independentei 313, sector 6, Bucharest, 060042, Romania
Tel.: +40 21 402 9168;
E-mail addresses: *popescuadrian_c@yahoo.com* (A. Popescu)

complex infrastructure and easy to implement in order to identify materials, components and equipment. The system presented in his paper is fully automated and allows the localization, identification and tracking of 3 elements, namely the production sites (off the enterprise site), route (transport) and production facilities in the enterprise.

Similarly, Chen et al. [6] propose a system capable of using the RFID technology to track the flow of materials into production systems, automatically generating and delivering VSM (value stream map) with real time data to users and then allowing them to remotely monitor the production system performance.

If properly implemented the radio frequency identification technology ensures complete process history, traceability and tracking of components which prevent production stopping so as to remedy process defects and product withdrawals [7].

In warehouses the RFID tags can be attached to palettes, pallets, containers or directly to the ceiling. Seungwoo et al. [8] propose for this purpose the localization of goods in the warehouse using passive RFID tags mounted on the ceiling. This reduces the time to identify the goods in the warehouse by spotting the necessary palette or pallet in real time [9].

2. APPLICATION COMPONENTS

2.1. The RFID System

It contains the following components:

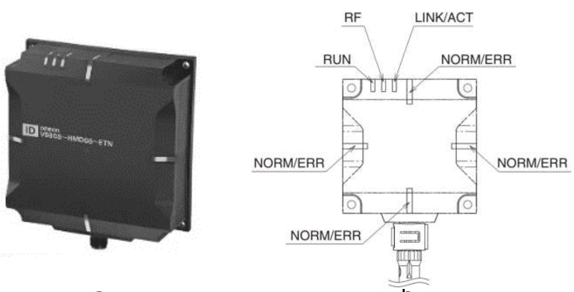
- an RFID reader;
- a programmable logical controller;
- RFID tags;
- an Ethernet switch;
- a voltage source;
- connecting cables;
- a server.

The RFID reader used in the application (Fig. 2) is produced by OMRON and integrates into one component the controller, the amplifier and the antenna.

Its main technical features are these:

- dimensions: 75 × 75 × 40 mm;
- power supply voltage: 24 VDC;
- communication interface: Ethernet 10BASE-T;
- communication protocol: Ethernet/IP.

The reading and writing distances of the information from and, respectively, on the tags, vary depending on tags performance and is between 0 and 100 mm.



a b

Fig. 2. RFID reader - V680S-HMD64-EIP: *a* – model; *b* – indicators status.

The programmable logical controller (Fig. 3) is used in the application to store the information retrieved/taken over from the RFID reader and to control the flow of information. Its main features are the following:

- number of digital inputs / outputs: 30 (18 inputs – 24 VDC, 12 relay outputs – 2 A);
- number of analog inputs: 2;
- program capacity: 10 k steps;
- data memory capacity: 10 k words;
- power supply voltage: 24 VDC;
- communication: Ethernet port;

The RFID tags used in the application (Fig,re 4) have a capacity of 1 kbyte. The reading/writing distance for these tags using the RFID-V680S reader is between 0 – 47 mm for reading the information on them and between 0 – 42 mm for writing the information on them.

The Ethernet switch (Fig. 5) is used to interconnect the elements of the RFID system. It has 5 Ethernet ports and the following technical features:

- power supply voltage: 24 VDC;
- switching capacity: 700 Mbps;
- throughput: 148800 pps;
- setting method: settings are made in the Switching Hub.

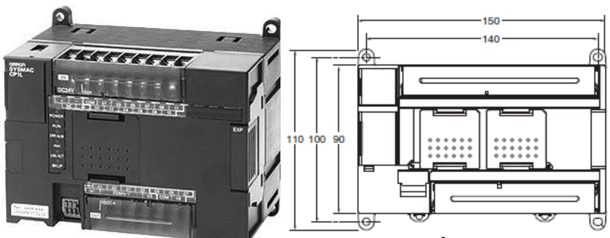


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Fig. 3. CP1L-EM30DR-D Programmable Logical Controller: *a* – model; *b* – overall and mounting dimensions.

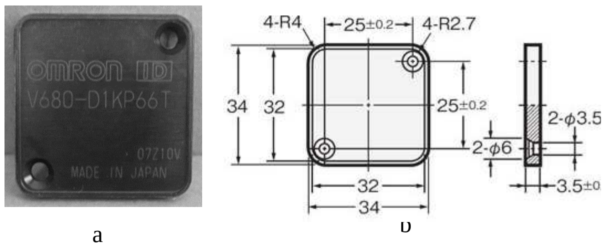

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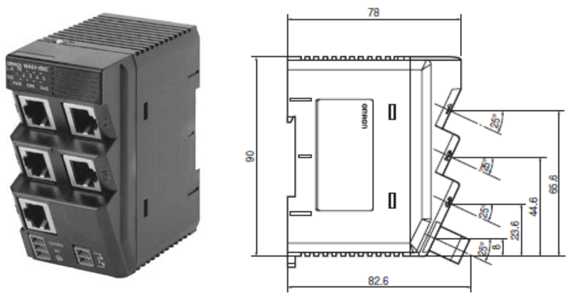
Fig. 4. RFID Tag - V680-D1KP66T: *a* – model; *b* – overall and mounting dimensions.



a b

Fig. 5. Ethernet Switch - W4S1-05B: *a* – model; *b* – overall and mounting dimensions.

2.2. The CNC Machine

The CNC machine used in the proposed application has 3 numerically controlled axes and the following technical features:

- Length of stroke on each axis:
  - axis X: 550 mm;
  - axis Y: 300 mm;
  - axis Z: 150 mm;
- Nominal torque for the engines on the X and Y axes: 1.85 Nm, rated torque for the Z-axis engine: 1.25 Nm;
- Maximum number of rotations for the milling engine: 29000 rpm;

The machine controller can command 4 CN axes and has in its structure inputs for specific commands received from external command systems.

3. MODELS OF ARCHITECTURES SPECIFIC TO RFID SYSTEMS

Connecting components in the RFID system can be done in many ways depending on the application's specificity [10]. The general architecture for connecting the system components when using a single RFID reader is shown in Fig. 6. The switch allows the connection between the programmable logical controller with Ethernet communication, the reader and the computer through which the communication results are monitored. The length of the Ethernet cable between the reader and the switch should not be more than 100 m.

The connection of the reader is made through a special connector that allows both the connection to the Ethernet switch as well as to the voltage power supply via special connectors.

Below we present two possible connection variants that can be used in production cells, flexible production systems, and in logistics flows.

The extension of the identification field is made if the tagged items do not have the same size and the tags have different orientations. This is done by positioning 4 RFID readers on both sides of the detectable item, as shown in Fig. 7 and also by using Field Extension Mode.

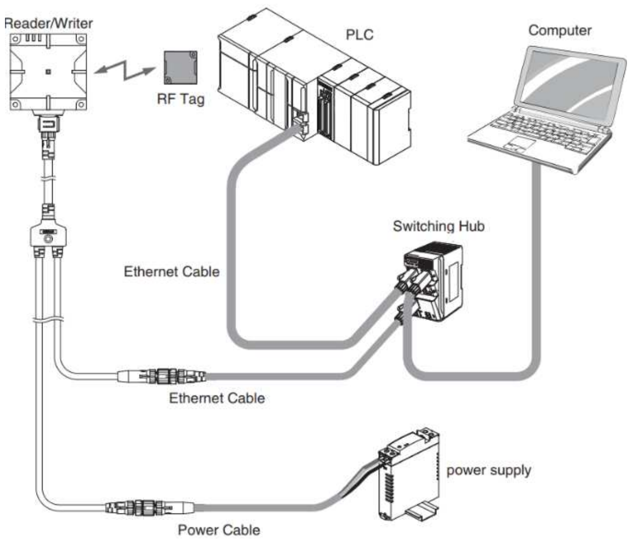


Fig. 6. Architecture specific to an RFID system with one reader.

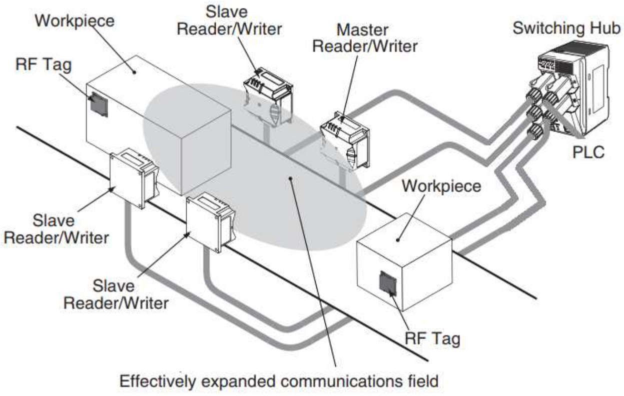


Fig. 7. Architecture specific to an RFID system allowing the identification field extension.

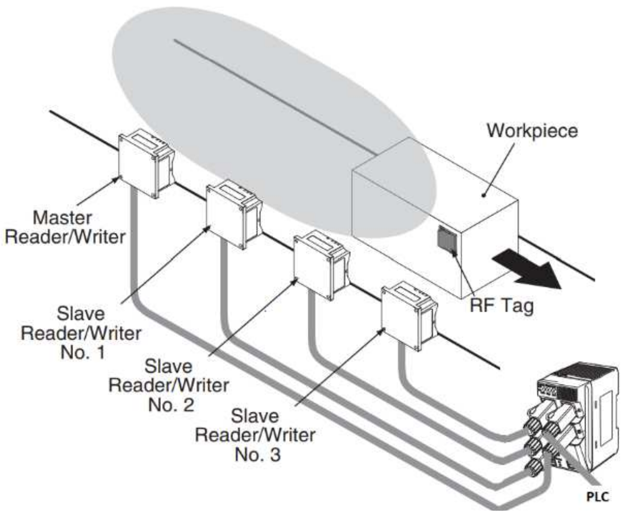


Fig. 8. Architecture specific to an RFID system allowing to reduce the time for information reading/writing.

If tagged goods are conveyed on high-speed flows, four readers can be used to allow each the reading of a data set separately which is then stored in a unitary manner by means of the High-Speed Traveling Mode, Fig 8.

5. CONFIGURING THE NETWORK SPECIFIC TO THE RFID SYSTEM

In the RFID system, the programmable logical controller controls all the actions to be transmitted to the reader. It reads and writes the information on the tags and then sends a response to the programmable logical controller.

The block diagram of the communication between the programmable logical controller and the RFID reader, relative to the type of actions that are done by these two components of the RFID system, is shown in Figure 9.

The exchange of information between the reader and the programmable logical controller is done through an Ethernet / IP protocol. The information to be transmitted from the programmable logical controller to the reader will be stored in memory areas different from the information that is transmitted from the reader to the programmable logical controller. This is shown in Fig. 10 by specifying the two D100 and D200 memory addresses [10].

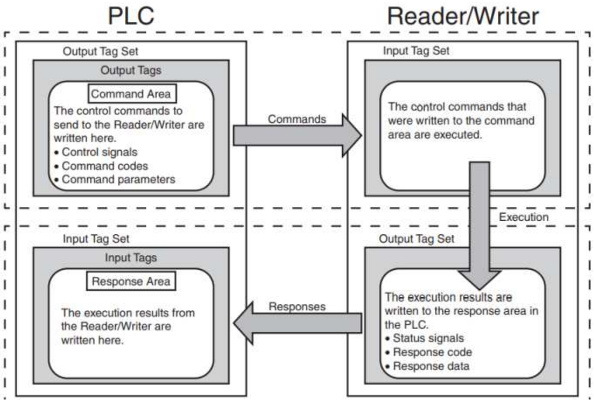


Fig. 9. The block diagram for communication RFID reader and PLC.

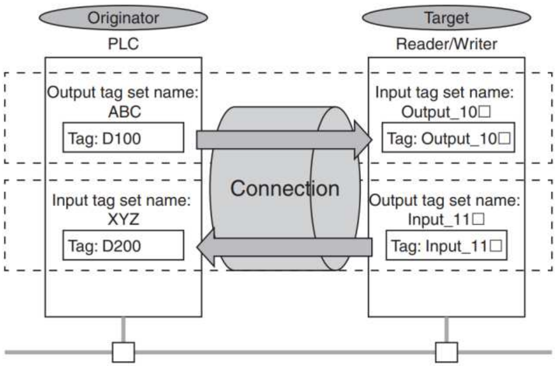


Fig. 10. Ethernet/IP protocol for information exchange between the RFID reader and PLC.

To configure the network specific to the RFID system with Omron components, the next these steps should be followed:

- connecting the reader, the programmable logical controller and the computer via the switch;
- setting the IPs through the web browser (Fig. 11) in correspondence with the values in Table 1.

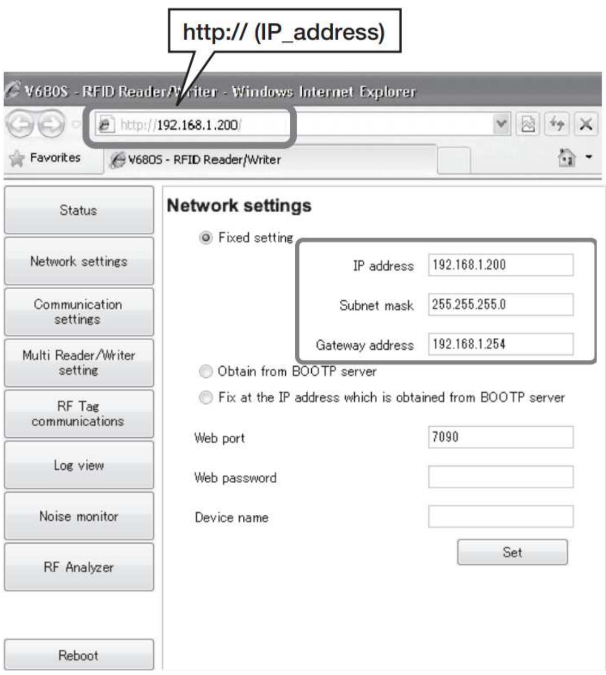


Fig. 11. Network interface for the IPs setting.

Table 1

Default IP address of the Reader/Writer

Setting	Default setting
IP address	192.168.1.200 (fixed setting)
Subnet mask	255.255.255.0 (fixed setting)
Default gateway	192.168.1.254 (fixed setting)

After selecting the IPs, the communication is set up and commands from the programmable logical controller to the RFID reader can be launched.

The most important actions that can be done through commands are these: tag specific ID reading, tag data reading, tag data writing, blocking of writing information on the tag, rewriting tag information, restoring data, copying data from one tag on another (in this case, two RFID readers are required), initialization, communication type setting and operation mode setting.

6. CASE STUDY

Integrating the RFID system into a manufacturing cell allows for more efficient management of information about the actions taken within that cell. In order to show how this can be done, an experimental stand consisting of the following equipment (Fig. 12) was used: the RFID system (reader, PLC, router, RFID tag), the CNC machine (including its controller) and the computer (server) that allows interfacing between the CNC machine control applications and the applications specific to the RFID system.

The positioning of the reader relative to the tag attached to the palette had to be done in such a way that it corresponds to the parameters specified in their technical data sheet (Fig. 13) to work properly. Thus, the angle θ between the tag and the reader, the distance *Y* between the reader and the tag, and the distance *D* between the tag and the metal object behind it (the metal palette), were used for the experimental research according to Table 2.

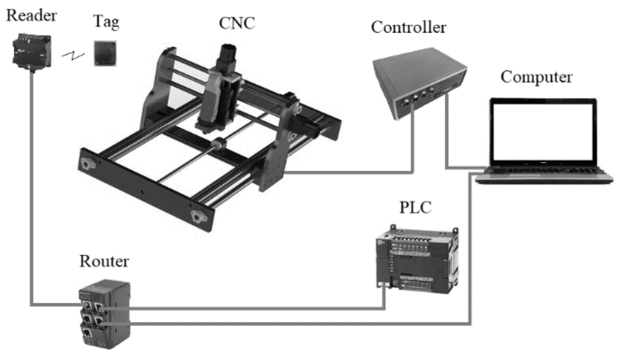


Fig. 12. The components of the experimental stand and the connections between them,

Table 2

Specific values for positioning distances

No.	θ [°] / communications range [%]	Y [mm]	D [mm] / communications range [%]
1	0 – 10 / 0	0 – 42	20 / 90
2	0 – 10 / 0	0 – 42	30 / 94
3	0 – 10 / 0	0 – 42	40 / 97

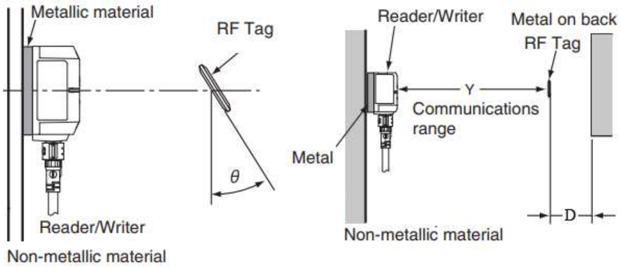


Fig. 13. Reader positioning distances relative to the RFID tag.

For example, 3 numerical control programs were used. Each program allowed the processing to obtain three different workpieces, having different processing characteristics. Since the emphasis was not on the CN program, but on how to identify it and how to write the information about the processing on the tags attached to the workpieces, simple CN programs were used.

Each workpieces item was positioned on an attached RFID tag palette.

After positioning the palette on the tool table, by means of the RFID system, the program-specific code to be used for processing could be identified. The correspondence between the codes written on the RFID tags and the CN programs on the basis of which the processing was carried out are presented below.

The "Read Data" command was used which allows to read the information from the tag if this is in the reader's field. Calling/Using this command is done by the 0002 hex function, which has a size of 2 bytes.

To the tag attached to the first workpiece, the 1100 hex code was assigned stored on 2 bytes. Therefore, the final form of the command that allows reading the tag attached to the palette which has the workpiece is shown in Table 3

The last line in the table corresponds to the allocated data memory and can be preset. In this case, the memory was preset at the value of a data word and can store 256 identification IDs specific to CN programs.

Similarly, for the other two tags attached to the palettes, the 1200 hex and 1300 hex codes, respectively, were assigned. Therefore, considering the IDs for identifying the CN programs used to process the three semi-finished products positioned on the tag palettes, as 34, 45, and 90, respectively, in Tables 4, 5 and 6, the codes read from their memory are also presented.

Table 3

Hexadecimal code which allows reading information on the tag attached to the first palette having the workpiece

Data name/ User address	Bit5-12	Bit11-8	Bit7-4	Bit3-0
CmdCode	0	0	0	2
CmdParam1	1	1	0	0
CmdParam2	0	0	0	1

Table 4

The code read from the tag attached to the first palette

User address	Bit15-12	Bit11-8	Bit7-4	Bit3-0
1100hex	0	0	2	2

Table 5

The code read from the tag attached to the second palette

User address	Bit15-12	Bit11-8	Bit7-4	Bit3-0
1200hex	0	0	2	D

Table 6

The code read from the tag attached to the third palette

User address	Bit15-12	Bit11-8	Bit7-4	Bit3-0
1300hex	0	0	5	A

Table 7

Information / IDs written on tags

Parameter Name	Tag 1	Tag 2	Tag 3
Processing Time	10 min	25 min	8 min
Processing Date	29.09	29.09	29.09
Semi-finished Material	Plastic 19	Aluminum 11	Wood 39
CN Machine Operator	Xyz 1	Xyz 1	Yzx 4

After the processing performed for each workpiece, information regarding the processing time, the date of the processing, the workpieces the material and the name of the operator who assisted the CN machine during the processing were written on the attached tags.

Table 7 lists the information that was written on each of the 3 tags or the IDs in the database stored on the server.

To write the information on the tag the "Write Data" command was used, which allows the tag to be written if it is in the reader's field. Using this command is done by the 0003 hex function, which has a size of 16 bits.

In correspondence with the assigned codes for each tag attached to the pallets (1100 hex, 1200 hex and 1300 hex respectively), the final form of the commands allowing the writing of the information in Table 7 on the 3 tags is presented in Tables 8, 9 and 10.

Table 8

Hexadecimal code which allows writing information on the tag attached to the first palette having the workpiece

Data name	Bit5-12	Bit11-8	Bit7-4	Bit3-0
CmdCode	0	0	0	3
CmdParam1	1	1	0	0
CmdParam2	0	0	0	4
CmdData[0-1]	0	0	0	A
CmdData[2-3]	2	9	0	9
CmdData[4-5]	0	0	1	3
CmdData[6-7]	0	0	0	1

Table 9

Hexadecimal code which allows writing information on the tag attached to the first palette having the workpiece

Data name	Bit5-12	Bit11-8	Bit7-4	Bit3-0
CmdCode	0	0	0	3
CmdParam1	1	1	0	0
CmdParam2	0	0	0	4
CmdData[0-1]	0	0	1	9
CmdData[2-3]	2	9	0	9
CmdData[4-5]	0	0	0	B
CmdData[6-7]	0	0	0	1

Table 10

Hexadecimal code which allows writing information on the tag attached to the first palette having the workpiece

Data name	Bit5-12	Bit11-8	Bit7-4	Bit3-0
CmdCode	0	0	0	3
CmdParam1	1	1	0	0
CmdParam2	0	0	0	4
CmdData[0-1]	0	0	0	8
CmdData[2-3]	2	9	0	9
CmdData[4-5]	0	0	2	7
CmdData[6-7]	0	0	0	4

The last 4 lines in each table represent the information written on the RFID tags.

Both for tag reading and, the identification codes for the specified parameters have been compared or taken from a database found on the server.

7. CONCLUSIONS

Radio frequency identification systems allow for the management of large amounts of information, and real-time information access by all the information systems of the applications.

Within production systems, access to real-time information is very important, and therefore the implementation and use of RFID systems allow for increased automation.

The proper exploitation is closely related to the proper implementation of the RFID equipment. Thus, in the experimental research presented in this paper, the three cases mentioned in Table 2 regarding the positioning of the readers with respect to the tags and, also, the positioning of the tags in relation to the surrounding metals were tested. Similar results have been obtained, the system functioning correctly, without reading or writing errors.

To read and write the tags, a very small number of parameters was used for the CN programs documentation. That is why in the future research it is desired that the number of stored information regarding the CN-specific parameters be much higher and the exploitation conditions be more diversified.

ACKNOWLEDGEMENTS: This work has been funded by University "Politehnica" of Bucharest, through the "Excellence Research Grants" Program, UPB – GEX 2017. Identifier: UPB- GEX2017, Ctr. No. 55/25.09.2017.

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