THE ROLE OF RFID TECHNOLOGY IN THE INTELLIGENT MANUFACTURING

Asst. Prof. Zeba G. PhD¹, M.Sc. Čičak M. ¹, Prof. Dabić M. PhD ²,³
Mechanical Engineering Faculty in Slavonski Brod, J. J. Strossmayer University of Osijek, Republic of Croatia ¹
Faculty of Economics and Business, University of Zagreb, Republic of Croatia ²; Nottingham Trent University, Burton Street, Nottingham, United Kingdom ³
gzeba@sfsb.hr

Abstract: The manufacturing industry is facing high competitiveness from rivals and high demands from customers. Industry 4.0, as a new manufacturing paradigm, also imposes its demands. The main driver of Industry 4.0 is the development of new innovative technologies including information and communication technologies whose rapid development has given impetus to the development of automated data acquisition systems. The RFID technology is one of the key technologies for intelligent manufacturing that encompasses advanced information and manufacturing technologies. Although the RFID technology is used in Croatia (mostly for identifying persons, access control, payment control, etc.), there is no wider use of the RFID technology in the industry where the main problem of low competitiveness is caused by low levels of innovative capabilities and obsolete technological equipment. The EU strategic documents (e.g. Europe 2020, Digitising European Industry initiative) encourage the digital transformation of industry (with an emphasis on investment in technology and innovation). One of the goals of the Industrial Strategy of the Republic of Croatia 2014-2020 is to increase productivity. To achieve this goal and improve competitiveness it is necessary to increase the use of the RFID technology in industry as the basis for digital transformation.

The goal of this paper is twofold: to present bibliometric literature review on the RFID technology, and to present advantages of the RFID technology in the context of intelligent manufacturing with reference to the case of Croatian economy.

Keywords: RFID, INTELLIGENT MANUFACTURING, INDUSTRY 4.0, INNOVATIVE TECHNOLOGIES

1. Introduction

Currently, the increased customer demands for high-quality customized and personalized products, with short delivery times, manufacturing companies need to respond quickly to these requirements, increase product efficiency and quality. Traditional production systems cannot respond to such requirements. In order to survive in the market and in view of the requirements of Industry 4.0, manufacturing companies must be digitally transformed and turn to a new paradigm, intelligent manufacturing.

Intelligent manufacturing with features such as learning, reasoning, and acting is closely related to Industry 4.0, as it is called the fourth industrial revolution [1]. Intelligent manufacturing depends on timely data acquisition, distribution and use of different types of data from production resources, products and production processes. The connection of all these elements enables manufacturing systems to become more agile, making decisions based on real-time information and being more adaptable to changing market demands. Technologies of manufacturing intelligence that can be linked to different enterprise information systems (e.g. Enterprise Resource Planning system (ERP), Supply Chain Management system (SCM) etc.) are being rapidly developed and facilitate improving timely decision-making based on real-time information of the actual state of manufacturing and supply chain processes. New innovative technologies that enable such transformation and intelligent manufacturing include: Information and Communication Technologies (ICT), Cloud Computing, Big Data Analysis, Artificial Intelligence. According to [2] there are the four key components of Industry 4.0 (based on literature review): Cyber-Physical Systems (CPS), Internet of Things (IoT), Internet of Services (IoS) and Smart Factory. The development of new, innovative technologies that support these components, especially IoT, leads to that a manufacturing in the context of Industry 4.0 will more and more intelligent [3]. One of the key technologies on which the Internet of Things is based is Radio Frequency Identification (RFID) technology.

Today, technologies of manufacturing intelligence that can be linked to different enterprise information systems are being rapidly developed and enable improving timely decision-making based on real time information of the actual state of manufacturing and supply chain processes.

2. RFID technology in manufacturing

The RFID technology for automatic identification and tracking enables data acquisition in real time, which can significantly improve planning, scheduling and production monitoring. Using RFID technology, sensors and actuators, resources of an enterprise become smart objects. The RFID technology has a significant role in digital and intelligent manufacturing because it enables all production resources (machines, people, products, etc.) to communicate with the manufacturing system in real time, wirelessly using radio waves. Using RFID technology, real-time and accurate production data such as material consumption, data on workers, the status of machines, order progress, data on scheduling, product location, data on materials and tools monitoring are gathered [4]. The collected data is transformed into information and knowledge that makes manufacturing intelligent. The RFID technology enables automatic identification and monitoring of all resources in production and products in all phases of its lifecycle.

The RFID technology is already widely used in manufacturing, to assembly lines, in maintenance, warehousing, transportation etc. [5-9].

RFID systems consist of three basic components: a transponder consisting of a chip connected to the antenna, a reader that transmits radio signals and collects data from the transponders and enterprise applications (Fig. 1). By attaching transponders to objects (all resources in manufacturing), they become smart objects that are capable of communicating with the environment.

![Fig. 1 Simplified working principle of RFID system](image)
2.1 Literature review

There are many published papers on the RFID technology. Within the databases of the Web of Science (WoS) platform, the first indexed article was published in 1985. The authors of article [Ngai, 2008] provided an extensive overview of published journal articles and conference papers on RFID technology for the 1995-2005 period. The classification of RFID technology applied in manufacturing, according to the author’s literature review, is presented in the article [9], the main application fields are: process management, tool management, warehouse management, supply chain management and life cycle management. The authors of the article [11] proposed a RFID-enabled real-time manufacturing model that would provide support to management to make the right decisions based on real time information. RFID, as one of the most significant technologies that enables mass personalized production in relation to mass customized production, is described in the article [12]. For the application of RFID technology in logistics, the Big Data Analysis methodology is suggested in the article [13]. The article [14] deals with RFID technology in terms of supply chain management. The opportunities for implementing the Just in Time philosophy in logistics using RFID technology are presented in the article [15]. Intelligent and integrated RFID (II-RFID) system that enhances traceability and visibility of products is presented in the article [16]. The article [17] emphasizes the advantages of using RFID technology in manufacturing that have been reported in the literature: reducing WIP, increasing utilization of machines, real-time information, improved scheduling and monitoring production, reducing errors in data entries compared to other methods (especially manual), shortened production cycle, improved satisfaction of customer.

A review of the literature shows that the RFID technology in production is dealt with from various aspects, proposals of technical solutions, models, production management, and supply chain management. Therefore, bibliometric literature analysis was conducted in order to gain a clearer insight into the trends in the research and development of the RFID technology in manufacturing, especially in the context of intelligent manufacturing and Industry 4.0.

3. Bibliometric Literature Analysis

The research methodology included searching the citation and index databases of the Web of Science (WoS) platform for the 1995-2017 period. The research involved only journal articles and proceeding papers, while other types of publications were excluded from the research. The first, search by keywords was conducted as:

- (“radio frequency identification” or RFID)
- (“intelligent manufacturing” or “smart manufacturing”)
- “Industry 4.0”.

Then, the databases of the WoS platform were searched to find overlappings of the main keywords in the articles, as stated below:

- The results derived from the keyword (“radio frequency identification” or RFID) were refined by the keywords: (“intelligent manufacturing” or “smart manufacturing”) delivered 31 results.
- The results derived from the keyword (“radio frequency identification” or RFID) were refined by the keywords: “Industry 4.0” delivered 32 results.
- The results obtained by keyword search (“intelligent manufacturing” or “smart manufacturing”) refined by the keyword: “Industry 4.0” yielded 112 results.
- The results obtained by keyword search (“radio frequency identification” or RFID) is refined by the keywords: (“intelligent manufacturing” or “smart manufacturing”) and “Industry 4.0”) yielded 7 results.

Figure 2 shows the number of journal articles and proceedings papers found in the databases of WoS platform according to the defined keywords.

4. Case of Croatia – PEST analysis

The implementation of innovative technologies that enable intelligent manufacturing and Industry 4.0 in Croatia, with a special focus on RFID technology, depends on the impacts of the political, economic, social and technological environment. In order to determine which impacts were carried out, the PEST analysis was performed. Table 1 shows PEST indicators by categories (political, economic, social, technological).

<table>
<thead>
<tr>
<th>Table 1: PEST indicators</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Political</td>
<td>As an EU member Croatia complies with the governmental strategies: Industrial Strategy of the Republic of Croatia 2014-2020, Smart Specialization Strategy of the Republic of Croatia 2016-2020, Strategy of Fostering the Innovation of the Republic of Croatia 2014-2020. However, there is a discrepancy between the strategies and the real-life situations; and investments in research, development and innovation are already becoming insufficient, although they have been additionally reduced, high VAT.</td>
</tr>
<tr>
<td>Economic</td>
<td>Opportunities for benefiting from the use of EU funds; GDP is stagnating or growing slowly; reduced foreign direct investment, foreign debt has been growing steadily; there is a risk that a strong entrepreneurial culture in Croatia will lose out if there is no basis for sustainable economic development (digital infrastructure, digitally skilled professionals and access to finance); according to EU Digital Transformation Enablers’ Index Croatia is very low (Croatia is only followed by Latvia and Romania).</td>
</tr>
<tr>
<td>Social</td>
<td>High unemployment; poverty; negative demographic trends and emigration; less and less skilled workforce; fewer students due to the emigration of young people; mismatch between education and labor market needs; low participation of population in lifelong learning; Croatia is among the most digitally aware countries in EU.</td>
</tr>
<tr>
<td>Technological</td>
<td>Obsolete technical equipment of the enterprises; lack of necessary knowledge and skills; level of innovation of the Croatian economy is low compared to the EU average; low level of business sector participation in research and development activities; slow progress on the integration of digital technology by businesses; low level of participation of researchers in the business sector; strong ICT industry; enterprises are above average users of cloud technologies.</td>
</tr>
</tbody>
</table>

According to the Eurostat data, the application of the RFID technology in the EU enterprises is on a steady rise. Compared to 2011, when the average RFID technology use for product identification in enterprises was 1.62% of enterprises, in 2017 it was 3.75% of enterprises. In Croatia, in 2017, or 4.54% of companies used RFID technology in product identification, compared to 2011 when only 2.49 % of enterprises used RFID for the same purpose.
In Bulgaria, the RFID technology was used for product identification in 9.18% of enterprises, more than in other EU member countries.

Figure 3 shows percentages of enterprises per EU member country that use Radio Frequency Identification (RFID) technology in 2018 as part of the production and service delivery or for the purpose of after sales product identification (data source: Eurostat). There are 4.5% of enterprises that use RFID technology for these purposes in Croatia compared to the EU average of 28 countries (4.2%).

Fig. 3 Percentage of enterprises per EU member, that use RFID technology in 2018 (as part of the production and service delivery or for purpose of after sales product identification).

5. Results and discussion

According to the results of the bibliometric literature analysis on WoS platform, term (“intelligent manufacturing” or “smart manufacturing”) first appeared in relevant literature in 1989. Since then researchers have shown continued interest in this topic, which grew rapidly after 2011 (see Fig. 4), which coincides with the emergence of the concept of Industry 4.0. There has been a significant increase in the number of relevant published articles and proceedings papers indexed in databases of the WoS platform.

The number of publications on intelligent / smart manufacturing is the largest in the research areas: Engineering, Computer Science and Automation Control Systems.

There are many published papers on the RFID technology. The first article that was indexed in citation and index databases of the WoS platform was published in 1985, although the technology itself was developed during World War II. The rapid rise in the number of published articles and proceedings papers on RFID technology emerged at the beginning of 2000, after the Internet of Things was development. A new, even greater, hike in the number of published articles and papers came after the emergence of the new Industry 4.0 paradigm. The bibliometric literature analysis within the WoS platform shows that RFID researches are represented in many areas such as engineering, computer science, telecommunications, oceanography, biodiversity conservation and many others. The number of articles and conference papers on RFID topic according to research areas with the greatest number of journal articles and proceedings papers is presented on Fig. 5. Most of the research on the RFID technology is in the field of engineering, followed by computer science, telecommunication, automation control systems and other areas that are important for intelligent manufacturing.

Fig. 4 Number of articles and proceedings papers published per year (indexed within Web of Science platform).

After filtering the results on the RFID technology according to the “Countries/Regions” field in the WoS platform and only for the EU member states, the largest number of published articles and proceedings papers on RFID have Italy, Germany, United Kingdom, France and Spain (Fig. 6).

The analysis of the journal articles and conference papers indexed in the databases of WoS platforms, according to keywords...
The industrial sector makes an important share in GDP in Croatia (21.76 % in 2017, according to the World Bank). Therefore, it is important to invest in new innovative technologies in order to enable the Croatian enterprises to meet the requirements of Industry 4.0 and become competitive.

7. References


6. Conclusion

Our research has highlighted the importance of the role of the RFID technology in manufacturing, which together with other new innovative technologies will facilitate the transformation of manufacturing into intelligent manufacturing.