RFID AS ONE OF THE CORE TECHNOLOGIES FOR REAL-TIME MANUFACTURING INTELLIGENCE

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ABSTRACT:

Growing competition in the global market, more demanding customers, the rapid development of advanced manufacturing and ICT technologies, impose on manufacturing enterprises the need for fast adaptation to the requirements of Industry 4.0, to remain competitive.
RFID technology for automatic identification, tracking, and data capturing in real-time, is one of the core technologies that enable the transformation of manufacturing to digital and intelligent manufacturing. This paper aims to provide a review of manufacturing in the context of Industry 4.0 and to emphasize the importance of RFID as real-time data capture technology for real-time manufacturing intelligence. Additionally, the paper presents trends in the research and application of RFID technology in intelligent manufacturing systems and Industry 4.0.

1. INTRODUCTION

Manufacturing industry has undergone several significant transformations through history, from the first industrial revolution when manufacturing was based on the power of water and steam, through the second industrial revolution with application of electric energy and mass production technologies and third industrial revolution with production automation, to today's digital manufacturing with interconnected automated systems and facilities in the fourth industrial revolution, named Industry 4.0. Increasingly complex customer demands and the rapid development of innovative technologies, particularly advanced manufacturing technologies and information and communication technologies, lead to the need for transformation of business models and manufacturing, that is knowledge and skills intensive and probably highly capital intensive [1]. Today's enterprises need to be more flexible, more effective and more agile and must quickly react to market demands for high quality customized products with shorter delivery times. The global market competition requires continuous modernization of manufacturing plants, business processes, and logistics, through a digital transformation that enables interaction between the physical and informational worlds. Digital transformation has a significant role in the global manufacturing industry and enables intelligent decision-making based on real-time information about the actual state of production and supply chain processes. Therefore, it is extremely important to collect data about production in real-time.
Industry 4.0 is based on the Industrial Internet of Things, Cloud Computing, Big Data Analysis, advanced robotics, additive manufacturing, Augmented Reality, Artificial Intelligence, simulation, horizontal and vertical integration, machine-to-machine communication, cybersecurity, etc. The main

pillars that enable intelligent manufacturing are Artificial Intelligence and Internet of Things [2]. One of the technologies that enable the Internet of Things, as significant supporting technologies for automated data acquisition and objects tracking, is Radiofrequency Identification (RFID) technology.

2. LITERATURE REVIEW

There are many definitions for Industry 4.0 in the literature, and one of them points out that it is the application of intelligent products and processes, which enables the automated gathering and analyzing data, and intraorganizational and interorganizational interaction using the Internet [3].
There are numerous papers on manufacturing in the context of Industry 4.0 and covering concepts smart factory, smart manufacturing, intelligent manufacturing systems, manufacturing intelligence, etc.

2.1. Intelligent manufacturing

There are papers on topic manufacturing intelligence and intelligent manufacturing systems, i.e. [4-7]. The term „Manufacturing Intelligence“ was registered in the WoS database in 1993 for the first time, meaning data representations, which may include the range of data and associated knowledge [8]. Figure 1 shows the number of publications on the topic of manufacturing intelligence by the years, in databases of WoS platform (all types of publications are excluded, except journal articles). It can be noted a rapid rise in interest of researchers, according to the number of published journal articles, after the concept of Industry 4.0 has emerged.

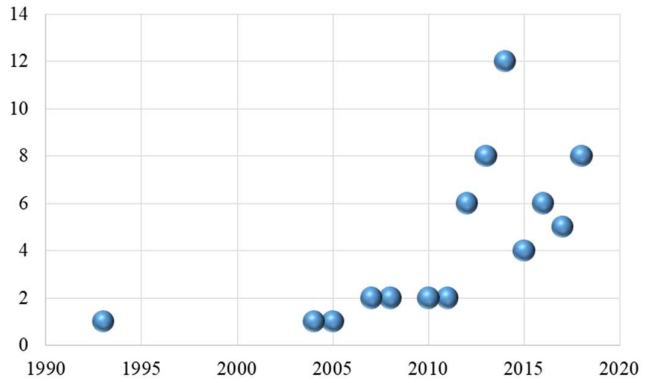

Figure 1: Number of articles on topic Manufacturing Intelligence, by years

Technologies that support manufacturing intelligence enable to production resources (e.g. devices, machines, people, products, etc) to communicate with each other, to act and make decisions autonomously and adjust their actions to changing requirements and current state of production,
Today, in the context of Industry 4.0, the concept of mass production of customized and personalized products is possible thanks to manufacturing intelligence. In the reference [9] authors integrated the emerging technologies (such as the Internet of things (IoT), Cyber-Physical Systems (CPS), Internet of Service (IoS), and RFID) into the framework for the realization of mass personalized production. The RFID technology as a key supporting technology of Internet of Things is one of the core technologies for the realization of intelligent manufacturing [10].

2.2. RFID technology

There are many publications on the topic of RFID technology. The first indexed article within the databases of the Web of Science (WoS) platform was published in 1985, but the wider use has begun in the 2000s. RFID is the ubiquitous technology today.

The RFID technology in the literature featured as one of the key technologies for automatic identification and tracking the status of objects in the production and logistics in real-time, and has applications in the manufacturing [11-13]. Prerequisites for application of Intelligent Manufacturing Systems in the industry are computer and factory automation systems with the application of sophisticated embedded devices (RFID transponders, sensors, actuators, etc) on a factory floor level and direct communication with manufacturing resources. Examples of applications of Intelligent Manufacturing System are described in the literature e.g. in metal component production [14]. An intelligent and active job shop scheduling system, based on RFID, is proposed by authors of paper [15]. Study case about the application of RFID technology and wireless networks for monitoring manufacturing status to obtain advantages for a manufacturer of tool-machines and molds is presented in paper [16]. Application of RFID technology to control an intelligent manufacturing system is described in the paper [17], etc.

RFID systems operate wirelessly, using radio waves, and comprise three main components: a transponder (chip connected to the antenna), a reader that transmits radio signals and collects data from the transponders and vice versa (both components are protected in the housings for adverse industrial conditions) and enterprise applications (Figure 2). The objects to which the RFID transponder is attached (all resources in manufacturing) become smart objects with the ability to interact with the environment (other objects and systems).

Figure 2: Simplified working principle of RFID system

3. BIBLIOMETRIC LITERATURE REVIEW

The research methodology is based on the search of publications within the database Web of Science Core Collection. We have conducted a search with keywords in the Topic section; RFID or „radio frequency identification“ or „radiofrequency identification“ or „radio-frequency identification“, Timespan is defined from 1955 to 2018. The search delivered 17.185 publications. We were focused on articles only, and refinement of results with publication type Articles delivered 8.923 results. After refinement with keyword „manufacturing", we have obtained 577 articles.

For the qualitative data analysis, we used software Atlas.ti to extract keyword frequencies. Figure 3 presents a word cloud with keywords used by the researchers about the topic RFID and manufacturing (words are visually weighted by their frequency of use).

The words with the highest frequency of occurrence are RFID and manufacturing, which is understandable considering that these terms form the basis of this research. It is important to note that the next most frequent words are: system, technology, identification, production, data, and also, as a result, obtained words: smart and intelligent (less than 20% of the occurrence for most frequented

word) and term real-time. This is in line with the topic of this study on the importance of RFID technology for real-time manufacturing intelligence.

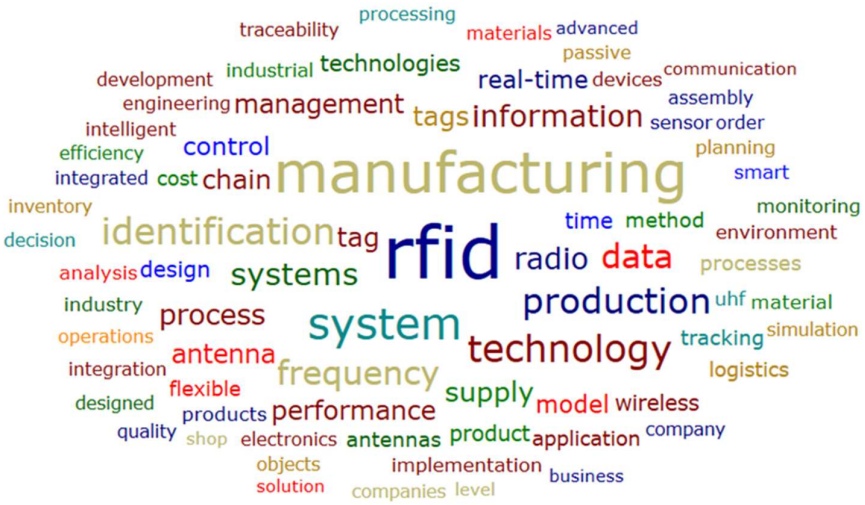

Figure 3: Word Cloud with the prominent words for topic RFID refined by manufacturing

Then conducted searches for the keyword „Intelligent Manufacturing System“ and timespan 1955-2018, and publication type articles only- Results obtained are 131 articles. Researches on topic „Intelligent Manufacturing System“ are present in many areas, and most of them are in the field of engineering, computer science, automation control systems, operation research management science and robotics as presented in Figure 4 (first five research areas according to number of publication).

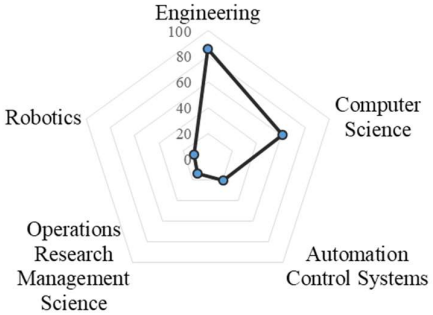

Figure 4: Number of publication on „Intelligent Manufacturing System“ a topic by research areas

Figure 5 and Figure 6 present the titles of journals and the countries with the most published articles on the topic „Intelligent Manufacturing System“. Journals with the most published articles are „Journal of Intelligent Manufacturing“ and „Robotics and Computer-Integrated Manufacturing“.

After filtering the results on „Intelligent Manufacturing System“ according to the “Countries/Regions” field, in the WoS platform, one can see that Peoples R China has most widely-publicized research results analyzed in this study, which significantly stands out in comparison to other countries. Understandable, countries with stronger economies have better results in publishing research results. Figure 6 shows only countries that have 5 and more published research results.

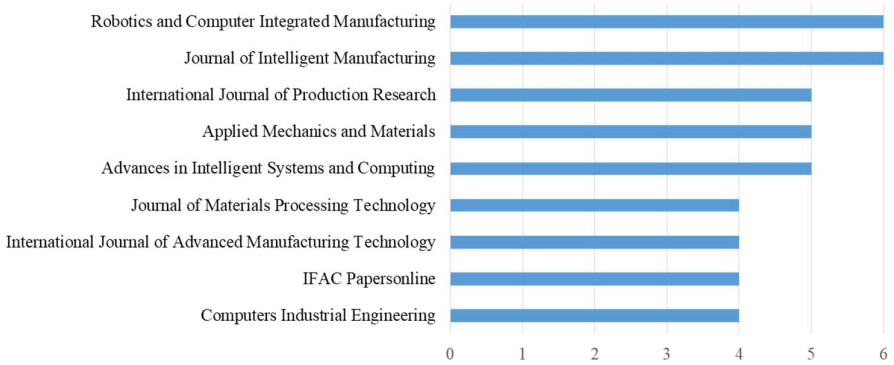

Figure 5: The titles of journals with the most published articles on the topic „Intelligent Manufacturing System“

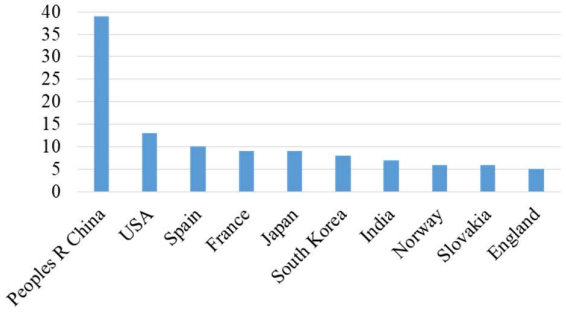

Figure 6: Countries with the most published articles on the topic „Intelligent Manufacturing System“

4. CONCLUSION

Our research has emphasized the significance of the RFID technology in manufacturing thanks to the ability to collect real-time data. Furthermore, it enables the interactions of manufacturing resources. Our bibliometric analysis shows that RFID is the core technology for manufacturing intelligence, and therefore, with other innovative technologies, makes the foundations for intelligent manufacturing systems in the Industry 4.0 framework.

The limitation of the study is an approach by which the only Web of Science Core Collection database was searched, so there is a possibility that relevant articles, that are indexed in other citation databases, are excluded from the research.

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