

The Role of Smart Sensors in Production Processes and the Implementation of Industry 4.0

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Abstract. In the world of global competition, customers have increasing demands that companies must meet in order to remain active in the global market. For this reason, it is necessary to use new technologies in the production processes, i.e. to implement Industry 4.0. In other words, we need to create a connected company through the digital transformation that enables production processes to discover new ways to increase productivity and improve overall business performance. Companies need to get involved and start a digital system, and from supplier to customer. It is a key to the hidden value that can contribute to the company's productivity, compliance, profitability, as well as the quality of the finished product, and eventually the introduction of flexible industrial automation of production processes. The aforementioned technologies and Internet of Things connect the physical and virtual world with a purpose to better collect and analyze data, transforming them into information that reaches decision-makers. To do this, it is necessary to implement smart sensors that provide information at all times. The implementation of Industry 4.0 in production processes is unthinkable without smart sensors and provides the following: faster product development time, lower overall costs, improved use of production processes and their optimization, as well as company risk management. The paper will outline the motives for the implementation of smart sensors and applications of smart sensors in production processes.

Keywords: production process, smart sensor, Industry 4.0, production automation, digital transformation, flexible automation.

1 Introduction

There is a steady increase in global demand in the world, which puts constant pressure on the world production industry, so companies have to constantly increase productivity and product quality. In order to survive in the global market and meet the above requirements, most companies in the world are using new technologies that monitor production data, monitor production processes, change and adjust the parameters of optimal production, thus creating new business values. Implementing the new technologies that form the core of the Industry 4.0 (smart technologies) in the production processes, real-time control is obtained, as well as information available on the platforms and devices that monitor the company's production processes. Industry 4.0 increases productivity and improves the overall business performance of the company. Smart sensors are the foundation of Industry 4.0. They present the sensors with integrated electronics, a combination of sensors with a microcontroller, which can perform one or more logical functions, two-way communication, and store data for future analysis. They have

new applications and new features that can perform communication with other devices. Smart sensors are an integral part of integrated systems, mainly because of MEMS (micro-mechanical systems) manufacturing technology, which performs functions that could not be performed before or that were not economically viable. Smart sensors have built-in communication modules with which they can exchange information and communicate with other objects, as well as built-in signal processing components, which is the goal of the Internet of Things (IoT). The Internet of Things / Digitization / Industrial IoT is a network of devices that are connected and mutually communicating [1–8, 10, 11]. By implementing the basic Industry 4.0 technologies in the production processes, including smart sensors, the company can improve productivity gains with continuous advancement, improve performance of the production system, improve business adaptability by quickly responding to market changes, improve product development time through efficiency system design and the integration of the production process itself, extend the product life cycle, secure environment and reduce energy consumption, miti-

gate security risk to assist with important tools such as people, equipment and information, etc. A new way of managing production processes aims to improve performance, better use of the existing data, and use a combination of tools that can act to improve the system or production process. By implementing the new technologies of Industry 4.0 each company will have an advantage and be competitive since technology continues to drive innovation. The digitalization throughout the company, and the integration of processes, serials, and discrete drives shift the company towards one connected infrastructure, thus increasing efficiency and productivity across all segments of the company. When we have access to production data in the production process at any time in real-time, it allows us to monitor and improve the performance of the production process itself, or we can have insight into energy consumption so that we can make the decision to supply energy at optimal prices or manage peak energy consumption. Companies implementing Industry 4.0 have new visibility that will enable them to provide value-added services, and a competitive advantage for product design, thus increasing the company's revenue [9–11]. In order to monitor parameters and any other data from the production processes, we need to implement smart sensors that deliver the data and connect them to the technology to be visible and controllable.

2 Research Methodology

2.1 Integration of smart sensors with other devices

Sensors are devices that convert an input signal into an electrical analog or digital output that is readable. The sensor converts a physical parameter (e.g. temperature, speed, humidity, etc.) into a signal that can be measured electrically. Sensors work by receiving a signal from a device such as a transducer, then respond to that signal by converting it to an easy-to-read and understandable output. In other words, the transducer converts one form of energy to another, while the sensor consisting of the transducer converts the output of the transducer to a readable format. Sensors are used in all aspects of life to detect or measure different conditions. Many companies in the world have developed different sensor designs to measure different physical sizes. Many changes are happening every day in all industries, including the transformation of production processes, the increased flexible automation of production processes, new form of delivery of finished products, and new way of consumption, as a result of the implementation of Industry 4.0, which is based on new technologies such as the IoT, 3D printers, robotic technology, radio frequency identification, etc.

The application of the aforementioned Industry 4.0 technologies would not be possible without the use of a smart sensor. Based on Figure 1, which presents a schematic illustration of a smart sensor, we see those smart sensors with built-in IO-Link (the first standardized IO technology in the world (IEC 61131-9) for communication with sensors and actuators) act as standard I/O sensors used until they connect to the IO-Link Master [16, 17]. When the sensors are connected to the IO-Link

Master, we are able to access all the advanced data and configuration capabilities that IO-Link has to offer.

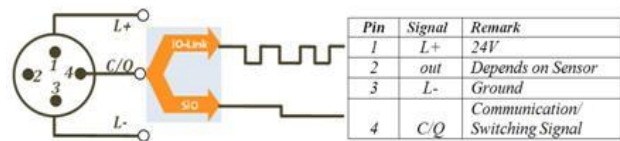


Figure 1 – Schematic illustration of the function of the smart sensor

Many companies in the world have developed a range of smart sensors for temperature, pressure, speed, proximity sensors, photoelectric sensors, laser sensors, etc. The leader in the implementation is company Rockwell Automation from the USA. Due to limitations, we can show only a small fraction of the design solutions of smart sensors in Figure 2 [16, 17].



Figure 2 – Smart sensors of different construction designs

The application of smart sensors in production processes has been greatly simplified through the standardization of process data and the latest developments of IO-Link devices with regard to self-interface and integration with many different engineering tools. If they are smart sensors with variable parameters, they allow us to change their parameters in a moment, which is one of their good features. Their adjustment to the subsequent parameters can also be executed in a moment, because changes in the production process are automatically delivered to the smart sensors, and they can be adjusted for that production process. The advantage of smart sensors is that the staff does not have to remember the multiple processes of instructing the sensors. In addition, we constantly have information not only about the monitored parameters but also about sensor damage, sensor replacement when necessary, whether the lens is dirty or clean, etc. Multiple profiles can be stored with smart sensors to support flexible image production 3.

The storage function, which ensures that device parameters are automatically downloaded, without tools, after the device is replaced, has also been successfully tested on various major devices and devices currently available in the market. These are two key user benefits when it comes to the practical application of IO-Link technology.

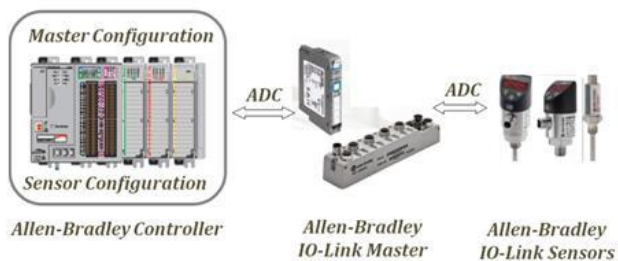


Figure 3 – Smart sensors connected to other data-monitoring devices

The first smart sensor profile devices are already available in the market. We need to mention that IO-Link wireless devices are already in the implementation and that a wide range of device classes are already expanded, so IO-Link is increasingly used outside the traditional manufacturing process automation. Decision-making data is obtained and monitored with the help of smart sensors. They are an integral part of the Industry 4.0 and tend to improve production in the following: detection of defects, efficient downtime, and maintenance planning, more efficient supply chain management, increased efficiency and productivity, rapid transition to the production of another product, increase of safety and health of workers, ensured high quality of production, reduced and planned electricity consumption in the production process, etc. [9, 12, 13]. Unless we have information on what is happening on machines that are installed in production processes minute by minute, it is impossible to maintain optimal productivity and efficiency at any time, and we are unable to avoid unplanned downtime and losses that occur in the production process. The integration of smart sensors provides the data we need to create a comprehensive image at any point in the production process, making it easy to apply and operate smart machines that increase the productivity and efficiency of the production process. Companies implementing Industry 4.0 have new visibility that will enable them to provide value-added services, and a competitive advantage for product design, thus increasing the company's revenue [9–13]. In order to monitor parameters and any other data from the production processes, we need to implement smart sensors that deliver the data and connect them to the technology to be visible and controllable.

2.2 The fundamentals of smart sensor implementation

The implementation of smart sensors in production processes provides a comprehensive view of the production process operation. Smart sensors are available for every possible parameter from temperature to pressure, flow rate, movement to distance, control of the accuracy of the performed operation, and many others that we have not listed. By knowing the current situation in the production system and the condition of the sensor, we can ensure and timely identify any type of potential malfunction, including the sensor itself [16–18]. The application of smart sensors with other necessary equipment in the production process is schematically presented in Figure 4.

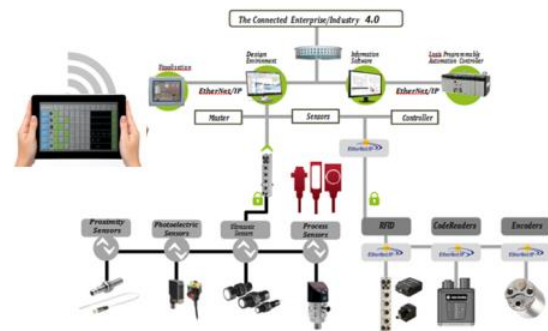


Figure 4 – Schematic representation of smart sensors implemented in the production process

Smart sensors provide a continuous flow of the valuation process and diagnostic data. They provide a visualization system, information software and a programmable controller such as the configuration shown in Figure 4, which enables the company's connectivity, benefits, and efficiency. Creating a connected company with smart sensors and smart machines reduces the complexity of production processes and errors. They simplify access to available data that can help achieve overall equipment efficiency and the average time between failures. The real-time diagnostics allows optimizing preventive maintenance and troubleshooting of problems that occur in the production process, thus reducing the resolution time by about 90 % [20]. Fully adjustable sensors improve the production process, as well as reduce the change time for each sensor. There is an option for automatic device configuration to reduce the error when replacing the sensor itself. Within each production process, there are many operations such as material handling, material transport, performing certain operations, assembly, packaging, varnishing, sorting, etc., where it is necessary to install smart sensor so that we can have information about the smooth performance of the operation or task at any time. Work assignment execution can be broken down into smaller events such as control, counting, indexing, ejecting, spraying, and transmitting, in which smart sensor helps us detect changes in conditions associated with the action and event. When implementing smart sensors in the production process, we need to identify key operations within the production system and define the focus area in which we need to verify the conditions. We need to know what the system is doing or what we want it to do, such as counting products, performing quality checks, orienting parts, etc. We need to know the feedback for each function, and what conditions must be met after each function in order to confirm that the function was correctly executed [16, 17]. Once we have identified the areas where the action is taking place in the production process, it is necessary to analyze whether each area is as important from the point of view of automating the production process and monitoring the data important in the production process. After obtaining the answer to the question about the damage caused by the errors occurring at that location, we decide on the application of the smart

sensor, and determine the best position or location to install the smart sensor.

2.3 Software

The statistical data on the implementation of smart sensors with service robots for logistics were downloaded from the International Federation of Robotics (IFR), the UN Economic Commission for Europe (UNECE) and the Organization for Economic Co-operation and Development (OECD). For the calculation of statistical descriptions parameter and graphical presentation of data, we used standard statistical analysis methods and software system MS-Excel.

3 Results

It is a well-known fact that “Industry 4.0” is present in all industrial branches in production processes for more than a decade. Its application is continuously increasing, including transportation, and supplying customers with finished products. All new technologies, including smart robots, are responsible for the development of robotic technology, so there has been an enormous increase in the application of service robots for logistics, as shown in Figure 5 [11].

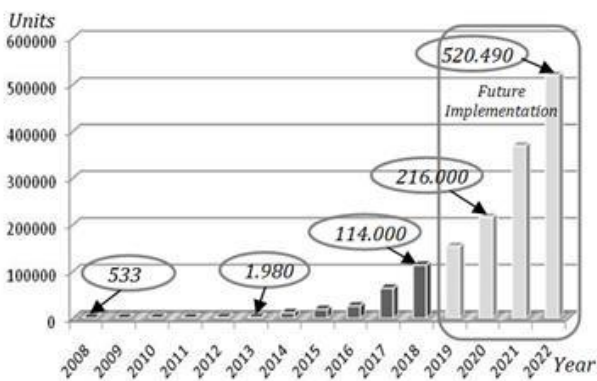


Figure 5 – The implementation of service robots for logistics in the world for the period 2008-2018 and estimated implementation by 2022

Based on Figure 5, it can be seen that the trend of application of service robots for professional use is continuously increasing. In the last five years, the application trend has gained exponential function, so that 271.000 service robots have been applied in 2018. The growth trend in the implementation of logistics service robots is also expected in the coming years, and it is estimated that in 2022 around 520.490 units of service robots for logistics in production processes will be applied. Company Mobile Industrial Robots – MiR has developed various designs of service robots for logistics (Figure 6), which apply smart sensors. Many companies, including Mobile Industrial Robots – MiR, have developed software solutions and service robots for logistics to optimize internal transport for heavy cargo pallets up to 1000 kg, as shown in Figure 6.



Figure 6 - The role of smart sensors in freight transport by service robots [14]

Mobile Industrial Robots – MiR service robots are collaborative and autonomous and can maneuver safely around all kinds of obstacles. If a person comes out in front of a robot, it will stop. Advanced technology and sophisticated software allow the robot to navigate independently and choose the most efficient route to its destination. When it encounters an obstacle, it automatically moves around it and can divert the route to avoid stopping or delaying material delivery thanks to smart sensors. Another example of the implementation of smart sensors in a single production process and setup site is shown in Figure 7 [17].

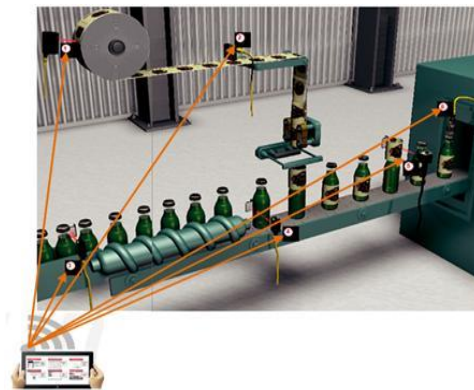


Figure 7 – The application of smart sensors in the production process of the process industry – Bottled product control

In the production operation of the process industry – bottled product control, smart sensors were used for the following: 1-Laser Measurement Sensor for bottle label diameter control, 2-Color Registration Mark Sensor for label registration, 3-Photoelectric Sensor A for detecting products exiting the battery, 4-Photoelectric Sensor B for label placement control, 5-Photoelectric Sensor for incorrect label control, and 6-Inductive Proximity Sensor for control of bottle cap presence. We can implement smart sensors in any production process depending on the role to be performed.

4 Conclusions

The development of new technologies has led to the development of sensor technology, resulting in smart sensors, which are continuously being developed and implemented in all segments of society. Many developed companies in the world are implementing Industry 4.0. They are digitizing all processes from raw material to end customers, which would be unthinkable without the smart sensors that support Industry 4.0. The implementation of smart sensors in production processes connects the company and reduces the complexity of production processes and errors.

They simplify access to available data that can help achieve overall equipment efficiency and the average time between failures. There are many advantages of implementing smart sensors in the production process, some of which are: detection of defects, efficient downtime and maintenance planning, more efficient supply chain management, increased efficiency and productivity, rapid transition to other product production, increased worker safety and health, high production quality, reduction and planning of electricity consumption in the manufacturing process, etc. The paper presents an example of the implementation of smart sensors in the production process with the aim of encouraging decision-makers to implement Industry 4.0 as soon as possible.

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Роль розумних датчиків у виробничому процесі та впровадженні Індустрії 4.0

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Анотація. У світі глобальної конкуренції клієнти висувають все більші вимоги, яким повинні відповідати промислові підприємства, щоб залишатися активними на світовому ринку. З цієї причини необхідно використовувати нові технології у виробничих процесах, впроваджуючи Індустрію 4.0. Іншими словами, потрібно створювати мережі компаній за допомогою цифрової трансформації, що дозволить виробничим процесам відкривати нові способи підвищення продуктивності та покращувати загальну ефективність виробничого процесу. Компаніям потрібно долучатися до запуску цифрових систем від постачальника до замовника. Це шлях, який сприятиме підвищенню продуктивності виробництва і рентабельності підприємства та якості готової продукції, а також впровадженню гнучкої промислової автоматизації виробничих процесів. Вищезазначені технології та Інтернету речей пов'язують фізичний і віртуальний світи з метою кращого збору та аналізу даних, перетворюючи їх на інформацію, яка доходить до осіб, які приймають рішення. Для цього необхідно впроваджувати розумні датчики, які надають інформацію у режимі реального часу. Впровадження Індустрії 4.0 у виробничі процеси, що реалізуються із застосуванням розумних датчиків, забезпечує зменшення часу на розроблення продукту, зменшення загальних витрат, удосконалення використання виробничих процесів і їх оптимізації, а також реалізує якісне управління ризиками виробничої компанії. У статті викладені шляхи впровадження інтелектуальних датчиків і їх практичного застосування у виробничих процесах.

Ключові слова: виробничий процес, розумний датчик, Індустрія 4.0, автоматизація виробництва, цифрове перетворення, гнучка автоматизація.