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Sensing and Monitoring in Industry 4.0

Temperature Measurement

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Foreword

The series "Digital Manufacturing" aims to present the technologies involved in modern manufacturing, controlled by specialized computer systems. Specific elements of manufacturing systems will be addressed, such as joint and micro-joint technologies, referral technologies for automated systems, mechanical processing technologies and others. The approach is a little descriptive, not wishing to develop manuals for training operators.
This book addresses to engineers and researchers who are involved in research and development activities related to measurement processes in order to be able to monitor and control industrial processes.
The topics discussed are related to principle of measurement in digital fabrication meeting the most common issues in temperature measurement using digital systems.

1. INTRODUCTION

The goal of this module is to present the general aspects related to the models used in monitoring of the digital processes for fabrication and fundamentals of the metrology and measurements in order to better understand to concept of sensing and monitoring in digital manufacturing.

1.1 Sensing and monitoring in digital manufacturing

Digital manufacturing cannot be applied without judicious monitoring of the process. This includes meaurements, store and transmit of the parameters to a central processing unit in order to have traceability of measurements and access to information for further applications. The central processing unit also called Cyber-Physical System (CPS) is based on AR, VR, MR technologies in order to put virtual, augmented and mixed realities in close connection with real life industrial application. The mix of information and communication technologies and real manufacturing is designed to work togheter and to exchange information in order to increase the quality of the products and to decrease the costs. In terms of sensing, the devices used in Industry 4.0 must comply with the following requirements:

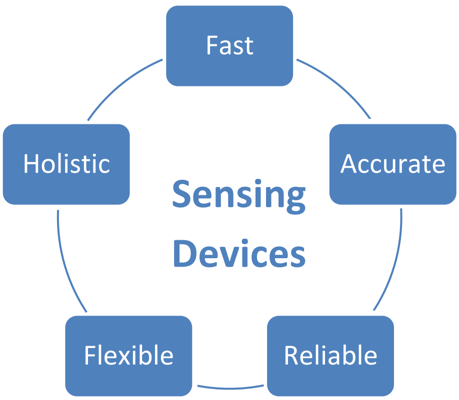

Fig. 1.1 Metrology requirements for sensing devices

Based on the requirements imposed by the metrology to the sensing devices, a smart measurement system should contain at least a minimal computer architeture besides the sensors, analog-digital converters, multiplexors and transmission lines. The mini-computers are capable to determine and measure the present state of both equipment and processes, to analyse the situation and to trigger particular actions which improve the overall state [1, 47].

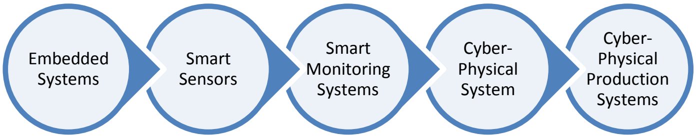

Fig. 1.2 Controlling technologies for digital manufacturing

The adoption of Cyber-Physical Systems in Industry 4.0 has given rise to emergence of the smart factories. The implementation of this systems requires monitoring and syncronization between devices and computers [2]. In addition, all information are stored in cloud and accessed by computers/human for improvement of the digital manufacturing process.

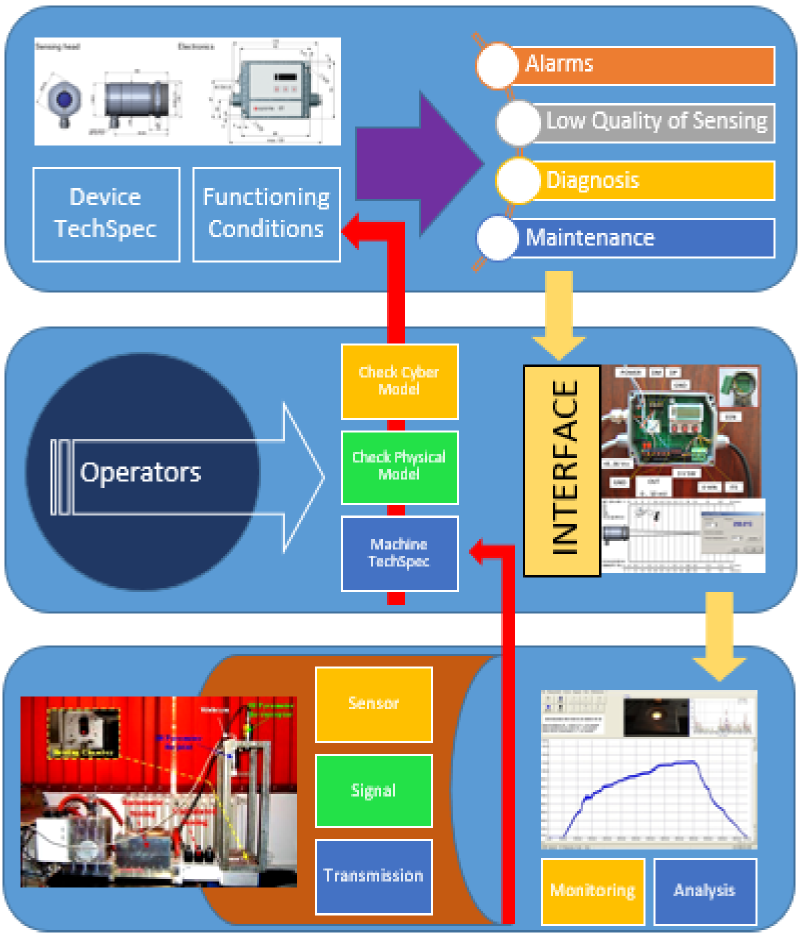

Fig. 1.3 Monitoring temperature in microwave processing

The monitoring temperature in microwave processing requires three levels divided in physical space, interface and digital environment. The physical space is dedicated to the sensing activity. The next level is focused on gathering information from sensors and recording/storing the data on local computer or network server connected to the internet. The third level is most related to proper functioning of the sensing system. This level provides information related to sensor state, alarms and data related to malfunctions.

1.1.1 From Industry 1.0 to Industry 4.0

Industry 4.0 has been claimed to be the fourth revolution of the manufacturing industry. The humankind has already seen three major revolutions in manufacturing industries. [50, 51]

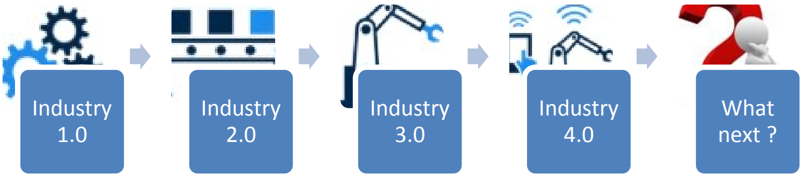

Fig. 1.4 From Industry 1.0 to Industry 4.0 and beyond [52]

Industry 1.0
Mechanization and the introduction of steam and water power
The first industrial revolution was the transition to new manufacturing processes using water and steam. It was hugely beneficial in terms of manufacturing a larger number of various goods and creating a better standard of living for some.

Fig. 1.5 Industry 1.0 image [55]

The textile industry, in particular, was transformed by industrialization, as was transportation. Fuel sources like steam and coal made machine use more feasible, and the idea of manufacturing with machines quickly spread. Machines allowed faster and easier production, and they made all kinds of new innovations and technologies possible as well. [53]

Industry 2.0
Mass production assembly lines using electrical energy
By the beginning of the 20th century, electricity became the primary source of power. It was easier to use than water and steam and enabled businesses to concentrate power sources to individual machines. Eventually machines were designed with their own power sources, making them more portable. This period also saw the development of a number of management programs that made it possible to increase the efficiency and effectiveness of manufacturing facilities. Division of labor, where each worker does a part of the total job, increased productivity.

Fig. 1.6 Industry 2.0 image [56]

Mass production of goods using assembly lines became commonplace. American mechanical engineer Frederick Taylor introduced approaches of studying jobs to optimize worker and workplace methods. Lastly, just-in-time and lean manufacturing principles further refined the way in which manufacturing companies could improve their quality and output. [54]

Industry 3.0
Automated production, computers, IT systems and robotics
Industry 3.0 is the bridge between Henry Ford's move towards greater productivity and the intelligent processes that we are now seeing arise under Industry 4.0. Not only were processes streamlined, as they were at Ford, but automation made vital parts of the production process safer and more efficient. The equipment manufacturing industry was naturally building machines driven by automation spawned by and for the emergence of Industry 3.0.

Fig. 1.7 Industry 3.0

Beginning in the 1950s, the third industrial revolution brought semiconductors, mainframe computing, personal computing, and the Internet—the digital revolution. Things that used to be analog moved to digital technologies, like an old television you used to tune in with an antenna (analog) being replaced by an Internet-connected tablet that lets you stream movies (digital). The move from analog electronic and mechanical devices to pervasive digital technology dramatically disrupted industries, especially global communications and energy. Electronics and information technology began to automate production and take supply chains global. [57]

The internet connected PLCs, PCs, mainframes, sensors, SCADA systems, robots and people all over the planet and enabled businesses to do things even more intelligently and efficiently. Now, computerized automation processes are the norm rather than the exception in industries around the world. They are very much a part of the present and the future. But they are not the technology, or the convergence of technologies, that defines the next frontier, Industry 4.0. [58]

Industry 4.0

The smart factory, autonomous systems, IoT and machine learning

Existing technologies exploited by measurement, control, and automation systems are mainly based on measuring physical parameters. Shape and distance measurements are critical for robots, flow measurement and temperature sensors are common in process control applications. The next big improvement will be deploying real-time chemical information from the measurement objects to an automation database and use it in automated control decisions. Spectroscopic technologies are well-established in off-line analysis in chemical laboratories. It is obvious that future smart factories will gain huge benefits when qualitative and quantitative material information can be generated with affordable and reliable sensors.

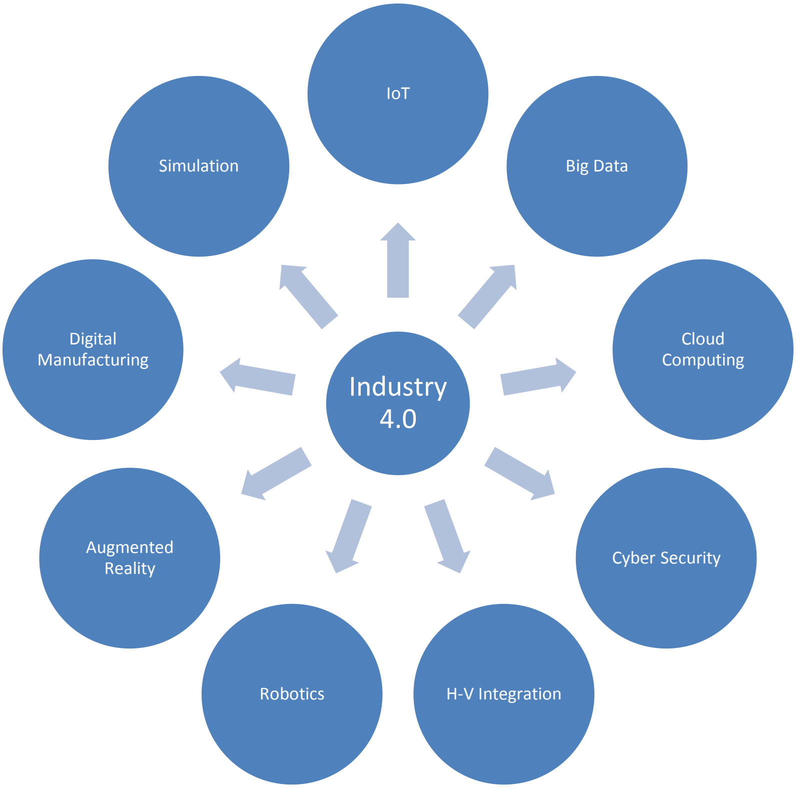

Fig. 1.8 Industry 4.0

1.1.2 Smart sensors for Industry 4.0

The use of sensors started with Industry 3.0. By using electronic control systems, information technology, electronics, robots, the increasing of sensors's usage made possible the automated production, assembling and logistics processes. Sensor technology is the necessary prerequisite for transparent processes in Industry 4.0. The sensor serves as the foundation for all subsequent applications. Simply put, without sensor technology, there would be no Industry 4.0.

In contrast to conventional, non-networked sensors, Industry 4.0 sensors deliver more than just measurement data. Their integrated decentralized computing power and flexible programmability are important characteristics for making production more flexible, dynamic, and efficient. [62]

Smart sensors provide operators, technicians, and engineers with real-time, meaningful information to increase productivity, efficiency, and flexibility of manufacturing sector. Since they are a basic tenet of Industry 4.0, they are an inescapable topic when preparing people to work in new manufacturing environments, whether training future workers or upskilling current workers. [59]

Working with smart sensor technology involves more skills than working with regular sensors. A thorough understanding of the advantages and characteristics of smart sensors, in addition to industrial network communication and IT skills, is necessary in order to reap their full benefits. [60]

Industry 4.0 requires smart systems (not only smart sensors) that will be able to directly interact with industrial processes. In terms of measurement processes, Industry 4.0 requires at least the following:

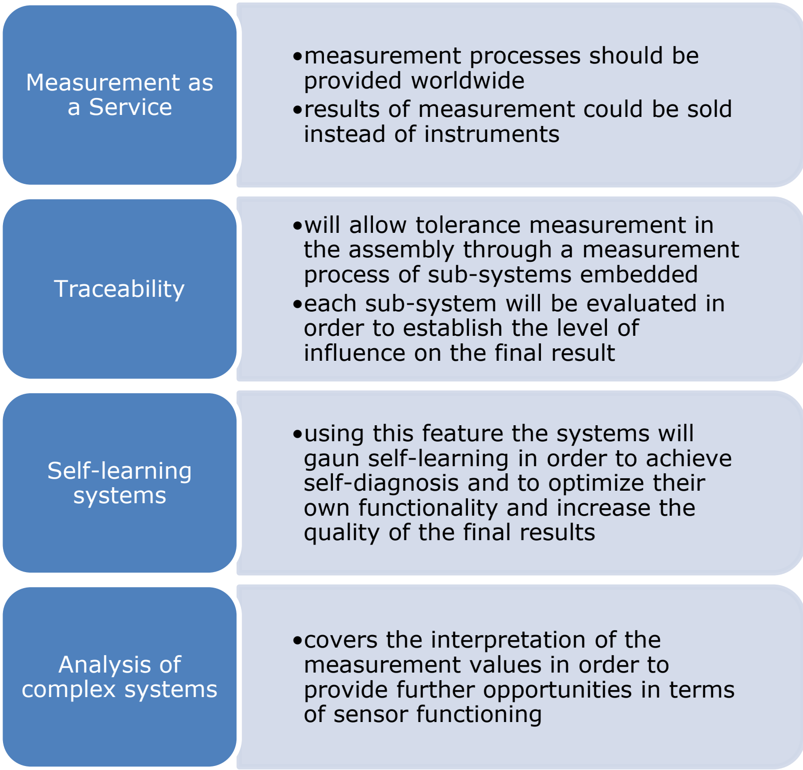

Fig. 1.9 Trends in smart sensing systems

In terms of sensor functioning are defined some faults that will be presented in the following chapters. Overall assessment of sensor performance can be summarized in: