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Editorial: Zero defect manufacturing in the era of industry 4.0 for achieving sustainable and resilient manufacturing

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Editorial on the Research Topic
Zero defect manufacturing in the era of industry 4.0 for achieving sustainable and resilient manufacturing

The manufacturing sector has experienced steady growth and change in recent years as businesses have been able to fulfill increased client expectations, mostly as a result of the innovations and technologies brought from the Industry-4.0 era (Powell et al., 2022). Additionally, new guidelines for the economic success and sustainable production are imposed due to the shift to digital and sustainable manufacturing as well as the rising desire for mass customisation. Therefore, efficient "quality" and "waste" management at both the product and process levels have become crucial to industry competitiveness (Psarommatis et al., 2020a).

To ensure that every consumer is happy, businesses pay close attention to product quality. Lean Manufacturing (LM), Six Sigma (SS), Theory of Constraints (TOC), Total Quality Management (TQM), and Lean Six Sigma (L6S) are examples of traditional quality improvement (QI) methods. These QI methods aim to improve product quality without learning from defects as they simply trace and remove them (Psarommatis et al., 2020b). Additionally, they do not fully utilize modern and cutting-edge data-driven technologies, imposed by Industry 4.0 concept. Finally, the key component of those methods does not consider prediction or its consequences. To accomplish a successful digital and green transition, these strategies can only offer a limited response and assistance to the new scenarios that must be addressed.

A contemporary approach known as Zero Defect Manufacturing (ZDM), which takes advantage of Industry 4.0 technologies, tries to overcome the drawbacks of traditional QI approaches (Psarommatis et al., 2021). The capacity to integrate digital technologies like AI, ML, or large industrial data into QI control loops that intelligently anticipate and eliminate problems at the product and process levels, ultimately enhancing their autonomy, is the foundation of this approach. It makes use of the capacity to integrate predictive solutions and enables the implementation of thorough feedforward and feedback control loops, both of which help to jointly achieve resilient and sustainable goals.

Researchers and the business community view ZDM as a potential substitute for the conventional QI methodologies (Psarommatis et al., 2020a; 2021). ZDM is rather a toolbox, and not a single technique, for reducing and managing manufacturing process failures and "to do things right the first time." ZDM includes the quality of both products and processes. Due to numerous technological and financial restrictions that limited its adoption, this concept has only been partially put into practice up to this point. For instance, corporations did not make the necessary investments in the pricey data recording equipment in the past.

But the industrial domain has changed. The application of the ZDM concept is now simpler than ever, due to the advances in digital technologies, improved computer power and data storage, and much lower sensor prices. On the one hand, Industry 4.0s advancements in digital and automation technologies, including intelligent machines, the IIoT, digital and cognitive twins, AI, etc., have made it possible for quicker and smarter reactions to unanticipated occurrences and disruptions. On the other hand, "industrialized" AI is now able to function properly in factories and along global value chains thanks to the availability of the vast volumes of data required for the creation of machine learning-based quality control procedures.

Zero defects (ZDM) and zero waste manufacturing, when combined with digital technologies, has the potential to become the new benchmark for businesses working toward sustainable and resilient manufacturing (Psarommatis et al., 2021). To use the zero defect, circular, and green manufacturing approaches and to expand the flexibility and autonomy at the level of the equipment and digital ZDM control loop, a significant amount of work is still needed (Psarommatis and May, 2022). This process calls for cutting-edge methods and techniques that enable the coordination and integration of digital intelligence and intelligent automation technologies for advanced manufacturing (Psarommatis et al., 2023).

Therefore, the manufacturing sector needs to be adept at managing integration complexity and data-driven flexibility throughout the entire product and process lifecycle (engineering, planning, commissioning, operation, and servicing) in order to take advantage of the cost-effective implementation of closed-loop cognitive feedforward and feedback control loops that satisfy ZDM optimization and emerging resiliency requirements (Ameri et al., 2021; Psarommatis and Bravos, 2022; Psarommatis et al., 2022).

The first paper, "*Zero Defect Manufacturing terminology standardization: definition, improvement and harmonization*" by Sousa et al., presents a methodological approach that will be used to generate consensus on the ZDM concept and related nomenclature during an open CEN-CENELEC Workshop. The ISO standards ISO 704, ISO 860, and ISO 10241-1/2 support the methodology. This study demonstrates how the terms for ZDM and those for quality management, metrology, reliability, statistics, non-destructive testing, and condition monitoring significantly overlap.

The second paper, "*A review on the advanced maintenance approach for achieving the zero-defect manufacturing system*" by Jun presents a review on advanced maintenance approaches for achieving ZDM. The advanced maintenance strategy, also known as condition-based maintenance plus (CBM+), prognostics and health management (PHM), and predictive maintenance, calls for a variety of interdisciplinary expertise and systematic integration. In this study, we will examine prior research, mostly on advanced maintenance as it relates to ZDM research, and briefly explore the difficult problems associated with using PHM technology in the ZDM.

The third paper, "*RMPFQ: A Quality-oriented Knowledge Modelling Method for Manufacturing Systems Towards Cognitive Digital Twins*" by Zheng et al., presents the RMPFQ (Resource, Material, Process, Function/Feature, Quality) semantic modelling method that links the key determinants of product quality during manufacturing processes. With an application ontology modeled after the IOF-Core middle-level and BFO top-level ontologies, the suggested RMPFQ model is defined. A semantic-driven digital twin architecture is created and mapped to the recently proposed Cognitive Digital Twin concept based on this ontology. A correlation matrix is created to quantify the connections between RMPFQ components and to make industrial applications easier.

The fourth paper, "*Semantic Systems Engineering Frameworks for Zero-Defect Engineering and Operations in the Continuous Process Industries*" by Cameron et al., presents a plan for integrating ZDM into the supply chain for the process industry. From the fields of system engineering, computer-aided process engineering, automation, and semantic technologies, the framework integrates modeling methodologies and models. Engineering firms can operate in novel ways thanks to the integration of their contributions into an information fabric. The fabric can be used by operators and contractors to transition from document-driven engineering to data-based procedures. To ensure that there are no design or construction flaws when facilities are delivered, started up, and operated, the fabric captures requirements and design intent. Additionally, the information is essential for safe and effective operations and maintenance.

The fifth paper, "*Defect detection on optoelectronical devices to assist decision making: a real industry 4.0 case study*" by Moustris et al., presents a ground-breaking method for tracking the life cycle of optoelectronic devices using deep learning and image processing methods for fault identification, based on industry 4.0 principles. The proposed system includes defect detection and categorization during the front-end stage of the production of optoelectronic devices, offering a two-stage approach. The first stage is the actual wafer-level defect identification, and the second stage is the pre-classification of these components based on the recognized defects.

The final paper, "*A Systematic Review on Machine Learning Methods for Root Cause Analysis towards Zero-Defect Manufacturing*" by Papageorgiou et al., presents a literature review on the most recent developments in Root Cause Analysis (RCA) in the direction of Zero Defect Manufacturing (ZDM). Recent research has demonstrated the potential of machine learning techniques for root cause analysis in the manufacturing industry. The predominance of various technologies is then summarized and shown in the form of graphs with illustrations. This made possible to identify the methods that are most frequently applied in modern industry.

Author contributions

FP conceptualization, writing, reviewing, FF writing and reviewing, JPM, OM, OL and DK reviewing.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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