Facilitating the Adoption of AI-driven Zero Defect Manufacturing in Production Systems

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Licentiate Thesis Defence

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Abstract

The increasing focus on sustainability is pushing companies to update their production systems. These systems need to facilitate the production of products with the latest sustainable technologies and innovations, while also producing these new products with lower environmental impact. To maintain high customer satisfaction, these systems must consistently deliver high-quality products. However, current quality management approaches, focused on minimal variations, might hinder this shift.

Zero Defect Manufacturing (ZDM), an emerging quality approach, leverages Artificial Intelligence (AI) to monitor products and processes in real-time, allowing for early defect detection and prevention. Many production systems generate vast amounts of data which is often not used to its full potential. Research shows that AI has the potential to unlock the hidden insights within this data, leading to transformative improvements in quality and overall efficiency. However, successfully adopting AI-driven ZDM requires expertise in AI and production while also overcoming technological and organizational challenges.

The purpose of this licentiate thesis is to investigate the adoption of AI-driven ZDM in production systems, examining its impacts, challenges, and facilitators during the development process. The research involved collaboration with a company producing transmission components for the heavy-duty automotive industry. A two-year case study was conducted, enabling the in-depth exploration of data throughout the development of four real-world AI-driven ZDM applications in a production system. This approach provided valuable insights into the practicalities of adopting AI to ensure ZDM.

The findings show that successful implementation requires specific prerequisites: lean manufacturing practices lay the groundwork for AI integration, a high-impact quality issue motivates investment and data collection, collaboration among diverse experts is crucial, and robust IT capabilities ensure smooth data storage and analysis. Furthermore, anomaly-detection AI models and the generation of "plausible defects" are key enablers for overcoming data limitations in complex defect detection. The study emphasizes the importance of early engagement to identify data needs, define extraction methods, and address potential implementation limitations.

In addition, it recommends an iterative approach to continuously improving the solution and incorporating feedback throughout the process. This comprehensive approach can pave the way for a future of sustainable manufacturing, leading to significant cost savings and increased customer satisfaction.

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List of publications in the thesis

Paper A
Leberruyer, N., Bruch, J., Ahlskog, M., and Afshar, S. (2023). Toward Zero Defect Manufacturing with the support of Artificial Intelligence—Insights from an industrial application. Computers in Industry, 147

Paper B
Leberruyer, N., Bruch, J., Ahlskog, M., and Afshar, S. (2023, September). Enabling an AI-Based Defect Detection Approach to Facilitate Zero Defect Manufacturing. In IFIP International Conference on Advances in Production Management Systems (pp. 634-649). Cham: Springer Nature Switzerland.

Paper C
Leberruyer, N., Ahlskog M. and Bruch, J. (Accepted). Addressing challenges when adopting AI-driven Zero Defect Manufacturing: Insights from industry. 57th CIRP Conference on Manufacturing Systems 2024.

Biography

Nicolas Leberruyer graduated with a MSc in Energy Technology from Polytech Orléans, France in 2004. For 16 years, he has worked in the automotive industry as a product development engineer in different stages of the development lifecycle: from advanced engineering to industrialization and aftermarket. His research areas are Industrial Artificial Intelligence (I-AI), Zero Defect Manufacturing (ZDM), human-AI collaboration and production innovation.

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