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The Future of Zero Defect Manufacturing: A Roadmap for Europe

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European Megatrends

Megatrends are defined as observable driving forces that are set to demonstrate lasting global impact. In terms of Zero Defect Manufacturing, the following megatrends promise significant impact on **European Industry:**

ACCELERATING TECHNOLOGICAL CHANGE & HYPER-CONNECTIVITY

AGGRAVATING RESOURCE SCARCITY & CLIMATE CHANGE

CHANGING NATURE OF WORK & SKILLS SHORTAGES

Industrial Trends

Related to the contemporary European megatrends listed previously, European industry is witnessing increased focus on the following industrial trends:

Smart manufacturing and Industry 4.0
With elevated customer expectations and increased product complexity, manufacturers are faced with the daunting task of mass customization, characterized by small batches and large variety of products. Industry 4.0 and its plethora of smart manufacturing technologies strives to simplify this task.

Supply chain resilience
The recent pandemic and increasing geopolitical tensions have exposed vulnerabilities in global supply chains, prompting manufacturers to reconsider sourcing strategies and respective risk mitigation measures. As such, supply chain resilience is a top trending priority in 2024.

Sustainability and circular economy
As environmental concerns intensify and regulatory pressures grow, sustainability remains a critical focus area for manufacturers worldwide. Sustainability initiatives will continue to surge, driven by the obligation to reduce carbon emissions, minimize waste, and conserve critical natural resources.

Human-centred manufacturing and upskilling
While automation and digitalization continue to transform manufacturing operations, the role of human workers remains indispensable. As such, manufacturers are placing greater emphasis on human-centred approaches, like employee well-being, employee engagement, and skills development.

Zero Defect Manufacturing

Zero Defect Manufacturing (ZDM) is a disruptive concept which promises to entirely reshape the manufacturing ideology. With three specific foci – namely product – (defective parts), process- (defective equipment) and people-oriented (defective knowledge) approaches – ZDM contains four quality management strategies:

DETECTION

Detecting (and containing) defects post-process, using con-ventional devices or advanced mechanisms (e.g., automatic optical inspection, AOI)

CORRECTION

Elimiantion of defects through physical correction of defect components / parts through costly repair and / or rework

PREVENTION

Prevention of defects by monitoring process / product parameters and stopping the process before defects propagate

PREDICTION

Predicting unstable process / product performance through real-time analysis of process data and use of intelligent algorithms and virtual sensors to adjust parameters

ZDM State-of-the-Art

Related to the contemporary European megatrends listed previously, European industry is witnessing increased focus on the following industrial trends:

ZDM Strategies Deployment

Detection, Correction and Prevention strategies are applied most prominently in global manufacturing industry
Prediction strategy is rarely used in practice

Sector analysis

- Semiconductor industry (20.33%)
- Steel industry (4.67%)
- Automotive (4.33%)
- Foundry (4.00%)
- Food (3.33%)
- Metal (3.00%)
- Ceramic (2.33%)
- Renewable energy Industries (2.33%)

Key Enabling Technologies

- Architecture and standards
- Artificial Intelligence (AI)
- Big data analytics (BDA)
- Blockchain
- Cloud-based solutions
- Cyberphysical production systems (CPPS)
- Digital twins
- Edge platforms
- Graphical user interfaces
- Industrial internet of things (IIOT)
- Inspection and monitoring
- Simulation and modelling

ZDM Opportunities

ZDM Strategy

- Focus on the adoption of a holistic approach (rather than the current trend for piecemeal implementation)
- Investigate ZDM in less-researched industry sectors
- Explore requirements for realising the predictive ZDM strategy
- Exploit repair strategy as a sustainable solution to meet stringent standards for industrial sustainability and to avoid resource waste

ZDM Methods

- Develop methods for adaptive quality drift prediction
- Develop unsupervised prevention techniques (this requires detailed knowledge of machinery and possible failures)
- Deepen the exploration of semi-supervised or unsupervised prediction methods
- Create more adaptable and flexible ZDM frameworks that can easily integrate with various manufacturing processes and technologies

ZDM Tech.

- Develop standardized solution for efficient data management (Data Management System)
- Develop hardware and software to ensure that required data is collected and available, data security protocols are in place, bad data is excluded, and gaps in data streams are properly managed
- Explore the role of AI in ZDM, particularly concerning the development and deployment of human-centred manufacturing systems
- Create a standardized design methodology to ensure uniformity in the development of digital twins for ZDM and develop an effective method and key performance indicators (KPIs) for evaluating the effectiveness of digital twins

ZDM Research Priorities

Extending ZDM to less-explored industrial sectors

Beyond ZDM towards zero-waste value-chain strategies

Artificial Intelligence & the pivotal role of humans in ZDM

Sustainable manufacturing and circular value chains

ZDM-oriented process- and machine innovation

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