# MANAGEMENT AND PRODUCTION ENGINEERING

## AMMIN/DIGEP - Monitoring and quality control of joining processes in human-centered and sustainable production systems

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| **Funded By** | Dipartimento DIGEP<br>Politecnico di TORINO [P.iva/CF:00518460019] |
| **Supervisor** | DE MADDIS MANUELA - manuela.demaddis@polito.it |
| **Contact** | CHIABERT PAOLO - paolo.chiabert@polito.it<br>RUSSO SPENA PASQUALE - pasquale.russospena@polito.it |
| **Context of the research activity** | Development of data-driven and sensor-based methodologies for the monitoring, analysis, and control of industrial joining processes in human-centered and sustainable manufacturing systems. |
| | Joining processes play a critical role in the industrialization of advanced products, directly influencing their quality, reliability, and sustainability. Advanced joining solutions for similar and dissimilar materials are increasingly required to enable the development of lightweight, high-performance, and multifunctional components for next-generation manufacturing applications.<br>Despite their growing relevance, these processes remain challenging to implement in industrial production due to process variability, defect formation, and the difficulty of ensuring consistent, repeatable, and traceable quality in real production environments.<br>These challenges are becoming even more significant in the context of the ongoing digital and sustainable transformation of manufacturing systems. Contemporary production environments are required to combine efficiency, flexibility, traceability, and responsible use of resources, while maintaining high levels of product quality and process reliability. In this context, conventional quality assurance approaches, still largely based on post-process inspections and destructive testing, are increasingly inadequate, as they lead to higher costs, longer validation times, and unnecessary material waste.<br>Against this background, the proposed research aims to develop an integrated framework for the monitoring, analysis, and control of joining processes based on multimodal sensing and data-driven methodologies.<br>The research will exploit heterogeneous sensing technologies, including thermographic systems, optical and high-speed cameras, acoustic sensors, to achieve a deeper understanding of process dynamics and of their |

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| **Objectives** | relationship with final joint quality.<br>The innovative value of the project lies in its ability to transform complex and heterogeneous process data into actionable knowledge for intelligent manufacturing. To this aim, advanced signal processing, statistical analysis, artificial intelligence, and non-destructive testing methods will be integrated within production environments to support predictive and more reliable quality assessment strategies. In parallel, the research will investigate how digital technologies can enhance the capabilities of operators, promoting a human-centered approach in which the interaction between human expertise and intelligent systems becomes central to achieve process control, quality assurance, and sustainability.<br>The specific objectives are:<br>- To analyze joining processes in terms of performance, variability, and their impact on final product quality.<br>- To define key process and quality indicators enabling effective monitoring, control, and decision-making.<br>- To design and implement sensor-based systems for real-time data acquisition during assembly operations.<br>- To develop frameworks for data structuring, management, and traceability to support advanced analytics.<br>- To apply data-driven approaches, including statistical methods and artificial intelligence techniques, to identify correlations between process parameters, sensor signals, and joint quality.<br>- To develop and integrate non-destructive testing (NDT) techniques for defect detection and characterization.<br>- To investigate strategies aimed at reducing the reliance on destructive testing, enhancing sustainability and resource efficiency<br>- To contribute to the development of intelligent, adaptive, and human-centered assembly systems with embedded quality control.<br>Overall, this research aims to integrate manufacturing processes with digital technologies, enabling the development of human-centered and sustainable assembly systems. |

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| **Skills and competencies for the development of the activity** | Desirable skills for the candidate include basic knowledge of manufacturing processes and technologies, materials science, methods and tools for production process management, data acquisition and analysis, Artificial Intelligence, quality control. |