Pioneer

Open Innovation Platform for Optimising Production Systems by Combining Product Development, Virtual Engineering Workflows and Production Data.

Data-Driven Intelligence for Product Optimisation

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PIONEER PROJECT SHOWCASES DATA-DRIVEN INTELLIGENCE FOR PRODUCT OPTIMISATION IN TWO INDUSTRIAL APPLICATIONS

In the framework of the PIONEER project, researchers and industrial partners have successfully demonstrated how data-driven intelligence can transform manufacturing by combining simulation and real process data. Through Reduced Order Models (ROMs) and Data-Driven Models (DDMs), engineers achieved faster, smarter optimisation of complex processes, improving quality while reducing cost and development time.

Two industrial use cases — Wire Arc Additive Manufacturing (WAAM) and Sheet Molding Compound (SMC) forming — highlight how this hybrid digital approach bridges the gap between physics-based modelling and real-world production, paving the way for next-generation process control and product performance.

For each application, real-world data was collected and used to showcase the methodology. Experiments at MX3D and AIMEN facilities were conducted for the WAAM process and at MARELLI facilities for the SMC process.
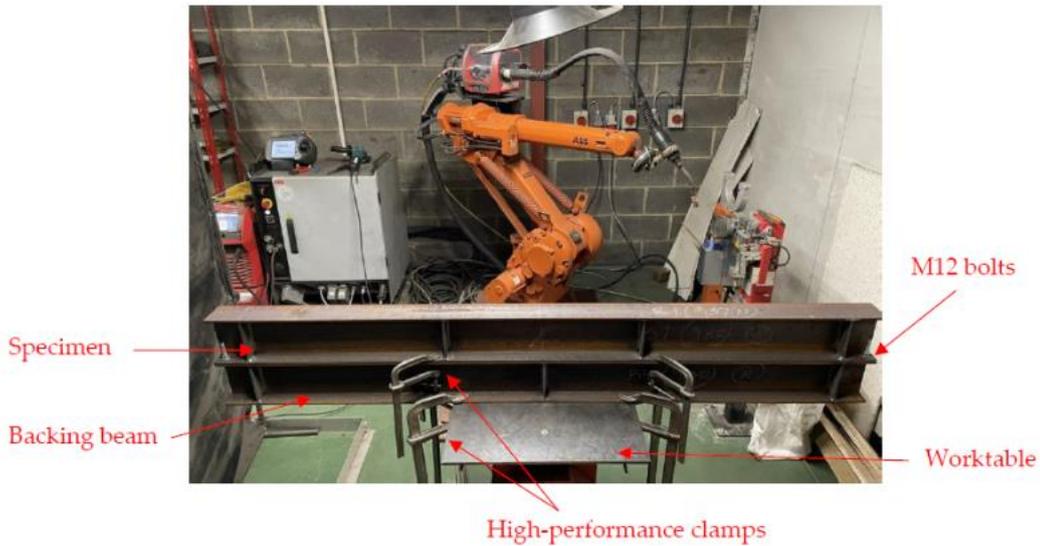
Figure 1: Experimental Setup for the WAAM Process at AIMEN's Facility

REDUCED ORDER MODELS: SPEED AND INSIGHT FROM SIMULATION

In both applications, detailed physics-based simulations have been used to predict process outcomes such as temperature evolution, deformation, or stress. However, these simulations are computationally heavy, often taking several hours for a single configuration.
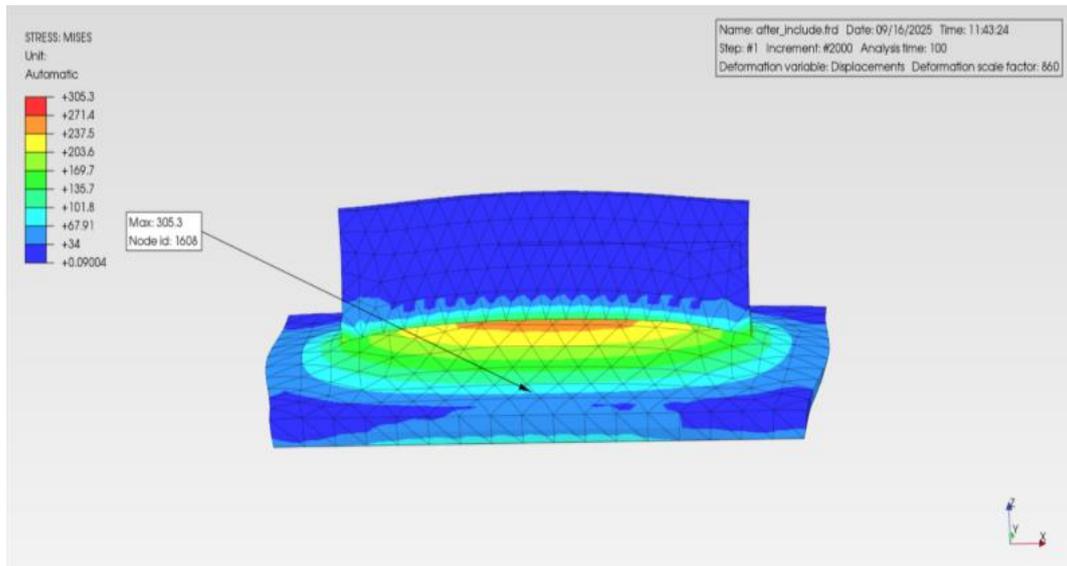

Figure 2: Stress Contour at the End of Printing

To overcome this limitation, Reduced Order Models (ROMs) were developed. ROMs compress the essential behaviour of a complex simulation into a lightweight predictive tool that can deliver results in seconds.

In the WAAM process, ROMs were used to replicate the thermal behaviour of the additive manufacturing process. This allowed engineers to quickly test combinations of parameters — such as machine efficiency or heat transfer coefficients — and find the settings that produced the best thermal profiles with minimal distortion.

In the SMC process, ROMs provided an efficient way to predict key variables such as temperature distribution, fibre orientation, and resulting mechanical properties across the formed part. The approach enabled engineers to map how process parameters influence part performance and to explore optimisation strategies faster than ever before.
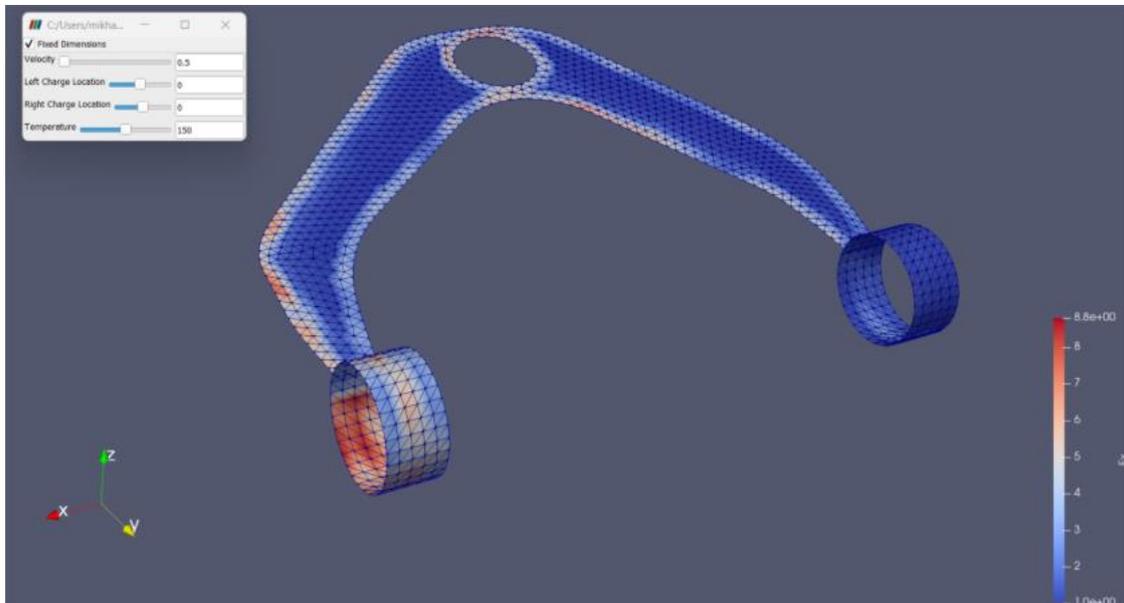

Figure 3: Young's Modulus according to X-axis (Ex) as Predicted by the ROM (Parameters as Shown on the Top Left)

DATA-DRIVEN MODELS: LEARNING FROM REALITY

While ROMs accelerate physics-based understanding, DDMs capture the actual behaviour of the process in real manufacturing conditions. Built on experimental data and in-line monitoring, DDMs detect relationships between process parameters and part quality that may not be fully captured by simulations.

For the WAAM process, DDMs were designed to interpret data collected from sensors and monitoring devices — such as temperature readings, melt pool characteristics, and geometric measurements — to identify the optimal conditions for stable deposition. These models help understand how parameters like cooling time, deposition strategy, and material type influence part deformation and cambering.

The DDM analysis revealed how specific parameter thresholds — such as critical cooling time or melt pool temperature — determine process stability and final part quality. These insights enable operators to make informed, data-based decisions in real time, ensuring process repeatability and consistency.

COMPLEMENTARY INTELLIGENCE FOR PROCESS OPTIMISATION

The real strength of the PIONEER framework lies in the synergy between ROMs and DDMs.

- ROMs offer a feedforward optimisation tool — predicting outcomes based on process settings before production begins.

- DDMs provide a feedback mechanism — learning from real process data to refine decisions and maintain process stability.

Together, they create a hybrid decision-support system that combines simulation-based foresight with real-world adaptability. In both WAAM and SMC cases, this combination helped identify optimal parameter settings, improve product quality, and reduce the need for costly trial-and-error iterations.

By leveraging this dual intelligence, manufacturers can ensure that process conditions remain within safe and efficient ranges, while also predicting potential deviations before they occur. This not only improves quality but also enhances sustainability by reducing material waste and rework.

TOWARD INTELLIGENT, CONNECTED MANUFACTURING

The results obtained in the PIONEER project clearly demonstrate how data-driven and model-based intelligence can reshape industrial manufacturing. Across the two applications, these digital tools have:

- Reduced simulation and analysis time from hours to seconds,

- Enabled real-time process monitoring and prediction,

- Improved understanding of key process-quality relationships,

- Supported robust decision-making for engineers and operators.

Both DDM and ROM are interconnected through the process control manager at the MARELLI facilities, enabling on-floor decision-making and corrective actions in real-time during the SMC process. Ultimately, this hybrid approach represents a major leap toward intelligent, data-driven manufacturing, where every process is optimised and every decision is informed by both physics and data.

ABOUT THE PROJECT

This Horizon Europe project took off in January 2023. PIONEER develops and implements an interoperable Materials-Modelling-Manufacturing Ecosystem, enabling multidirectional dataflow throughout the material value chain by connecting the production's various stages. Combining a design-by-simulation approach with manufacturing and quality data, PIONEER optimises product development strategies in high-mix/low-volume production schemes.

Project Title: Open Innovation Platform for Optimising Production Systems by Combining Product Development, Virtual Engineering Workflows and Production Data.

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Project Partners:

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