



ISO/TR 23247-101

Automation systems and integration — Digital twin framework for manufacturing —

Part 101: Use case on management of robotic multilayer and multipass gas- shielded metal arc welding process

*Systèmes d'automatisation industrielle et intégration —
Cadre technique de jumeau numérique dans un contexte de
fabrication —*

*Partie 101: Cas d'utilisation concernant la gestion d'un procédé
robotisé de soudage à l'arc sous protection gazeuse multicouche
et multipasse*

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CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Email: copyright@iso.org
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Multilayer and multipass gas-shielded metal arc welding is a critical process for thick plate welding, which is widely used in the welding of large metal structures in engineering machinery, ships, aerospace and other fields.

Although robotic technology has enhanced automation, reduced manual intervention, and improved quality in multilayer and multipass gas-shielded metal arc welding, the process remains challenging for highly customized, large-scale workpieces such as tunnel boring machine cutterheads. Key issues include reliance on manual parameter optimization and insufficient real-time process control, leading to poor adaptability, inconsistent weld quality, and unplanned downtime.

A digital twin of robotic multilayer and multipass gas-shielded metal arc welding can effectively address these challenges. By simulating and optimizing the entire process in a virtual environment, it reduces reliance on manual experience and enables real-time monitoring, early warning, and dynamic adjustment of welding parameters. This significantly enhances welding quality control and process stability.

The application of a digital twin for monitoring and controlling the robotic multilayer and multipass gas-shielded metal arc welding offers the following advantages:

- Monitoring and early warning: A digital twin facilitates continuous real-time monitoring of the welding process, displaying key parameters - such as current, voltage, travel speed, and molten pool state - and triggers immediate alerts upon anomaly detection to prompt corrective operator actions.
- Process parameter optimization: A digital twin can analyse the influence of groove forms (e.g. V-groove, J-groove) and their geometry parameters on stress, heat input, and deformation to optimize selection and design. Additionally, it monitors weld quality and joint characteristics layer-by-layer, enabling predictive optimization of subsequent welding parameters.
- Process plan optimization: A digital twin can evaluate the deformation and residual stress under various welding sequences to identify the optimal welding sequence scheme. Using sensor-derived deformation data, it also simulates straightening strategies to determine the most effective pressure, temperature, and positioning parameters.
- Predictive maintenance of equipment: A digital twin enables predictive maintenance of welding equipment by continuously monitoring and analysing its operational status. This allows for early detection of potential faults, facilitating proactive interventions that minimize unplanned downtime.
- Training and simulation: A digital twin supports operator and engineer training through a virtual environment that simulates diverse welding scenarios without physical equipment, improving skills, enabling solution testing, and enhancing risk response capabilities.

A digital twin enhances precision in monitoring and optimizing the robotic multilayer and multipass gas-shielded metal arc welding process, reducing defects and facilitating intelligent management of the full workflow. By leveraging this technology, manufacturers achieve deeper process insight, improved parameter optimization, strengthened quality control, and enhanced overall productivity and efficiency.

This document is structured into an overview, operational sequences, framework mapping and a conclusion. Following the ISO 23247 series, the use case analysis yields a systematic implementation view and a high-level digital twin design, ready for direct implementation with standard-compliant tools and languages.