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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

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This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 4, *Industrial data*.

A list of all parts in the ISO 23247 series can be found on the ISO website.

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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.

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1 Scope

This document describes a digital twin system for monitoring and managing the robotic multilayer and multipass gas-shielded metal arc welding process.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 23247-1, *Automation systems and integration — Digital twin framework for manufacturing — Part 1: Overview and general principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 23247-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
welding
joining process in which two or more parts are united producing a continuity in the nature of the workpiece material(s) by means of heat or pressure or both, and with or without the use of filler material

3.2
gas-shielded metal arc welding
metal arc welding using a wire electrode in which the arc and the weld pool are shielded from the atmosphere by a shroud of gas supplied from an external source

3.3
multipass welding
welding process in which the entire weld is completed using more than two weld passes

Note 1 to entry: The weld beads of multipass welding are usually deposited continuously within the same layer. Special attention can be paid to adjusting welding parameters such as welding current and welding voltage to ensure the compactness and mechanical properties of the weld joint.