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General requirements for cyber-physically controlled smart machine tool systems (CPSMT) —

Part 2: Reference architecture of CPSMT for subtractive manufacturing

Exigences générales relatives aux systèmes de machines-outils intelligents à commandes cyber-physiques (CPSMT) —

Partie 2: Architecture de référence des CPSMT pour la fabrication soustractive

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184 *Automation systems and integration*, Subcommittee SC 1, *Industrial cyber and physical device control*.

A list of all parts in the ISO 23704 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

A machine tool is a key device in manufacturing since it is used indispensably in the production of machine parts used in various industrial areas. Many institutions have long been devoted to technological development from the viewpoint of reducing downtime and defects and are considering smart technologies such as the Internet-of-Things (IoT) as a new means to achieve this.

From the market perspective, there is a variety of so-called smart machine tools incorporating smart technologies based on their own concepts using, e.g. local terminologies by machine tool builders (MTBs), machine tool control, e.g. computerized numerical control (CNC) vendors, solution vendors and service providers, which can be confusing to stakeholders, including end-users. For this and other reasons, standards and substantial modelling for smart machine tool systems are needed.

From the standards perspective, RAMI 4.0 (IEC PAS 63088) and IEC TR 63319[1)] TR-SMRM provide a reference model for Industry 4.0 and smart manufacturing on a high level. The ISO 23247 series defines a generic framework to support the creation of a digital twin of observable manufacturing elements. Furthermore, although some existing standards deal with Industry 4.0 enabling technologies, e.g. OPC-UA (IEC TR 62541-1), MTConnect (ANSI/MTC1.4-2018), ISO/IEC 30141, the IEC 62769 series, and many machine tool standards from ISO TC39, no standard yet exists for smart machine tools for realizing smart manufacturing / Industry 4.0 in the shop floor via cyber-physical systems (CPSs).

The ISO 23704 series specifies general requirements on smart machine tools for supporting smart manufacturing in the shop floor via cyber-physical system control scheme, namely cyber-physically controlled smart machine tool systems (CPSMT).

Figure 1 shows the overall structure of the ISO 23704 series, including:

— Overview and fundamental principles of a CPSMT in ISO 23704-1,

— Reference architecture of a CPSMT for subtractive manufacturing in ISO 23704-2, and

— Reference architecture of a CPSMT for additive manufacturing in ISO 23704-3[2)].

Other related parts such as implementation guidelines or reference architectures for other types of manufacturing will be added if and when necessary.

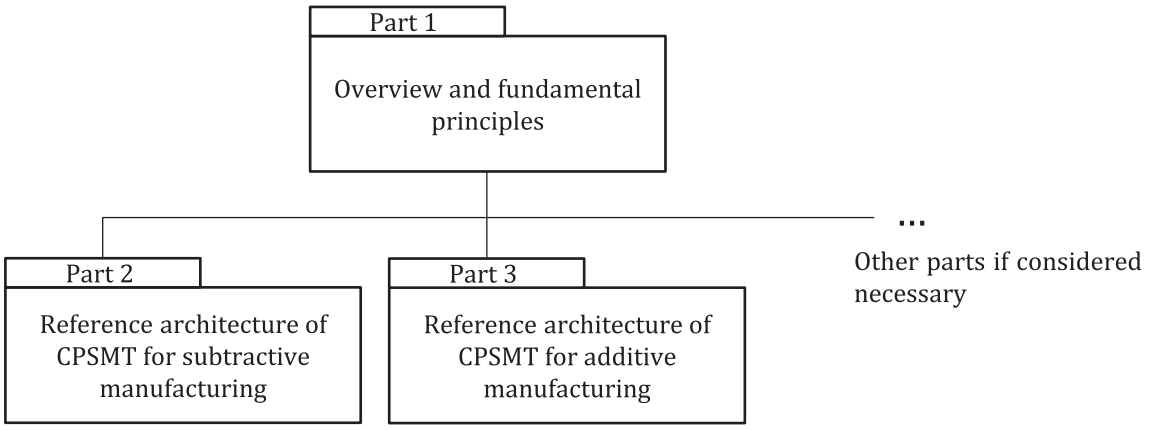

Figure 1 — Overall structure of the ISO 23704 series on general requirements for cyber-physically controlled smart machine tool systems (CPSMT)

This document can be used as a reference and guidelines for users such as, but not limited to:

a) Design engineers in the area of smart machine tools,

1) Under development. Stage at the time of publication: IEC/DTR 63319.

2) Under development. Stage at the time of publication: ISO/DIS 23704-3.

b) System architects in the area of smart machine tools,

c) Software engineers at the MTBs in the area of smart machine tools,

d) Machine tool control vendors in the area of smart machine tools,

e) Solution and service providers in the area of smart machine tools, and

f) End users such as factory operators working with smart machine tools.

General requirements for cyber-physically controlled smart machine tool systems (CPSMT) —

Part 2: Reference architecture of CPSMT for subtractive manufacturing

1 Scope

This document specifies a reference architecture of cyber-physically controlled smart machine tool systems (CPSMT) for subtractive manufacturing based on the reference architecture of a CPSMT as provided in ISO 23704-1.

The reference architecture of a CPSMT for subtractive manufacturing includes:

— the reference architecture of a cyber-physically controlled machine tool (CPCM),

— the reference architecture of a cyber-supporting system for machine tools (CSSM), and

— the interface architecture of a CPSMT.

This document also provides:

— a conceptual description of a shop floor device system (SFDS),

— a conceptual description of a shop floor control system (SFCS),

— a conceptual description of a unified interface system (UIS), and

— example use cases of a reference architecture of a CPSMT for subtractive manufacturing.

This document does not specify physical or implementation architecture.

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 23704-1:2022, *General requirements for Cyber-Physically Controlled Smart Machine Tool Systems (CPSMT) —Part 1: Overview and fundamentals principles*

3 Terms, definitions and abbreviated terms

For the purposes of this document, the terms and definitions given in ISO 23704-1 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 Terms and definitions

3.1.1
context data
data specifying in which circumstances the *state data* (3.1.16) is obtained from the various perspectives, e.g. products, processes, tool paths and process variables

3.1.2
cyber-physical system unit
CPS unit
instance of a cyber-physical system (CPS) according to the reference architecture

Note 1 to entry: The CPS unit provides advanced control functionalities for the machine tool unit (see 3.1.12), interfacing with data from sensors, numerical control kernel / programmable logic controller, the cyber-supporting system for machine tool (CSSM), shop floor control system (SFCS), and unified interface system (UIS).

3.1.3
data model
graphical and/or lexical representation of data, specifying their properties, structures and interrelationships.

[SOURCE: ISO/IEC 19778-1:2015, 3.1.7]

3.1.4
data processing unit
DPU
instance of data processing according to the reference architecture of cyber-physically controlled smart machine tool (CPSMT) for subtractive manufacturing

3.1.5
digital twin unit
instance of a digital twin according to the reference architecture of cyber-physically controlled smart machine tool (CPSMT) for subtractive manufacturing

Note 1 to entry: The digital twin unit describes the digital replica or digital representation of a machine tool system and its surrounding environment.

Note 2 to entry: The perspective of digital representation of the machine tool system contains: a) machine body, b) cutting tool, c) workpiece, and d) environment.

Note 3 to entry: The digital representation of the machine tool consists of the data model and behaviour model.

3.1.6
element
component or part as a constituent function in a *unit* (3.1.17)

3.1.7
engineering phase context data
part of the context data for machining specified in the engineering phase, e.g. computer-aided design, process planning and manufacturing data

Note 1 to entry: Example data is included in, e.g. the ISO 14649 series, ISO 6983-1, ISO 13399-1.

3.1.8
external interface unit
unit (3.1.17) that receives data from a) the *data processing unit* (3.1.4), b) the *MAPE unit* (3.1.13) via execution element, and transmits that data to a shop floor control system (SFCS) and a unified interface system (UIS) instance of interface with external entities according to the reference architecture for subtractive manufacturing

3.1.9
inner-loop element
part of the cyber-physical system *(CPS) unit* (3.1.2) that detects and resolves abnormalities for the *machine tool unit* (3.1.12) in hard-real time

3.1.10
inter-loop element
part of the cyber-physical system *(CPS) unit* (3.1.2) that generates event-driven control instructions for the *machine tool unit* (3.1.12) based on data from a shop floor control system (SFCS) for the sake of collaboration

3.1.11
intra-loop element
part of the cyber-physical system *(CPS) unit* (3.1.2) that generates control instructions for the *machine tool unit* (3.1.12) based on the data from a cyber-supporting system for machine tools (CSSM) in soft-real time

3.1.12
machine tool unit
MTU
instance of machine tool according to the reference architecture for subtractive manufacturing

Note 1 to entry: According to ISO 14955-1, 3.12: 2017, the machine tool function of a machine tool unit consists of machine tool operation (machining process, motion and control), process conditioning, workpiece handling, tool handling or die change, recyclables and waste handling and machine tool cooling / heating. This functionality is used for determining areas for abnormalities.

3.1.13
monitoring, analysis, planning, and execution unit
MAPE unit
instance of monitoring, planning, and execution according to the reference architecture

3.1.14
numerical control kernel
NCK
component for controlling the servo motors consisting of, e.g. an interpreter, interpolator, acceleration / deceleration controller and position controller

Note 1 to entry: Numerical control kernel is the key module not only of the computerized numerical control (CNC) but it is also a typical position control for servo motors[38].

3.1.15
operation phase context data
set of data specified at the machine tool before machining operation start, including, e.g. setup data of machine tool, cutting tool and workpiece

3.1.16
state data
set of data on the state of the *machine tool unit* (3.1.12) during machining operation from which the key performance indicators (KPIs) of the machine body, cutting tool, workpiece and environment can be identified

Note 1 to entry: Typical means for obtaining the state data are various sensors and a computerized numerical control (CNC) on the machine tool components.

3.1.17
unit
group of *elements* (3.1.6) that constitutes part of the reference architecture of a cyber-physically controlled machine tool (CPCM) and a cyber-supporting system for machine tools (CSSM) for subtractive manufacturing

Note 1 to entry: The term "unit" in this document is used as an instance of a collection of elements.

3.2 Abbreviated terms

CAx	computer-aided-x
CNC	computerized numerical control
CPCA	cyber-physically controlled autonomous guided vehicle
CPCM	cyber-physically controlled machine tool
CPCR	cyber-physically controlled robot
CPCS	cyber-physically controlled storage
CPS	cyber physical system
CPSMT	cyber-physically controlled smart machine tool
CSSA	cyber supporting system for autonomous guided vehicle
CSSM	cyber supporting system for machine tool
CSSR	cyber supporting system for robot
CSSS	cyber supporting system for storage
FFT	fast Fourrier transform
HMI	human machine interface
MAPE	monitoring, analysis, planning, execution
MTB	machine tool builder
MTU	machine tool unit
NCK	numerical control kernel
PLC	programmable logic controller
SFCS	shop floor control system
SFDS	shop floor device system
UIS	unified interface system

4 Conformance with the CPSMT reference architecture for subtractive manufacturing

To claim conformance, the definition of specific system architecture provided by a vendor or system integrator should use the terminology, architectural concepts, and have the capabilities defined in this document, within the scope of their specific use cases.

5 Goals and objectives of the CPSMT reference architecture for subtractive manufacturing

The CPSMT reference architecture for subtractive manufacturing describes an architecture of smart machine tool systems for subtractive manufacturing based on the generic reference architecture specified in ISO 23704-1. It provides guidance for designers developing smart machine tool systems

for subtractive manufacturing and aims to give a better understanding of smart machine tools to the stakeholders of such systems.

NOTE Examples of stakeholders are MTBs, computerized numerical control (CNC) vendors, solution vendors, service providers, customers and end-users.

The CPSMT reference architecture for subtractive manufacturing supports the following important standardization objectives:

a) To ensure clear and unambiguous communication between all interested parties of smart machine tools for subtractive manufacturing.

b) To ensure the interoperability of smart machine tools with related hardware devices, software, service, and manufacturing system for subtractive manufacturing.

c) To ensure the quality / capability of smart machine tools for subtractive manufacturing.

d) To ensure the use of smart machine tools for subtractive manufacturing.

e) To ensure systematic development, modification of smart machine tools for subtractive manufacturing.

Figure 2 illustrates the context of how the CPSMT reference architecture for subtractive manufacturing is derived and viewed from various perspectives based on the architecture description defined in ISO/IEC/IEEE 42010:2011[29].

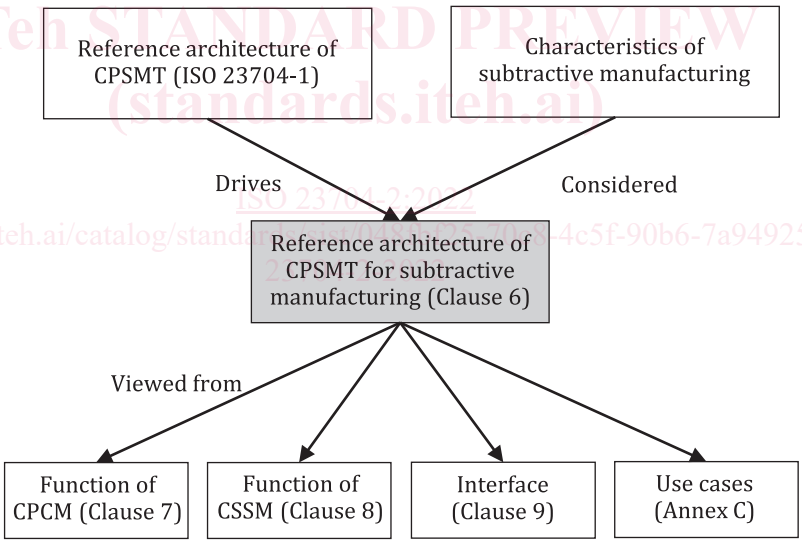

Figure 2 — Context of the CPSMT reference architecture for subtractive manufacturing

Based on Figure 2, this document includes the following descriptions:

— The reference architecture of a CPSMT for subtractive manufacturing in Clause 6.

— The reference architecture of a CPCM viewed from functionality perspective in Clause 7.

— The reference architecture of a CSSM viewed from functionality perspective in Clause 8.

— The reference architecture of a CPSMT viewed from the interface perspective in Clause 9.

— The use cases of the reference architecture in Annex C.