TECHNICAL SPECIFICATION

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Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers —

Part 201: Machine tool data for cutting processes

Systèmes d'automatisation industrielle et intégration — Commande des dispositifs physiques — Modèle de données pour les contrôleurs numériques informatisés —

Partie 201: Données de la machine-outil pour les procédés de coupe

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of document:

— an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote;

— an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

An ISO/PAS or ISO/TS is reviewed after three years in order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn. If the ISO/PAS or ISO/TS is confirmed, it is reviewed again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 14649-201 was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 1, *Physical device control*.

ISO/TS 14649 consists of the following parts, under the general title *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers*:

— *Part 1: Overview and fundamental principles*

— *Part 10: General process data*

— *Part 11: Process data for milling*

— *Part 12: Process data for turning*

— *Part 13: Process data for wire electrical discharge machining (wire-EDM)*

— *Part 14: Process data for sink electrical discharge machining (sink-EDM)*

— *Part 111: Tools for milling machines*

— *Part 121: Tools for turning machines*

— *Part 201: Machine tool data for cutting processes* [Technical Specification]

Introduction

Modern manufacturing enterprises are built from facilities spread around the globe, which contain equipment from hundreds of different manufacturers. Immense volumes of product information need to be transferred between the various facilities and machines. Today's digital communications standards have solved the problem of reliably transferring information across global networks. For mechanical parts, the description of product data has been standardized by ISO 10303, leading to the possibility of using standard data throughout the entire process chain in the manufacturing enterprise.

Impediments to realizing this principle are the data formats used at the machine level. Most computer numerical control (CNC) machines are programmed in the ISO 6983 “G and M code” language. Programs are typically generated by computer-aided manufacturing (CAM) systems that use computer-aided design (CAD) information. However, ISO 6983 limits program portability for the following three reasons:

a) the language focuses on programming the tool centre path with respect to machine axes, rather than the machining process with respect to the part;

b) the standard defines the syntax of program statements, but in most cases leaves the semantics ambiguous;

c) vendors usually supplement the language with extensions that are not covered in the limited scope of ISO 6983.

ISO 14649 is a new model of data transfer between CAD/CAM systems and CNC machines, which replaces ISO 6983. It remedies the shortcomings of ISO 6983 by specifying machining processes rather than machine tool motion, using the object-oriented concept of workingsteps. Workingsteps correspond to high-level machining features and associated process parameters. CNCs are responsible for translating workingsteps into axis motion and tool operation. A major benefit of ISO 14649 is its use of existing data models from ISO 10303. As ISO 14649 provides a comprehensive model of the manufacturing process, it can also be used as the basis for a bi- and multi-directional data exchange between all other information technology systems.

ISO 14649 represents an object-oriented, information- and context-preserving approach for numerical control (NC) programming that supersedes data reduction to simple switching instructions or linear and circular movements. As it is object- and feature-oriented and describes the machining operations executed on the workpiece, rather than machine dependent axis motions, it will be running on different machine tools or controllers. This compatibility will spare all data adaptations by post-processors if the new data model is correctly implemented on the NC controllers. If old NC programs in ISO 6983 are intended to be used on such controllers, the corresponding interpreters will need to be able to process the different NC program types in parallel.

In developing ISO 14649, a gradual evolution from ISO 6983 programming to portable feature-based programming has been envisaged. Early adopters of ISO 14649 will certainly support data input of legacy “G and M codes” manually or through programs, just as modern controllers support both command-line interfaces and graphical user interfaces. This is likely to be made easier as open-architecture controllers become more prevalent. Therefore, ISO 14649 does not include legacy program statements, which would otherwise dilute its effectiveness.

The information form in ISO 14649 already allows for major improvements over existing methods, but in order to support even more efficient production, a description of the manufacturing environment will be needed in addition to the manufacturing information. Consequently, this part of ISO 14649 is a first step to permitting the description of machine tools as a manufacturing resource. The description allows process planners to describe their machine needs for a micro-process plan (an ISO 14649 file), referred to as a requirements model. The model also allows existing machine tools to be described as resources for manufacturing, referred to as catalogue models. This part of ISO 14649 is intended to provide a basis for process planning and simulation, for controller developers and for machine tool developers to describe their products, as well as for

research, for example. This part of ISO 14649 is not intended to replace existing standards for machine tool descriptions, but to provide the information necessary for manufacturing applications in a concise way. It is envisaged that there will be a continuing effort to describe the manufacturing resource environment in a standardized manner, so as to support efficient advanced and flexible manufacturing.

Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers —

Part 201:
Machine tool data for cutting processes

1 Scope

This part of ISO 14649 specifies the technology-specific machine tool description data elements needed as process data for manufacturing and machine characteristics. The machine tool descriptions covered in this schema are, initially, milling machines, machining centres, turning machines and multi-tasking machines.

This part of ISO 14649 is not intended to replace existing machine tool description standards, but to cover the specific needs of manufacturing resource description for manufacturing needs in the technologies described in ISO 14649.

Examples of manufacturing applications of this model are:

— part programming for CNC machining;

— process planning;

— a simulation of machining processes;

— analysis of expected machining time and machine tool energy use;

— a description of new machine tools for manufacturing evaluation and/or controller development.

The schema specified in this part of ISO 14649 does not include representations, executable objects and base classes that are common for all technologies. These are referenced from the generic resources of ISO 10303 and from ISO 14649-10.

2 Normative references

The following referenced documents are indispensable for the application 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 10303-105, *Industrial automation systems and integration — Product data representation and exchange — Part 105: Integrated application resource: Kinematics*

ISO 10303-240, *Industrial automation systems and integration — Product data representation and exchange — Part 240: Application protocol: Process plans for machined products*

ISO 14649-1, *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers — Part 1: Overview and fundamental principles*

3 Terms and definitions

3.1 Terms defined in ISO 14649-1

For the purposes of this document, the following terms and definitions given in ISO 14649-1 apply:

— executable;

— machining operation;

— NC function;

— workingstep.

3.2 Terms defined in ISO 10303-105

For the purposes of this document, the following terms and definitions given in ISO 10303-105 apply:

— base;

— frame;

— joint;

— kinematics;

— link;

— link frame;

— mechanism;

— pair;

— placement.

3.3 Terms defined in ISO 10303-240

For the purposes of this document, the following terms and definitions given in ISO 10303-240 apply:

— process plan.

3.4 Other terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.4.1
multi-channel control
control of multiple machining operations simultaneously

NOTE This can also be referred to as multi-path control.

3.4.2
multi-tasking machine tool
numerically-controlled machine tool with a swivel tool-spindle head that can be continuously rotated and a workholding spindle that can be oriented continuously around the axis, as well as an automatic tool changer and tool magazine (including turret head), and having two or more different machining abilities (such as turning, milling, hobbing) without change of set-up of a workpiece

NOTE This machine can include additional functions, such as measurement or heat treatment.

4 Machine tool data for cutting processes

4.1 Header and references

The following listing gives the header for the machine tool schema and the list of types and entities, which are imported within this schema.

```
USE FROM DATE_TIME_SCHEMA
  (calendar_date);

USE FROM GEOMETRY_SCHEMA
  (axis2_placement_3d);

USE FROM KINEMATIC_STRUCTURE_SCHEMA
  (cylindrical_pair,
   cylindrical_pair_range,
   kinematic_joint,
   kinematic_link,
   kinematic_link_representation,
   kinematic_link_representation_association,
   kinematic_link_representation_relation,
   kinematic_pair,
   kinematic_property_definition,
   kinematic_structure,
   mechanism,
   pair_actuator,
   prismatic_pair,
   prismatic_pair_range,
   revolute_pair,
   revolute_pair_range,
   rotational_range_measure,
   simple_pair_range,
   spherical_pair,
   spherical_pair_range,
   su_parameters,
   translational_range_measure,
   unlimited_range);

USE FROM MACHINING_SCHEMA
  (project,
   rot_speed_measure,
   workplan);

USE FROM MEASURE_SCHEMA
  (acceleration_measure,
   count_measure,
   electric_current_measure,
   length_measure,
   mass_measure,
   plane_angle_measure,
   power_measure,
   pressure_measure,
   ratio_measure,
   time_measure,
   velocity_measure,
   volume_measure);

USE FROM PRODUCT_DEFINITION_SCHEMA
  (product_definition);
```

```
USE FROM PRODUCT_PROPERTY_DEFINITION_SCHEMA
  (characterized_definition,
   characterized_object,
   characterized_product_definition);

USE FROM PRODUCT_PROPERTY_REPRESENTATION_SCHEMA
  (shape_representation);

USE FROM SUPPORT_RESOURCE_SCHEMA
  (identifier,
   label,
   text);
```

NOTE The schemas referenced above are specified in the following parts of ISO 10303 and ISO 14649:

date_time_schema	ISO 10303-41
geometry_schema	ISO 10303-42
kinematic_structure_schema	ISO 10303-105
machining_schema	ISO 14649-10
measure_schema	ISO 10303-41
product_definition_schema	ISO 10303-41
product_property_definition_schema	ISO 10303-41
product_property_representation_schema	ISO 10303-41
support_resource_schema	ISO 10303-41

4.2 General type definitions

4.2.1 Measure units

The types of units supported by ISO 14649 are SI units as well as derived or conversion based units as defined in ISO 10303-41. If the following defined types are used, the following units are assumed.

acceleration_measure	metres per square second [m/s^2]
count_measure	no unit
electric_current_measure	amperes [A]
length_measure	millimetres [mm]
mass_measure	kilograms [kg]
plane_angle_measure	degrees [°]
power_measure	watt [W]
pressure_measure	Pascal [pa]

rot_speed_measure	revolutions per second [1/s]
ratio_measure	no unit
time_measure	seconds [s]
velocity_measure	metres per second [m/s]
volume_measure	cubic metre [m^3]

4.2.2 jerk_measure

This is a measure for linear jerk. If the type is used, the unit of the value is metres per cubic second [m/s^3].

```
TYPE jerk_measure = REAL;
END_TYPE;
```

4.2.3 rot_acceleration_measure

This is a measure for rotational acceleration. Positive values indicate rotation in the mathematical positive sense, i.e. counter-clockwise motion. If the type is used, the unit of the value is revolutions per second squared [$1/s^2$].

```
TYPE rot_acceleration_measure = REAL;
END_TYPE;
```


4.2.4 rot_jerk_measure

This is a measure for rotational jerk. Positive values indicate rotation in the mathematical positive sense, i.e. counter-clockwise motion. If the type is used, the unit of the value is revolutions per second cubed [$1/s^3$].

```
TYPE rot_jerk_measure = REAL;
END_TYPE;
```

4.2.5 torque_measure

This is a measure for torque. If the type is used, the unit of the value is Newton metres [N·m].

```
TYPE torque_measure = REAL;
END_TYPE;
```

4.3 Machine tool

4.3.1 machine_tool

This entity is a supertype of machine_tool_specification and machine_tool_requirements.

```
ENTITY machine_tool
  SUPERTYPE OF (ONEOF(machine_tool_specification, machine_tool_requirements));
    description : text;
END_ENTITY;
```

description : This attribute specifies the word, or group of words, that describe the machine tool needed.

4.3.2 machine_tool_specification

This entity describes the properties of a machine tool that is a device with various moving parts that performs work.

```
ENTITY machine_tool_specification
  SUBTYPE OF(machine_tool);
    machine_class             : machine_class;
    device_id                 : device_id;
    machining_capabilities    : SET [1:?] OF machining_capability;
    measuring_capability      : OPTIONAL measuring_capability;
    location                  : OPTIONAL locator;
    installation              : OPTIONAL installation;
    nc_controller_information : nc_controller;
    environment               : OPTIONAL environmental_evaluation;
    its_elements              : OPTIONAL SET [1:?] OF machine_tool_element;
END_ENTITY;
```

machine_class : This attribute specifies the classification of the machine tool based on its main function.

device_id : This attribute specifies the identification information of the specified machine tool.

machining_capabilities : This attribute specifies the properties to show the machining characteristics of the machine tool.

measuring_capability : This attribute specifies the properties to show the measurement characteristics of the machine tool.

location : This attribute specifies the location and ownership information of the machine tool within a company.

installation : This attribute specifies the installation and facility planning information.

nc_controller_information : This attribute specifies the properties of the machine tool numerical controller.

environment : This attribute specifies the information to evaluate the machine tool environmentally.

its_elements : This attribute specifies the elements of which the machine tool is composed.

4.3.2.1 machine_class

This type is used for selecting a machine class.

```
TYPE machine_class = ENUMERATION OF
  (DRILLING_MACHINE,
   GUNDRILL_MACHINE,
   MACHINING_CENTRE,
   MILLING_MACHINE,
   MULTI_TASKING_MACHINE,
   TURNING_MACHINE);
END_TYPE;
```

DRILLING_MACHINE : Milling machine only for machining holes with a drilling tool.

GUNDRILL_MACHINE : Milling machine only for machining deep (long) holes with a gundrill tool.

MACHINING_CENTRE : A numerically controlled milling machine with programmable tool changing capabilities and the capacity for performing multiple operations, including milling, drilling, tapping, turning, and boring.

MILLING_MACHINE: Machine tool with at least one main spindle equipped for holding rotating tools. The purpose of this spindle is to generate sufficient speed between the tool and the part to allow for effective material removal by cutting.

MULTI_TASKING_MACHINE: Numerically controlled turning machine equipped with power driven tool(s) and the capability for orienting the work-holding spindle around its axis. This machine may include additional features such as programmable tool changing from a magazine.

TURNING_MACHINE: Machine tool in which the principle movement is the rotation of the workpiece against stationary cutting tool(s) and where cutting energy is provided by the workpiece rotation.

4.3.3 device_id

This entity describes the device identification information.

```
ENTITY device_id;
    id                : identifier;
    model_name        : label;
    serial_number     : identifier;
    manufacturer      : label;
    date_manufactured : OPTIONAL calendar_date;
END_ENTITY;
```


id : This attribute specifies a site-specific designation that uniquely identifies the device.

model_name : This attribute specifies the model designation used by the device vendor.

serial_number : This attribute specifies the serial number.

manufacturer : This attribute specifies the name of the manufacturer.

date_manufactured : This attribute specifies the date the device was manufactured.

4.3.4 locator

This entity describes the location and ownership information of the machine within a company. The exact content of locator is company specific.

```
ENTITY locator;
    business_unit  : label;
    plant_location : label;
    building       : label;
    cell           : label;
END_ENTITY;
```

business_unit : This attribute specifies the facility code of the business unit within the company to which the machine belongs.

plant_location : This attribute specifies the geographic location of the plant where the machine resides.

building : This attribute specifies the designation of the building in which the machine is installed.

cell : This attribute specifies the description of the actual location of the cell.

4.3.5 installation

This entity describes the installation and facility planning information.

```
ENTITY installation;
    weight                   : mass_measure;
    size                     : machine_size;
    electrical               : electrical;
    air_pressure_requirement : OPTIONAL pressure_measure;
    water_flow_rate          : OPTIONAL REAL;
    hydraulics               : OPTIONAL hydraulics;
END_ENTITY;
```

weight : This attribute specifies the mass of the machine.

size : This attribute specifies the dimensions of the machine.

electrical : This attribute specifies the properties for the electrical power supplied.

air_pressure_requirement : This attribute specifies the pressure of air supplied.

water_flow_rate : This attribute specifies the maximum flow rate of water supplied (m^3/s).

hydraulics : This attribute specifies the properties of the hydraulics system.

4.3.6 machine_size

This entity describes the overall dimensions of a machine.


```
ENTITY machine_size;
    machine_length : length_measure;
    machine_width  : length_measure;
    machine_height : length_measure;
END_ENTITY;
```

machine_length : This attribute specifies the length of the machine footprint (horizontal dimension orthogonal to that of the machine width).

machine_width : This attribute specifies the width of the machine footprint (horizontal dimension, usually in X, along the direction of material flow between machines).

machine_height : This attribute specifies the maximum height of the machine.

4.3.7 electrical

This entity describes the properties of the supplied electrical power.

```
ENTITY electrical;
    electric_phase       : INTEGER;
    electric_power       : power_measure;
    electrical_current   : electric_current_measure;
    electrical_frequency : STRING;
    electrical_grounding : STRING;
    electrical_voltage   : REAL;
END_ENTITY;
```

electric_phase : This attribute describes the number of phases.

electric_power : This attribute describes the maximum power consumption.

electrical_current : This attribute describes the maximum required amperage.

electrical_frequency : This attribute describes the number of cycles (frequency).

electrical_grounding : This attribute describes the grounding state of the machine.

electrical_voltage : This attribute describes the steady state line voltage required to operate the machine.

4.3.8 hydraulics

This entity describes the properties of a hydraulics system.

```
ENTITY hydraulics;
    type_of_hydraulic_oil       : label;
    pump_outlet_pressure        : pressure_measure;
    capacity_of_hydraulics_tank : volume_measure;
END_ENTITY;
```

type_of_hydraulic_oil : This attribute describes the type of hydraulic oil.

pump_outlet_pressure : This attribute describes the pump outlet pressure.

capacity_of_hydraulics_tank : This attribute describes the capacity of hydraulic tank.

4.3.9 nc_controller

This entity is the control device that commands tool paths for workpiece and operations for machining to its machine tool through numerical data.

```
ENTITY nc_controller;
    controller_model                              : label;
    controller_manufacturer                       : label;
    units                                         : units_type;
    maximum_number_of_simultaneous_control_axes   : count_measure;
    maximum_total_number_of_control_feed_axes     : count_measure;
    maximum_total_number_of_control_spindles      : count_measure;
    minimum_linear_increment                      : length_measure;
    minimum_angle_increment                       : plane_angle_measure;
    maximum_number_of_multi_channel_control       : count_measure;
    cycle_functions                               : OPTIONAL SET [1:?] OF text;
    interpolation_functions                       : SET [1:?] OF interpolation;
    look_ahead                                    : OPTIONAL INTEGER;
    adaptive_control                              : OPTIONAL text;
    miscellaneous_controller_functions            : OPTIONAL text;
    program_memory_size                           : OPTIONAL length_measure;
    cutting_feed_rate_override                    : OPTIONAL SET [1:?] OF
                                                    ratio_measure;
    rapid_traverse_override                       : OPTIONAL SET [1:?] OF
                                                    ratio_measure;
    tool_compensation_functions                   : OPTIONAL SET [1:?] OF
                                                    tool_compensation;
    time_sampling                                 : OPTIONAL time_measure;
    clock_frequency                               : OPTIONAL count_measure;
END_ENTITY;
```