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

Part 10:
General process data

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

Partie 10: Données des procédés généraux

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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.

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 14649-10 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 1, *Physical device control*.

This second edition cancels and replaces the first edition (ISO 14649-10:2003), of which it constitutes a minor revision.

ISO 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 111: Tools for milling machines*

— *Part 121: Tools for turning*

Gaps in the numbering of parts were left to allow further additions. The future Parts 2 and 3 will be for language bindings according to ISO 10303 methods. Part 10 is the ISO 10303 Application Reference Model (ARM) for process-independent data. ISO 10303 ARMs for specific technologies are added after Part 10. The future Part 50 will be the ISO 10303 Application Interpreted Model (AIM) for process-independent data. ISO 10303 AIMs for specific technologies are added after Part 50.

ISO 14649 is harmonised with ISO 10303 in the common field of Product Data over the whole life cycle. Figure 1 of ISO 14649-1 shows the different fields of standardisation between ISO 14649, ISO 10303 and CNC manufacturers with respect to implementation and software development.

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 must 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 standardised by ISO 10303. This leads to the possibility of using standard data throughout the entire process chain in the manufacturing enterprise. Impediments to realising 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 three reasons. First, the language focuses on programming the tool center path with respect to machine axes, rather than the machining process with respect to the part. Second, the standard defines the syntax of program statements, but in most cases leaves the semantics ambiguous. Third, 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 to 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 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, and not machine dependent axis motions, it will be running on different machine tools or controllers. This compatibility will spare all data adaptations by postprocessors, if the new data model is correctly implemented on the NC-controllers. If old NC programs in ISO 6983 are to be used on such controllers, the corresponding interpreters shall be able to process the different NC program types in parallel.

ISO TC184/SC1/WG7 envisions a gradual evolution from ISO 6983 programming to portable feature-based programming. 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 will likely be made easier as open-architecture controllers become more prevalent. Therefore, ISO 14649 does not include legacy program statements, which would otherwise dilute the effectiveness of the standard.

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

Part 10:
General process data

1 Scope

This part of ISO 14649 specifies the process data which is generally needed for NC-programming within all machining technologies. These data elements describe the interface between a computerised numerical controller and the programming system (i.e. CAM system or shop-floor programming system). On the programming system, the programme for the numerical controller is created. This programme includes geometric and technological information. It can be described using this part of ISO 14649 together with the technology-specific parts (ISO 14649-11, etc.). This part of ISO 14649 provides the control structures for the sequence of programme execution, mainly the sequence of working steps and associated machine functions.

The “machining_schema” defined in this part of ISO 14649 contains the definition of data types which are generally relevant for different technologies (e.g. milling, turning, grinding). The features for non-milling technologies like turning, EDM, etc. will be introduced when the technology specific parts like ISO 14649-12 for turning, ISO 14649-13 for EDM, and ISO 14649-14 for contour cutting of wood and glass are published. It includes the definition of the workpiece, a feature catalogue containing features which might be referenced by several technologies, the general executables and the basis for an operation definition. Not included in this schema are geometric items and representations, which are referenced from ISO 10303’s generic resources, and the technology-specific definitions, which are defined in separate parts of ISO 14649.

This part of ISO 14649 cannot stand alone. An implementation needs in addition at least one technology-specific part (e.g. ISO 14649-11 for milling, ISO 14649-12 for turning).

Additionally, the schema uses machining features similar to ISO 10303-224 and ISO 10303-214. The description of process data is done using the EXPRESS language as defined in ISO 10303-11. The encoding of the data is done using ISO 10303-21.

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 286-1:1988, *ISO system of limits and fits — Part 1: Bases of tolerances, deviations and fits*

ISO 10303-11, *Industrial automation systems and integration — Product data representation and exchange — Part 11: Description methods: The EXPRESS language reference manual*

ISO 10303-21, *Industrial automation systems and integration — Product data representation and exchange — Part 21: Implementation methods: Clear text encoding of the exchange structure*

ISO 10303-41, *Industrial automation systems and integration — Product data representation and exchange — Part 41: Integrated generic resource: Fundamentals of product description and support*

ISO 10303-42, *Industrial automation systems and integration — Product data representation and exchange — Part 42: Integrated generic resource: Geometric and topological representation*

ISO 10303-43, *Industrial automation systems and integration — Product data representation and exchange — Part 43: Integrated generic resource: Representation structures*

ISO 10303-214, *Industrial automation systems and integration — Product data representation and exchange — Part 214: Application protocol: Core data for automotive mechanical design processes*

ISO 10303-224:2001, *Industrial automation systems and integration — Product data representation and exchange — Part 224: Application protocol: Mechanical product definition for process planning using machining features*

ISO 10303-514:1999, *Industrial automation systems and integration — Product data representation and exchange — Part 514: Application interpreted construct: Advanced boundary representation*

3 Terms and definitions

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

3.1
2D
Geometry in a xy-plane, where all the geometry's points have only x and y coordinates.

3.2
2½D machining
Machining of a prismatic part. Typically, the workpiece is processed in several layers which are located perpendicular to the tool axis. In the EXPRESS listing of ISO14649, the term "two5D" is used for entity and attribute names.

3.3
3D
Geometry in three-dimensional space, where all points have x, y, and z coordinates.

3.4
freeform machining
Machining of freeform surfaces. For this kind of machining, the tool has to move in at least three axes simultaneously while processing the workpiece. Sometimes five-axes milling machines are used to reach an optimised angle between the tool and the workpiece surface.

3.5
CAM
Computer Aided Manufacturing

3.6
CNC
Computer Numerical Control

3.7
EDM
Electrical Discharge Machining

3.8
EXPRESS
The language described in ISO10303-11

3.9
EXPRESS-G
The graphic representation of the EXPRESS language as described in ISO10303-11

3.10
Feature
A geometric entity of a workpiece which has semantic significance. In the context of ISO 14649, manufacturing features are used

3.11
SI
International system of units

4 General Process data

4.1 Header and references

The following listing gives the header and the list of entities which are referenced within this schema.

```
SCHEMA machining_schema;
(*
Version of April 30, 2004
Author: ISO TC184/SC1/WG7
*)


REFERENCE FROM approval_schema              (*ISO 10303-41e3*)
  ( approval,
    approval_status);

REFERENCE FROM date_time_schema             (*ISO 10303-41e3*)
  ( date_and_time,
    date);
REFERENCE FROM person_organization_schema   (*ISO10303-41e3*)
  ( person,
    address);

REFERENCE FROM support_resource_schema      (*ISO10303-41e3*)
  ( bag_to_set,
    identifier,
    label,
    text);

REFERENCE FROM measure_schema               (*ISO10303-41e3*)
  ( length_measure,
    parameter_value,
    plane_angle_measure,
    positive_length_measure);

REFERENCE FROM product_property_representation_schema  (*ISO10303-41e3*)
  ( shape_representation);

REFERENCE FROM representation_schema        (*ISO10303-43e2*)
  ( definitional_representation);

REFERENCE FROM geometry_schema              (*ISO10303-42e3*)
  ( trimming_select,
    trimming_preference,
    transition_code,
```

```
      trimmed_curve,
      composite_curve,
      composite_curve_segment,
      axis2_placement_3d,
      bounded_curve,
      bounded_surface,
      cartesian_point,
      circle,
      conic,
      curve,
      direction,
      elementary_surface,
      plane,
      polyline
      );

  REFERENCE FROM topology_schema              (*ISO10303-42e3*)
    ( edge, edge_curve, edge_loop, face, loop);

  REFERENCE FROM geometric_model_schema       (*ISO10303-42e3*)
    ( block,
      right_circular_cylinder
     );

  REFERENCE FROM aic_advanced_brep            (*ISO10303-514*)
     (advanced_brep_shape_representation
     );
```


4.2 General types and 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 no units are given then, the following units are assumed:

length_measure	millimetres [mm],
time_measure	seconds [s],
plane_angle_measure	degrees [°],
pressure_measure	Pascal [pa],
speed_measure	meters per second [m/sec],
rot_speed_measure	revolutions per second [1/sec].

4.2.1.1 Toleranced length measure

Length measure with tolerance.

```
  ENTITY toleranced_length_measure;                            (* m1 *)
    theoretical_size:       positive_length_measure;
    implicit_tolerance:     tolerance_select;
  END_ENTITY;
```


theoretical_size: The theoretical length.

implicit_tolerance: The type of tolerance to apply to theoretical_size.

Note that all geometric properties of the workpiece are specified using toleranced_length_measure. If the NC controller has the ability to generate toolpaths or to make decisions about the tool used, it is the controller's responsibility to meet these tolerance requirements. On the other hand, data provided to the NC controller for explicit specification of movements will have no tolerances as the controller cannot do more than try to follow the given theoretical values to the best of its abilities. The same is true for offsets and other data referring to already toleranced dimensions.

4.2.1.1.1 Tolerance select

Select type offering different etities to describe tolerances for scalar values.

```
TYPE tolerance_select = SELECT(plus_minus_value, limits_and_fits);
END_TYPE;
```

4.2.1.1.2 Plus minus value

The plus_minus_value describes the upper and lower limits valid for a scalar dimension referencing this entity.

```
ENTITY plus_minus_value;                                    (* m1 *)
  upper_limit:            positive_length_measure;
  lower_limit:            positive_length_measure;
  significant_digits:     INTEGER;
END_ENTITY;
```


upper_limit: The value of the tolerance that shall be added to the exact value to establish the maximum allowed value.

lower_limit: the value of the tolerance that shall be subtracted from the exact value to establish the minimum allowed value.

significant_digits: The number of decimal digits indicating the accuracy of the lower_bound and upper_bound values.

4.2.1.1.3 Limits and fits

A limits_and_fits contains the necessary information to express a tolerance of the limits-and-fits system standardised by ISO 286.

```
ENTITY limits_and_fits;                                     (* m1 *)
  deviation:              length_measure;
  grade:                  length_measure;
  its_fitting_type:       OPTIONAL fitting_type;
END_ENTITY;
```

deviation: The difference between a measured actual size and the corresponding basic size as defined in ISO 286-1.

grade: The grade specifies the quality or the accuracy grade of a tolerance. The grade is based on the international standard tolerance grades IT01 to IT18 as defined in ISO 286-1.

fitting_type: Specification whether the tolerance declaration applies to a shaft or to a hole.

4.2.1.1.4 Fitting type

The enumeration used to specify the type of fitting.

```
TYPE fitting_type = ENUMERATION OF (shaft,hole);
END_TYPE;
```

4.2.1.2 Speed measure

A measure for a linear speed used for cutting speeds and feed rates.

```
TYPE speed_measure = REAL;
END_TYPE;
```

4.2.1.3 Rotational speed measure

A measure for a rotational speed. Positive values indicate rotation in the mathematical positive sense, i. e. counter-clockwise motion.

```
TYPE rot_speed_measure = REAL;
END_TYPE;
```

4.2.1.4 Pressure measure

A measure for pressure.


```
TYPE pressure_measure = REAL;
END_TYPE;
```

4.2.2 Other general types

4.2.2.1 Rotational direction

Enumeration used to identify the direction (sense) of the tool's rotation or of the direction of a circular movement. It should not be used in conjunction with rot_speed_measure which carries its own sense of rotation.

```
TYPE rot_direction = ENUMERATION OF (cw,ccw);
END_TYPE;
```

Note: cw means clockwise, ccw means counter-clockwise.

4.2.2.2 Shape tolerance

Type for definition of shape tolerance.

```
TYPE shape_tolerance = length_measure;
END_TYPE;
```

4.3 Where to start: Project

Each part programme, i.e. data model, based on ISO14649 must include exactly one top-level entity, called project. The project indicates the workplan to be executed upon interpretation of this model (as several workplans might be included), and it may also provide the workpiece(s) upon which actions are to be performed.

```
ENTITY project;                                                    (* m0 *)
  its_id:                   identifier;
  main_workplan:            workplan;
  its_workpieces:           SET [0:?] OF workpiece;
  its_owner:                OPTIONAL person_and_address;
  its_release:              OPTIONAL date_and_time;
  its_status:               OPTIONAL approval;
  (* Informal proposition:
     its_id shall be unique within the part programme.
  *)
END_ENTITY;
```

its_id:	The project's identifier. It shall be unique within the part programme.
main_workplan:	The top-level workplan in this model.
its_workpieces:	The workpieces upon which actions are to be performed.
its_owner:	Optional information on the owner of the project.
its_release:	Optional date and time reference of the project.
its_status:	Optional attribute to indicate the current status of the project.

4.3.1 Person and address

Entity includes data to name and reference a person, who for instance is responsible for creating a project.


```
ENTITY person_and_address;                                         (* m0 *)
  its_person:               person;
  its_address:              OPTIONAL address;
END_ENTITY;
```

4.4 What to machine: Workpiece and manufacturing feature

4.4.1 Workpiece

The workpiece entity contains the entire description of the workpiece, if available. This includes material, surface condition and geometric data. Each workpiece has only one surface condition and one material. Dependent on the conformance class the workpiece entity includes the raw part dimension only as an including box or cylinder, or, in a higher class, as a representation which can be a complete geometric model, e.g. the state after previous manufacturing operations.

```
ENTITY workpiece;                                                  (* m1 *)
  its_id:                   identifier;
  its_material:             OPTIONAL material;
  global_tolerance:         OPTIONAL shape_tolerance;
  its_rawpiece:             OPTIONAL workpiece;
  its_geometry:             OPTIONAL advanced_brep_shape_representation;
  its_bounding_geometry:    OPTIONAL bounding_geometry_select;
  clamping_positions:       SET [0:?] OF cartesian_point;
END_ENTITY;
```

its_id:	The unique identification of a workpiece.
its_material:	The material attribute identifies the workpiece material. This data shall be used for determining the technological process parameters for the manufacturing process. It can be done by the machine operator or by an automatic feed rate/cutting condition selection (from a table or a data base on the CNC).
global_tolerance:	Tolerance for the workpiece, valid where no other tolerances are specified.
its_rawpiece:	The rawpiece geometry of the workpiece may be described here. A recursive description is used, i.e. the rawpiece is of type workpiece itself.
its_geometry:	An exact description of the final workpiece geometry according to ISO 10303-514.
its_bounding_geometry:	By this attribute the workpiece´s bounding geometry might be defined as a box, a cylinder or a geometry according to the definition of the entity advanced_brep_shape_representation (ISO 10303--514).
clamping_positions:	Positions of the clamping device on the workpiece's surface.

All attribute's locations, directions and geometrical information are defined relatively to the workpiece's coordinate system.

4.4.1.1 Material

This entity is for identifying the workpiece material.


```
ENTITY material;                                        (* m1 *)
  standard_identifier:     label;
  material_identifier:     label;
  material_property:       SET [0:?] OF property_parameter;
END_ENTITY;
```

standard_identifier:	The standard used for identifying the material. This can be a national standard or one used internally in the company.
material_identifier:	The name which identifies the material.
material_property:	The parameter which describes the properties of material. Since the demand for material properties varies, a generic type „property parameter" is used.

4.4.1.2 Property parameter

Generic property parameter which may be used to characterise any kind of property any kind of parameter might have. Subtypes are descriptive parameters (strings) and numeric parameters.

