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Industrial automation systems and integration

Physical device control

ISO 14649 Data model for Computerized Numerical Controllers

Part 111: TOOLS FOR MILLING

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Information on technical or structural contents are available at the following addresses:

Convener:	Friedrich Glantschnig
	AMT Consulting
Address:	Höhenweg 33a
	CH-5417 Untersiggenthal
Telephone:	+41 (056) 288 2042
FAX;	+41 (056) 288 3942
E-mail:	fglantschnig@swissonline.ch

Owners of this part of documents,

	Yong Tak Hyun	Dr. Chiaki Sakomoto
	WZL, RWTH-Aachen	Komatsu Engineering Co. LZD
Adress:	Werkzeugmaschinenlabor	3-20-1 Nakase
	RWTH	Kawasaki-Ward
	D-52074 Aachen	J-210-0818 Kawasaki City
Telephone:	+49 (0241) 8027458	+89 (44) 288 8782
FAX:	+49 (0241) 8022293	+89 (44) 288 8777
E-mail:	hyt@wzl.rwth-aachen.de	chiaki_sakamoto@KEG.komatsu.co.jp

Contents

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.

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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 part of ISO 14649 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

International Standard ISO 14649-111 was prepared by Technical Committee ISO/TC 184, *Industrial automation systems and integration*, Subcommittee SC 1, *Physical device control*.

ISO 14649 consists of the following parts, under the general title

Data model for Computerized Numerical Controllers

— Part 1 *: Overview and fundamental principles, published as actual DIS Phase 1•*

— Part 2: *Language bindings, Fundamentals, will be published as Phase 3*

— Part 3: *Language binding in Java, will be published as Phase 3*

— Part 9: *Glossary, will be published as Phase 3*

— Part 10: *General Process Data, published as actual DIS Phase 1*

— Part 11: *Process Data for Milling, published as actual DIS Phase 1*

— Part 12: *Process Data for Turning, will be published as Phase 3*

— Part 13: *Process Data for EDM, will be published as Phase 3*

— Part 50: *AIM of General Process Data, will be published as Phase 2*

— Part 51: *AIM of Process Data for Milling, will be published as Phase 2*

— Part 52: *AIM of Process Data for Turning, will be published as Phase 3*

— Part 53: *AIM of Process Data for EDM, will be published as Phase 3*

— Part 111: *Tools for Milling, published as actual DIS Phase 1*

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 standardized by ISO 10303. This leads 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 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 111: Tools for milling

1 Scope

This part of ISO 14649 specifies the data elements needed as tools for milling. They work together with ISO 14649-11, the process data for milling. These data elements can be used as a criteria to select one of several milling and drilling type tools, not to describe a complete information of a particular tool. Therefore, leaving out optional attributes gives the controller more freedom to select from a larger set of tools. The NC is assumed to have access to complete description of specific tools in a database.

The milling_tool_schema defined in this part of ISO 14649 serves as a basic tool schema including just the most important information. It is intended to give the controller enough information to select the tool specified in the NC-program. In ISO 6983, the tool is defined just with its number (e.g. T8). No further information concerning the tool type or geometry is given. This information is part of the tool set-up sheet, which is supplied with the NC-program to the machine. The tool set-up sheet gives the relationship between the tool location (e.g. slot 8) and the type of tool (e.g. "drill 4 mm").

The approach of this tool sheet to ISO 14649-11 is to include the information which is contained in the tool set-up sheet mentioned above in the NC program. Therefore, the most important information which needs to be included in the tool description is:

- tool type
- tool geometry
- expected tool life

The tool schema does not include information which is part of the tool database. The tool database is related to the machine and the tools themselves but independent of the NC program. This means that data like the following data types are not included in the tool schema:

- normative tool life
- tool location in the tool changer

The tool schema does not include information about tool holders and tool assembly components.

It is important to understand that all length measure types used in this Part are not toleranced length measure types because they are used to describe the tools **required** for the manufacturing of a workpiece, not the actual dimensions of the tools available at the machine. A real tool must be selected by the tool management based on the actual tool dimensions and the tolerances of features.

The overall structure of the tool description in this part of ISO 14649 and ISO 14649-10 is the same with ISO/DIS 13399-1. Many definitions of tool body and it's geometry are referenced from the NIST tool model. [NISTIR5707:Modeling of Manufacturing Resource Information, July,1995]The scope of this part of ISO 14649 does not include tools for any other technologies, like turning, grinding, or EDM. Tools for these technologies will be described in further parts of ISO 14649.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of ISO 14649. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of ISO 14649 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 10303 Part11, Industrial automation systems and integration - Product data and exchange - Description methods: the EXPRESS Language Reference Manual.

ISO/DIS 13399 Part1, Cutting tool data representation and exchange: Overview and fundamental principles.

ISO/DIS 13399 Part2, Cutting tool data representation and exchange: Reference hierarchy for cutting tools.

ISO/DIS 13399 Part3, Cutting tool data representation and exchange: General data for cutting tools.

3 Terms and definitions

For the purposes of this part of ISO 14649, the terms and definitions given in ISO 14649-10 and ISO 14649-11 apply.

4 Cutting tools for milling

4.1 Header and references

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

```
SCHEMA milling_tool_schema;
(* Version 13 of February 6, 2002
   Author: ISO TC184/SC1/WG7 *)

REFERENCE FROM machining_schema (*ISO14649-10*)
    (plane_angle_measure,
     length_measure,
     direction,
     label,
     cutting_tool,
     tool_body,
     technology);
```

4.2 Milling_cutting Tool

Entity to describe the technology specific information needed for description of cutting tool for milling, which includes all milling type tools (e.g. milling cutter, reamer, drill, tap, boring tool). It is a subtype of entity cutting_tool defined in Section 4.6.2.3.5 of ISO 14649-10.

```
ENTITY Milling_cutting_tool
SUBTYPE OF (cutting_tool);
  direction_for_spindle_orientation:
                        OPTIONAL direction;
  tool_holder_diameter_for_spindle_orientation:
                        OPTIONAL length_measure;
END_ENTITY;
```

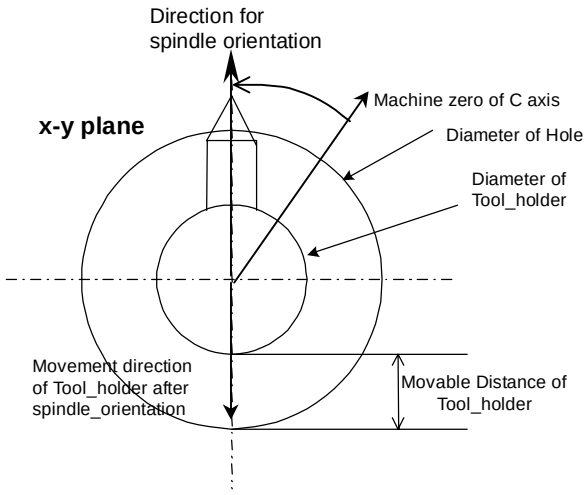


Fig. 1: Hole boring

direction_for_spindle_orientation:

The direction of spindle orientation for a specific tool. If specified, the oriented_spindle_stop of milling_machine_function in Part 11 should be done in this position (see figure 1)

tool_holder_diameter_for_spindle_orientation:

The diameter of the tool holder. (see figure 1)

4.3 Milling_tool body

This is the abstract base class for all types of tool bodies for milling. It is a subtype of entity tool_body defined in ISO 14649-10. These types include countersink, drill, milling cutter, tap, counterbore, reamer, and boring tool. Technological information about the tool body for milling is also defined.

```
ENTITY milling_tool_body
  ABSTRACT SUPERTYPE OF (ONEOF(centerdrill, countersink, drill, milling_cutter,
    tap, threading_tool, counterbore, reamer, boring_tool, user_defined_tool))
  SUBTYPE OF(tool_body);
  dimension:               tool_dimension;
  number_of_teeth:         OPTIONAL INTEGER;
  hand_of_cut:             OPTIONAL hand;
  coolant_through_tool:    OPTIONAL BOOLEAN;
  pilot_length:            OPTIONAL length_measure;
  END_ENTITY;
```

dimension: The information specifying the dimensions of the tool body.

number_of_teeth: The number of teeth the tool has.

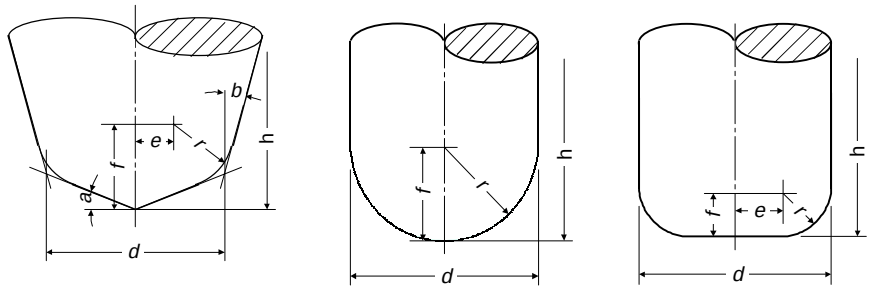
hand_of_cut: Direction of cutter feed or cutter rotation as defined by type hand.

coolant_through_tool: Does the tool body have through-the-tool coolant capabilities?[Valid values: Yes, No]. [ISO/DIS 13399-3, Table 2]

pilot_length: Length from the tip of the tool to the start of the sinking region.

4.3.1 Tool dimension

Entity to describe the dimensions of tool body. The figure 3 describes a generalised tool, a ball endmill, and a bullnose endmill. A real tool will have only some of the tool dimensions, and the other dimensions will be zero. E.g. for a ball endmill, ”e”, ”b”, and ”a” will be zero, ”r” will equal ”f” and ”d” will be twice as big as ”r”. For a bullnose endmill, ”b” and ”a” will be zero, ”d” will be twice as big as ”r” plus ”e”.



Generalised tool Ball endmill Bullnose endmill

d: diameter
[subclause 5.3.3 of this part]
r: edge_radius
e: edge_center_horizontal
f: edge_center_vertical h:
a: tool_tip_half_angle
b: tool_circumference_angle
h: cutting_edge_length

Fig. 2: Tool dimension

```
ENTITY tool_dimension;
  diameter:              length_measure;
  tool_tip_half_angle:   OPTIONAL plane_angle_measure;
  tool_circumference_angle:
                         OPTIONAL plane_angle_measure;
  cutting_edge_length:   OPTIONAL length_measure;
  edge_radius:           OPTIONAL length_measure;
  edge_center_vertical:  OPTIONAL length_measure;
  edge_center_horizontal:OPTIONAL length_measure;
END_ENTITY;
```

diameter: The diameter of the cutting tool.

tool_tip_half_angle: The angle of the tool at its tip. (a)

tool_circumference_angle: The angle of the tool at its circumference (b). This angle is identical to the taper_angle for the case of tapered_drill, tapered_endmill, tapered_tap and tapered_reamer. If both attributes are given, this attribute will be ignored.

cutting_edge_length: The length measured along the longest major cutting edge to the cutting tip (h). It is the maximum cutting depth (or width, depending on the tool) which can be achieved with this tool.

edge_radius: The edge radius of the tool (r).

edge_center_vertical: The vertical offset for the edge radius (f).

edge_center_horizontal: The horizontal offset for the edge radius (e).

4.3.2 Hand

Direction of cutter feed or cutter rotation. Also called cutting direction. For rotating tools, the Hand of Cut may be determined by observing the drive end of the tool body when mounted so as to a make a cut (as defined in ISO 3002-1:1982, Subclause 8.2). If the rotary motion of the tool body is clockwise, the Hand of Cut is right-hand. If the rotary motion of the tool body is counterclockwise, the Hand of Cut is left-hand. For stationary or single-point tools,

the Hand of Cut is the direction of cutter feed. A value of ”neutral” typically refers to single-point tools. [ISO/DIS 13399-3, Table 2]

```
TYPE hand = ENUMERATION OF(left, right, neutral);
END_TYPE;
```

4.4 Catalogue of tool body

4.4.1 Centerdrill

Entity to describe the tool body of centerdrill. A centerdrill is used to center a tool shaft prior to cutting.

```
ENTITY centerdrill
SUBTYPE OF (milling_tool_body);
END_ENTITY;
```

4.4.2 Countersink

Entity to describe the tool body of countersink. A countersink is a drill capable of cutting a tapered enlargement at the opening of a hole.

```
ENTITY countersink
   SUPERTYPE OF (backside_countersink)
   SUBTYPE OF (milling_tool_body);
   countersink_radius:    OPTIONAL length_measure;
END_ENTITY;
```

countersink_radius: The minimum cutting diameter of the sinking region

4.4.2.1 Backside countersink

Entity to describe the tool body of backside countersink.

```
ENTITY backside_countersink
  SUBTYPE OF (countersink);
END_ENTITY;
```

4.4.3 Drill

This is the abstract base class for drills. A drill is rotary end-cutting tool used for the production of holes.

```
ENTITY drill
  ABSTRACT SUPERTYPE OF (ONEOF(twist_drill, spade_drill))
  SUBTYPE OF (milling_tool_body);
END_ENTITY;
```

4.4.3.1 Twist drill

Entity to describe the tool body of twist drill. A twist drill is a drill having one or more cutting lips and one or more straight or helical flutes for the passage of chips and cutting fluids.

```
ENTITY twist_drill
  SUPERTYPE OF (tapered_drill)
  SUBTYPE OF (drill);
END_ENTITY;
```

4.4.3.1.1 Tapered drill

Entity to describe the tool body of tapered drill.

```
ENTITY tapered_drill
  SUBTYPE OF (twist_drill);
  taper_angle:           OPTIONAL plane_angle_measure;
END_ENTITY;
```

taper_angle: Angle formed between a line parallel to the cutting edges and a line parallel to the tool axis.

4.4.3.2 Spade drill

Entity to describe the tool body of spade drill. A spade drill is a drill capable of producing large deep holes with a variety of bottom profiles. A spade drill typically consists of a removable blade or tip clamped in a holder on the drill shank.

```
ENTITY spade_drill
  SUBTYPE OF (drill);
END_ENTITY;
```

4.4.4 Milling cutter

This is the abstract base class for milling cutters. A milling cutter is a rotary cutting tool, usually with straight or helical flutes, capable of producing a variety of forms, contours, or profiles such as slots, pockets, and peripheral surfaces.

```
ENTITY milling_cutter
    ABSTRACT SUPERTYPE OF (ONEOF(facemill, endmill, t_slot_mill,
      dovetail_mill, woodruff_keyseat_mill, side_mill, thread_mill))
    SUBTYPE OF (milling_tool_body);
END_ENTITY;
```

4.4.4.1 Facemill

Entity to describe the tool body of facemill. A facemill is a milling cutter used for machining large surfaces perpendicular to the tool axis.

```
ENTITY facemill
  SUBTYPE OF (milling_cutter);
END_ENTITY;
```

4.4.4.2 Endmill

Entity to describe the tool body of endmill. An endmill is a cylindrical milling cutter capable of cutting on the end and on the periphery.

```
ENTITY endmill
  SUPERTYPE OF (ONEOF(tapered_endmill, ball_endmill, bullnose_endmill))
  SUBTYPE OF (milling_cutter);
END_ENTITY;
```

4.4.4.2.1 Tapered endmill

Entity to describe the tool body of tapered endmill.

```
ENTITY tapered_endmill
    SUBTYPE OF (endmill);
```

```
        taper_angle:          OPTIONAL plane_angle_measure;
END_ENTITY;
```

taper_angle: Angle formed between a line parallel to the cutting edges and a line parallel to the tool axis. The taper region begins at the head of the tool and may extend the full Flute Length. The Flute Length is the length of the cutting edge along the tool body, measured parallel to the tool axis. Also referred to as the Length of Cut.

4.4.4.2.2 Ball endmill

Entity to describe the tool body of ball endmill.

```
ENTITY ball_endmill
  SUBTYPE OF (endmill);
WHERE
  WR1: (NOT EXISTS(SELF.dimension.edge_center_horizontal))
       OR ((EXISTS(SELF.dimension.edge_center_horizontal)) AND
       (SELF.dimension.edge_center_horizontal = 0));
  WR2: (NOT EXISTS(SELF.dimension.edge_center_vertical))
       OR ((EXISTS(SELF.dimension.edge_center_vertical)) AND
       (SELF.dimension.edge_center_vertical = SELF.dimension.diameter/2));
  WR3: (NOT EXISTS(SELF.dimension.edge_radius))
       OR ((EXISTS(SELF.dimension.edge_radius)) AND
       (SELF.dimension.edge_radius = SELF.dimension.diameter/2));
  WR4: (NOT EXISTS(SELF.dimension.tool_tip_half_angle))
       OR ((EXISTS(SELF.dimension.tool_tip_half_angle)) AND
       (SELF.dimension.tool_tip_half_angle = 0));
  WR5: (NOT EXISTS(SELF.dimension.tool_circumference_angle))
       OR ((EXISTS(SELF.dimension.tool_circumference_angle)) AND
       (SELF.dimension.tool_circumference_angle = 0));
END_ENTITY;
```

4.4.4.2.3 Bullnose endmill

Entity to describe the tool body of bullnose endmill.

```
ENTITY bullnose_endmill
  SUBTYPE OF (endmill);
WHERE
  WR1: (NOT EXISTS(SELF.dimension.tool_tip_half_angle))
       OR ((EXISTS(SELF.dimension.tool_tip_half_angle)) AND
       (SELF.dimension.tool_tip_half_angle = 0));
  WR2: (NOT EXISTS(SELF.dimension.tool_circumference_angle))
       OR ((EXISTS(SELF.dimension.tool_circumference_angle)) AND
       (SELF.dimension.tool_circumference_angle = 0));
END_ENTITY;
```

4.4.4.3 T slot mill

Entity to describe the tool body of T slot mill. A T-slot mill is a milling cutter used to produce “T“ shaped slots through surfaces perpendicular to the tool axis.

```
ENTITY t_slot_mill
  SUBTYPE OF (milling_cutter);
  cutting_thickness:     OPTIONAL length_measure;
END_ENTITY;
```

cutting_thickness: The length measurement between opposite faces of the milling cutter, measured along the tool axis.

4.4.4.4 Dovetail mill

Entity to describe the tool body of dovetail mill. A dovetail mill is a milling cutter used to produce “dovetail“ shaped slots through a surface perpendicular to the tool axis.

```
ENTITY dovetail_mill
  SUBTYPE OF (milling_cutter);
  included_angle:        OPTIONAL plane_angle_measure;
END_ENTITY;
```

included_angle: Angle formed between a line parallel to the side cutting edge and a plane normal to the tool axis, measured from the projection onto a plane that is parallel to the tool axis.

4.4.4.5 Woodruff keyseat mill

Entity to describe the tool body of woodruff keyseat mill. A woodruff keyseat mill is a milling cutter used to produce a slot with a rectangular cross-section perpendicular to the tool axis and a circular-arc cross-section parallel to the tool axis. The slot is used to mount a Woodruff Key.

```
ENTITY woodruff_keyseat_mill
  SUBTYPE OF (milling_cutter);
  cutter_width:          OPTIONAL length_measure;
END_ENTITY;
```

cutter_width: The length measurement between opposite faces of the milling cutter, measured along the toll axis.

4.4.4.6 Side mill

Entity to describe the tool body of side mill. A side mill is a cylindrical milling cutter having teeth on the periphery as well as on one or both ends.

```
ENTITY side_mill
  SUBTYPE OF (milling_cutter);
  cutter_width:          OPTIONAL length_measure;
END_ENTITY;
```

4.4.4.7 Thread mill

Entity to describe the tool body of thread mill. A thread mill is a milling cutter having cutting edges capable of producing threads on internal holes or external shafts.

```
ENTITY thread_mill
  SUBTYPE OF (milling_cutter);
END_ENTITY;
```

4.4.5 Tap

Entity to describe the tool body of tap. A tap is a rotary cutting tool with multiple cutting teeth used to produce internal threads.

```
ENTITY tap
  SUPERTYPE OF (ONEOF (tapered_tap, combined_drill_and_tap))
  SUBTYPE OF (milling_tool_body);
END_ENTITY;
```

4.4.5.1 Tapered tap

Entity to describe the tool body of tapered tap.

```
ENTITY tapered_tap
  SUBTYPE OF (tap);
  taper_angle:          OPTIONAL plane_angle_measure;
END_ENTITY;
```

taper_angle: Angle formed between a line parallel to the cutting edges and a line parallel to the tool axis.

4.4.5.2 Combined drill and tap

Entity to describe the tool body of combined drill and tap. A combined drill and tap is a tap capable of drilling and tapping a hole in a single pass.

```
ENTITY combined_drill_and_tap
  SUBTYPE OF (tap);
  drill_length:         OPTIONAL length_measure;
END_ENTITY;
```

drill_length: Length of the portion of drill.

4.4.6 Threading tool

Entity to describe the tool body of threading tool. A threading tool is a single point cutter and is used for thread_drilling_manufacturing_data.

```
ENTITY threading_tool
  SUBTYPE OF (milling_tool_body);
END_ENTITY;
```

4.4.7 Counterbore

Entity to describe the tool body of counterbore. A counterbore is a drill capable of enlarging the opening of a previously formed hole.

```
ENTITY counterbore
  SUPERTYPE OF (backside_counterbore)
  SUBTYPE OF (milling_tool_body);
END_ENTITY;
```

4.4.7.1 Backside counterbore

Entity to describe the tool body of backside counterbore.

```
ENTITY backside_counterbore
  SUBTYPE OF (counterbore);
END_ENTITY;
```

4.4.8 Reamer

Entity to describe the tool body of reamer. A reamer is a multiple-cutting-edge tool used to enlarge or finish round holes, to give accurate dimensions as well as reduced surface roughness. The cutting edges of a reamer can be both on the end and on the periphery.

```
ENTITY reamer
  SUPERTYPE OF (ONEOF (tapered_reamer, combined_drill_and_reamer))
```

```
    SUBTYPE OF (milling_tool_body);
  END_ENTITY;
```

4.4.8.1 Tapered reamer

Entity to describe the tool body of tapered reamer.

```
  ENTITY tapered_reamer
    SUBTYPE OF (reamer);
    taper_angle:           OPTIONAL plane_angle_measure;
  END_ENTITY;
```

taper_angle: Angle formed between a line parallel to the flutes and a line parallel to the tool axis. The taper region begins at the head of the tool and may extend the full length of the flutes.

4.4.8.2 Combined drill and reamer

Entity to describe the tool body of combined drill and reamer. A combined drill and reamer is a reamer capable of both drilling and finishing a hole in one pass.

```
  ENTITY combined_drill_and_reamer
    SUBTYPE OF (reamer);
    drill_length:          OPTIONAL length_measure;
  END_ENTITY;
```

drill_length: Length of the portion of drill.

4.4.9 Boring tool

Entity to describe the tool body of boring tool. A boring tool is a single point cutting tool used to enlarge or finish internal holes coaxial with the boring tool axis. The cutting point(s) of the boring tool can be used singly or in pairs.

```
  ENTITY boring_tool
    SUBTYPE OF (milling_tool_body);
    retract_movement_forbidden:  BOOLEAN;
  END_ENTITY;
```

retract_movement_forbidden: If true, the boring tool is not allowed to move to the opposite direction of direction_for_spindle_orientation after spindle_orientation at the bottom of a hole.(see Section 5.2). This prevents the collision of boring tool which have two cutting points working on the same circle of diameter from the center of a hole.

4.4.10 User defined tool

User can describe a tool body here.

```
  ENTITY user_defined_tool
    SUBTYPE OF (milling_tool_body);
    identifier:   label;
  END_ENTITY;
```

identifier: Name of the tool. If this identifier is not unique, a match will be made based upon the other (optional) attributes inherited from tool_body. If it is unique and the optional attributes are given but do not match the properties of the named tool, no tool will be selected.

Annex A
(normative)

EXPRESS listing

The following EXPRESS is the whole schema given in clause 4. In the event of any discrepancy between the short form and this expanded listing, the expanded listing shall be used. The short names of entities are included in annex B of ISO 14649-11.

```
SCHEMA milling_tool_schema;
(*
Version 13 of February 6, 2002
Author: ISO TC184/SC1/WG7
*)

REFERENCE FROM machining_schema (*ISO14649-10*)
    (plane_angle_measure,
     length_measure,
     direction,
     label,
     cutting_tool,
     tool_body,
     technology);

(*======================== milling cutting tool ================================*)

ENTITY milling_cutting_tool
SUBTYPE OF (cutting_tool);

        direction_for_spindle_orientation:
                              OPTIONAL direction;
        tool_holder_diameter_for_spindle_orientation:
                              OPTIONAL length_measure;
END_ENTITY;
(*======================== milling tool body ===================================*)

ENTITY milling_tool_body
    ABSTRACT SUPERTYPE OF (ONEOF(centerdrill, countersink, drill,
      milling_cutter, tap, threading_tool, counterbore, reamer,
      boring_tool, user_defined_tool))
    SUBTYPE OF (tool_body);
        dimension:             tool_dimension;
        number_of_teeth:       OPTIONAL INTEGER;
        hand_of_cut:           OPTIONAL hand;
        coolant_through_tool:  OPTIONAL BOOLEAN;
        pilot_length:          OPTIONAL length_measure;
END_ENTITY;

(*========================== tool dimension ====================================*)

ENTITY tool_dimension;
        diameter:              length_measure;
        tool_tip_half_angle:   OPTIONAL plane_angle_measure;
        tool_circumference_angle:
                              OPTIONAL plane_angle_measure;
        cutting_edge_length:           OPTIONAL length_measure;
        edge_radius:           OPTIONAL length_measure;
```

```
        edge_center_vertical:  OPTIONAL length_measure;
        edge_center_horizontal:OPTIONAL length_measure;
END_ENTITY;

TYPE hand = ENUMERATION OF(left, right, neutral);
END_TYPE;

ENTITY centerdrill
    SUBTYPE OF (milling_tool_body);
END_ENTITY;

ENTITY countersink
    SUPERTYPE OF (backside_countersink)
    SUBTYPE OF (milling_tool_body);
        countersink_radius:    OPTIONAL length_measure;
END_ENTITY;

ENTITY backside_countersink
    SUBTYPE OF (countersink);
END_ENTITY;

ENTITY drill
    ABSTRACT SUPERTYPE OF (ONEOF(twist_drill, spade_drill))
    SUBTYPE OF (milling_tool_body);
END_ENTITY;

ENTITY twist_drill
    SUPERTYPE OF (tapered_drill)
    SUBTYPE OF (drill);
END_ENTITY;

ENTITY tapered_drill
    SUBTYPE OF (twist_drill);
        taper_angle:           OPTIONAL plane_angle_measure;
END_ENTITY;

ENTITY spade_drill
    SUBTYPE OF (drill);
END_ENTITY;

ENTITY milling_cutter
    ABSTRACT SUPERTYPE OF (ONEOF(facemill, endmill, t_slot_mill,
      dovetail_mill, woodruff_keyseat_mill, side_mill, thread_mill))
    SUBTYPE OF (milling_tool_body);
END_ENTITY;

ENTITY facemill
    SUBTYPE OF (milling_cutter);
END_ENTITY;

ENTITY endmill
    SUPERTYPE OF (ONEOF(tapered_endmill, ball_endmill, bullnose_endmill))
    SUBTYPE OF (milling_cutter);
END_ENTITY;

ENTITY tapered_endmill
    SUBTYPE OF (endmill);
        taper_angle:           OPTIONAL plane_angle_measure;
END_ENTITY;

ENTITY ball_endmill
```

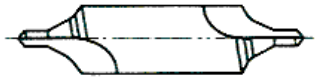
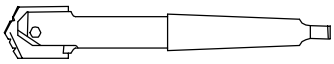
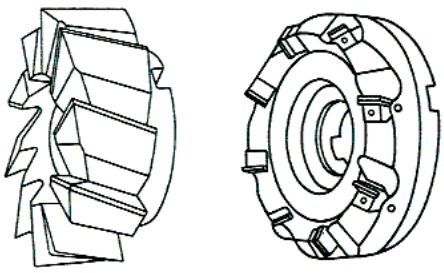
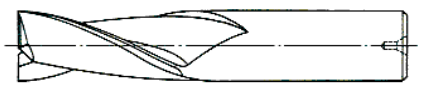
```
    SUBTYPE OF (endmill);
WHERE
    WR1: (NOT EXISTS(SELF.dimension.edge_center_horizontal))
         OR ((EXISTS(SELF.dimension.edge_center_horizontal)) AND
         (SELF.dimension.edge_center_horizontal = 0));
    WR2: (NOT EXISTS(SELF.dimension.edge_center_vertical))
         OR ((EXISTS(SELF.dimension.edge_center_vertical)) AND
         (SELF.dimension.edge_center_vertical = dimension.diameter/2));
    WR3: (NOT EXISTS(SELF.dimension.edge_radius))
         OR ((EXISTS(SELF.dimension.edge_radius)) AND
         (SELF.dimension.edge_radius = dimension.diameter/2));
    WR4: (NOT EXISTS(SELF.dimension.tool_tip_half_angle))
         OR ((EXISTS(SELF.dimension.tool_tip_half_angle)) AND
         (SELF.dimension.tool_tip_half_angle = 0));
    WR5: (NOT EXISTS(SELF.dimension.tool_circumference_angle))
         OR ((EXISTS(SELF.dimension.tool_circumference_angle)) AND
         (SELF.dimension.tool_circumference_angle = 0));
END_ENTITY;

ENTITY bullnose_endmill
    SUBTYPE OF (endmill);
WHERE
    WR1: (NOT EXISTS(SELF.dimension.tool_tip_half_angle))
         OR ((EXISTS(SELF.dimension.tool_tip_half_angle)) AND
         (SELF.dimension.tool_tip_half_angle = 0));
    WR2: (NOT EXISTS(SELF.dimension.tool_circumference_angle))
         OR ((EXISTS(SELF.dimension.tool_circumference_angle)) AND
         (SELF.dimension.tool_circumference_angle = 0));
END_ENTITY;

ENTITY t_slot_mill
    SUBTYPE OF (milling_cutter);
        cutting_thickness:     OPTIONAL length_measure;
END_ENTITY;

ENTITY dovetail_mill
    SUBTYPE OF (milling_cutter);
        included_angle:        OPTIONAL plane_angle_measure;
END_ENTITY;

ENTITY woodruff_keyseat_mill
    SUBTYPE OF (milling_cutter);
        cutter_width:          OPTIONAL length_measure;
END_ENTITY;

ENTITY side_mill
    SUBTYPE OF (milling_cutter);
        cutter_width:          OPTIONAL length_measure;
END_ENTITY;

ENTITY thread_mill
    SUBTYPE OF (milling_cutter);
END_ENTITY;

ENTITY tap
    SUPERTYPE OF (ONEOF(tapered_tap, combined_drill_and_tap))
    SUBTYPE OF (milling_tool_body);
END_ENTITY;

ENTITY tapered_tap
    SUBTYPE OF (tap);
```

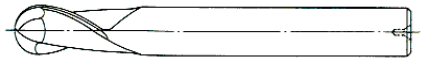
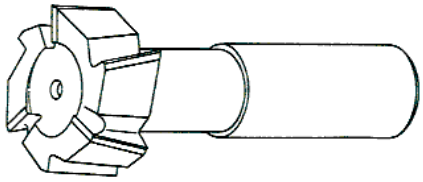
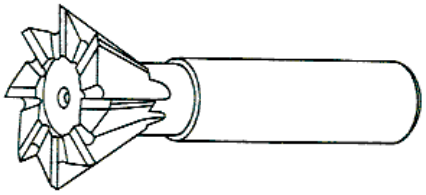
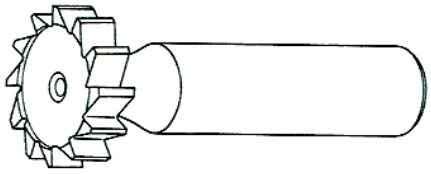
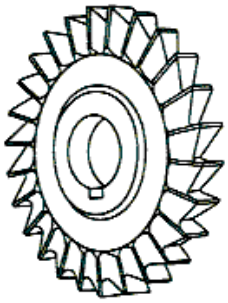
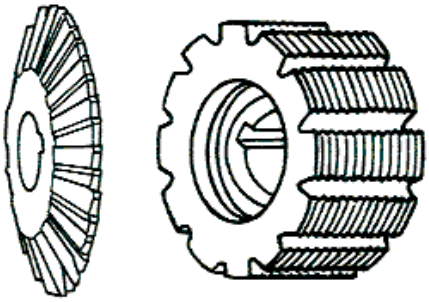
```
        taper_angle:           OPTIONAL plane_angle_measure;
END_ENTITY;

ENTITY combined_drill_and_tap
    SUBTYPE OF (tap);
        drill_length:          OPTIONAL length_measure;
END_ENTITY;

ENTITY threading_tool
    SUBTYPE OF (milling_tool_body);
END_ENTITY;

ENTITY counterbore
    SUPERTYPE OF (backside_counterbore)
    SUBTYPE OF (milling_tool_body);
END_ENTITY;

ENTITY backside_counterbore
    SUBTYPE OF (counterbore);
END_ENTITY;

ENTITY reamer
    SUPERTYPE OF (ONEOF (tapered_reamer, combined_drill_and_reamer))
    SUBTYPE OF (milling_tool_body);
END_ENTITY;

ENTITY tapered_reamer
    SUBTYPE OF (reamer);
        taper_angle:           OPTIONAL plane_angle_measure;
END_ENTITY;

ENTITY combined_drill_and_reamer
    SUBTYPE OF (reamer);
        drill_length:          OPTIONAL length_measure;
END_ENTITY;

ENTITY boring_tool
    SUBTYPE OF (milling_tool_body);
    retract_movement_forbidden: BOOLEAN;
END_ENTITY;

ENTITY user_defined_tool
    SUBTYPE OF (milling_tool_body);
    identifier:   label;
END_ENTITY;


END_SCHEMA; (* milling_tool_schema *)
```

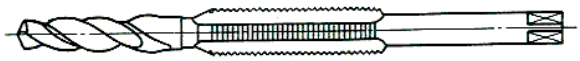
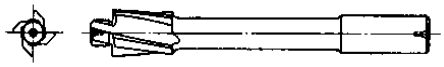
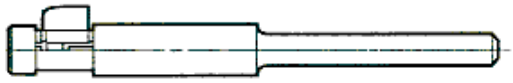
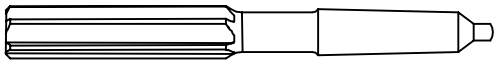
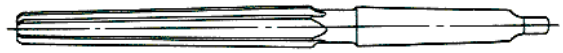
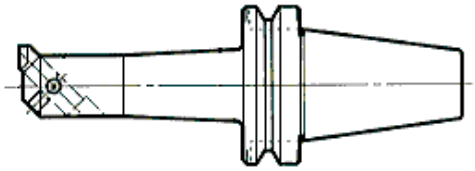
Annex B
(informative)

Tool body figures

Table 1 — Tool body figures

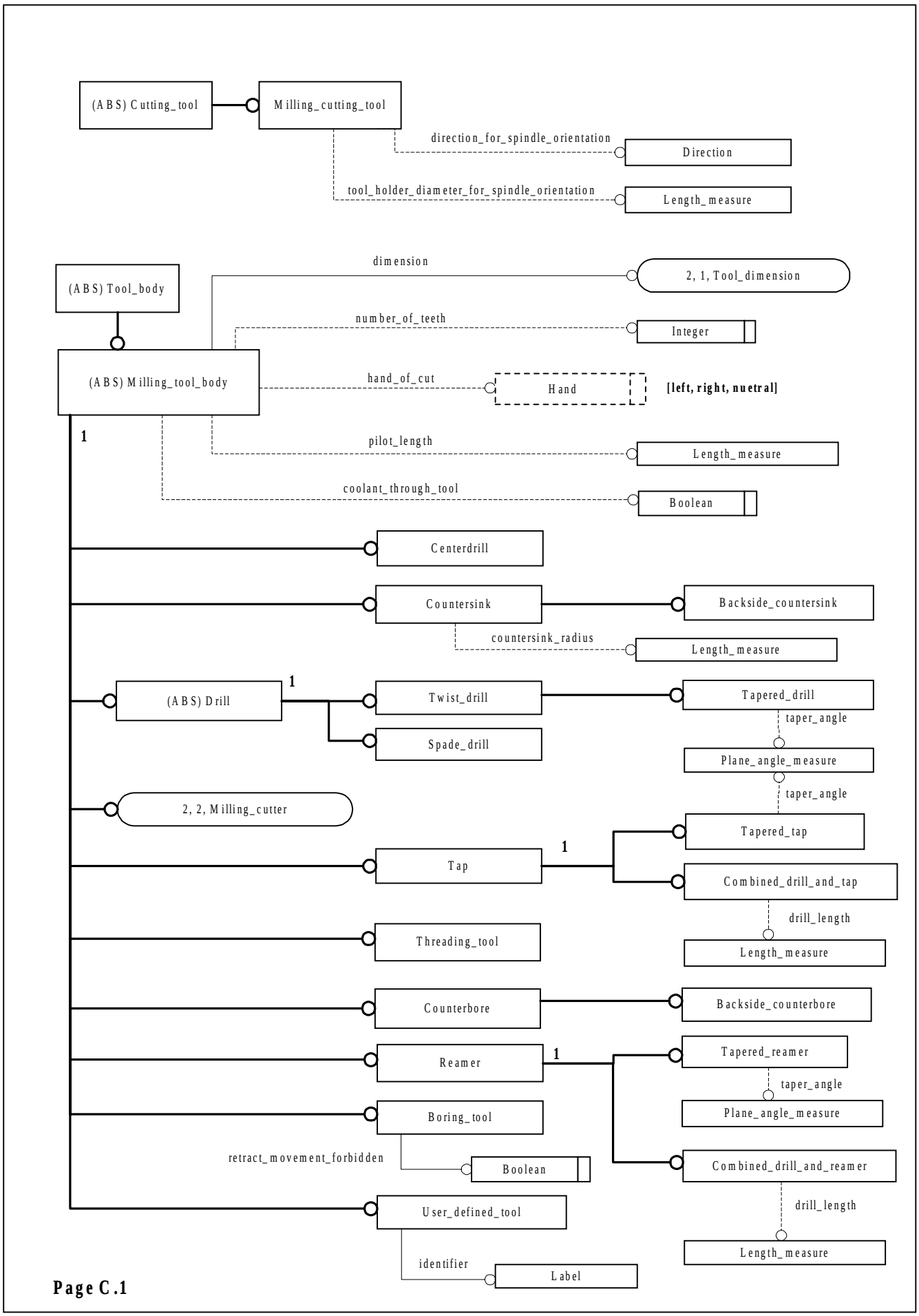
the Type of tool body	the Subtype of tool body	the Figure of tool body
Centerdrill		
Countersink	Countersink	
	Backside_countersink	
Drill	Twist_drill	
	Tapered_drill	
	Spade_drill	
Milling cutter	Facemill	
	Endmill	
	Tapered_endmill	

	Ball_endmill	
	Bullnose_endmill	
	T_slot_mill	
	Dovetail_mill	
	Woodruff_keyseat_mill	
	Side_mill	
	Thread_mill	
Tap	Tap	

	Tapered_tap	
	Combined_drill_and_tap	
Threading_tool		
Counterbore	Counterbore	
	Backside_counterbore	
Reamer	Reamer	
	Tapered_reamer	
	Combined_drill_and_reamer	
Boring_tool		
	User_defined_tool	

Annex C
(informative)

EXPRESS-G diagram



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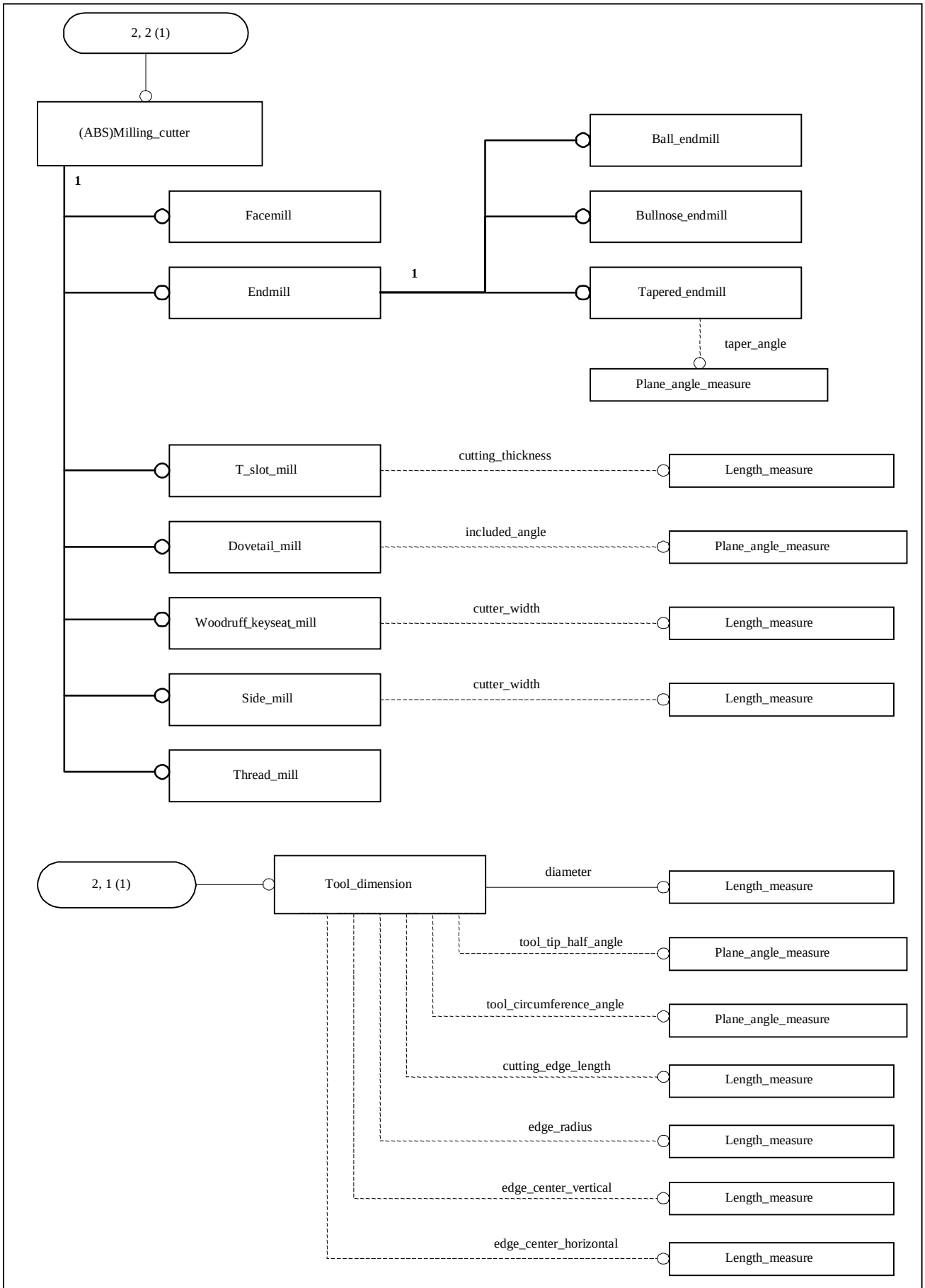

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