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Industrial automation systems and integration - Physical device control- Data model for Computerised Numerical Controllers

Part 121: TOOLS FOR TURNING MACHINES

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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 3.

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 14649-121 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 Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers:

NOTE Phase numbers below refer to the planned release phases of ISO 14649 which are described in Annex D of ISO 14649-1:2002.

Part 1: Overview and fundamental principles (Phase 1)

Part 10: General Process Data (Phase 1)

Part 11: Process Data for Milling (Phase 1)

Part 12: Process Data for Turning (Phase 2)

Part 13: Process Data for wire-EDM (Phase 2)

Part 14: Process Data for sink-EDM (Phase 2)

Part 111: Tools for Milling Machines (Phase 1)

Part 121: Tools for Turning Machines (Phase 2)

Gaps in the numbering were left to allow further additions. ISO 14649-10 is the ISO 10303 Application Reference Model (ARM) for process-independent data. ISO 10303 ARMs for specific technologies are added after part 10.

ISO 14649 is harmonized 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 standardization 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 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 TC 184/SC 1/WG 7 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 Computerised Numerical Controllers — Part 121: Tools for Turning Machines

1 Scope

This part of ISO 14649 specifies the data elements needed as tools for turning machines.

They work together with part 12 of the same standard, the process data for turning. These data elements can be used as criteria to select one of several turning and boring type tools. Therefore, leaving out optional attributes gives the controller more freedom to select from a larger set of tools. The NC controller is assumed to access the complete description of specific tools in a database.

The turning_machine_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 for turning. 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 and the type of tool.

The approach of this tool sheet to ISO 14649-12 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

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 is similar to part 111 of this standard. The scope of this part of ISO 14649 does not include tools for any other technologies, like milling, grinding, contour cutting, or EDM.

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 resisters of currently valid international Standards.

ISO 3002-1: 1993, *Basic quantities in cutting and grinding — Part 1: Geometry of the active part of cutting tools — General terms, reference systems, tool and working angles, chip breakers*

ISO 5610:1998, *Single-point tool holders for turning and copying, for indexable inserts — Dimensions*

ISO 14649-10:2003, *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers — Part 10: General process data*

ISO 14649-12:2003, *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers — Part 11: Process data for milling*

ISO 14649-111:2003, *Industrial automation systems and integration — Physical device control — Data model for computerized numerical controllers — Part 111: Tools for milling machines*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 14649-10, ISO 14649-12 apply.

4 Tools for turning machines

4.1 Header and references

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

```
SCHEMA turning_machine_tool_schema;
(*
    Version : 09
    Date    : 19.07.2003
    Author  : ISO TC184/SC1/WG7
    Contact : Suk-Hwan Suh (shs@postech.ac.kr) or
              Heusinger (stefan.heusinger@isw.uni-stuttgart.de)
*)
(* ************************************************************************ *)
(* Types from machining_schema                ISO 14649-10                  *)
(* ************************************************************************ *)
REFERENCE FROM machining_schema (
    cutting_tool,
    direction,
    label,
    length_measure,
    machining_tool,
    material,
    plane_angle_measure,
    time_measure,
    tool_body);

USE FROM milling_machine_tool_schema
```

4.2 Turning machine tool

This entity describes the technology specific information needed for description of cutting tool for turning machines. It is a subtype of entity *cutting_tool* defined in 4.6.2.3.5 of ISO 14649-10:2002. As illustrated in Figure 1, *overall_assembly_length* means the total length of holder including any portion in front of the cutting point, and *overall_assembly_width* means the total width of holder including any portion in front of the cutting point. The definitions are valid for other types of turning machine tools, such as shown in Figure 2 referenced from ISO 5610.

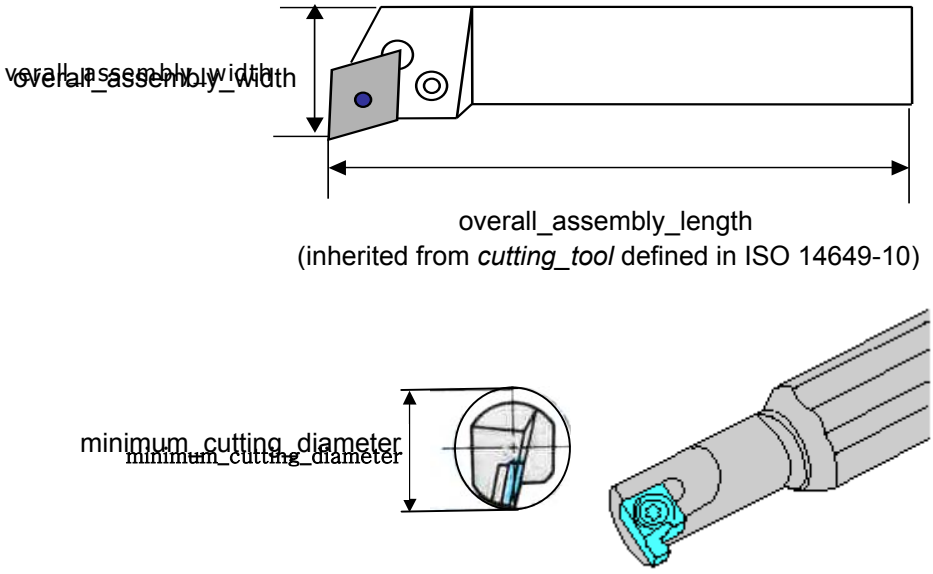


Figure 1 : Turning machine tool.

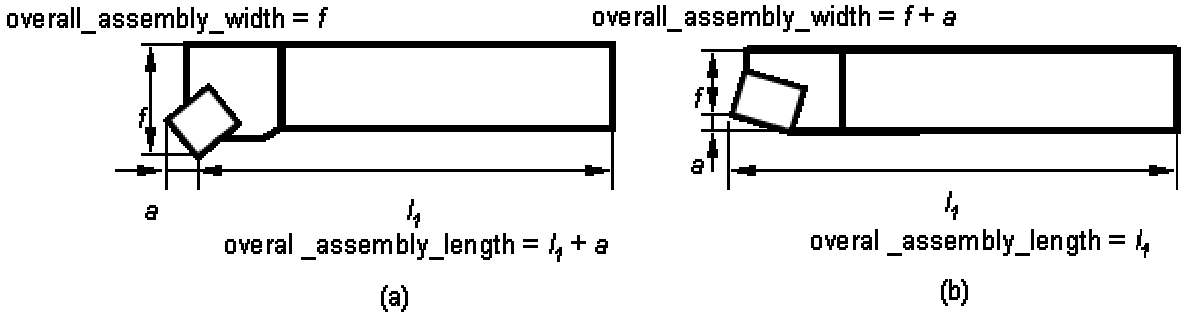


Figure 2 (Informative): Attributes illustrated in ISO 5610.

```
ENTITY turning_machine_tool
    SUBTYPE OF (cutting_tool);
    overall_assembly_width    : OPTIONAL length_measure;
    minimum_cutting_diameter  : OPTIONAL length_measure;
END_ENTITY;
```

overall_assembly_width: The width of the assembled tool (see Figure 1).

minimum_cutting_diameter: The minimum cutting diameter that can be achieved by the cutting tool. This may be used for internal machining; where the hole diameter of the workpiece should be larger than this value.

4.2.1 Turning machine tool body

This is the abstract base class for all types of tool bodies for turning. It is a subtype of entity *tool_body* defined in ISO 14649-10. These types include general_turning, grooving, knurling and threading. Technological information about the tool body for turning is also defined.

Drilling type tools and boring type tools (such as drill, reamer and boring tool) are also used in turning operation. Since they are defined in ISO 14649-111 (as subtypes of *milling_machine_tool_body*), they are not defined in this part. However users can use them by referencing ISO 14649-111.

```
ENTITY turning_machine_tool_body
    ABSTRACT SUPERTYPE OF (ONEOF(general_turning_tool, knurling_tool,
    turning_threading_tool, grooving_tool, user_defined_turning_tool))
    SUBTYPE OF (tool_body);
    dimension                  :  turning_tool_dimension;
    hand_of_tool               :  OPTIONAL hand_of_tool_type;
    maximum_side_cutting_depth :  OPTIONAL length_measure;
    maximum_end_cutting_depth  :  OPTIONAL length_measure;
    tool_body_height           :  OPTIONAL length_measure;
    tool_body_width            :  OPTIONAL length_measure;
END_ENTITY;
```

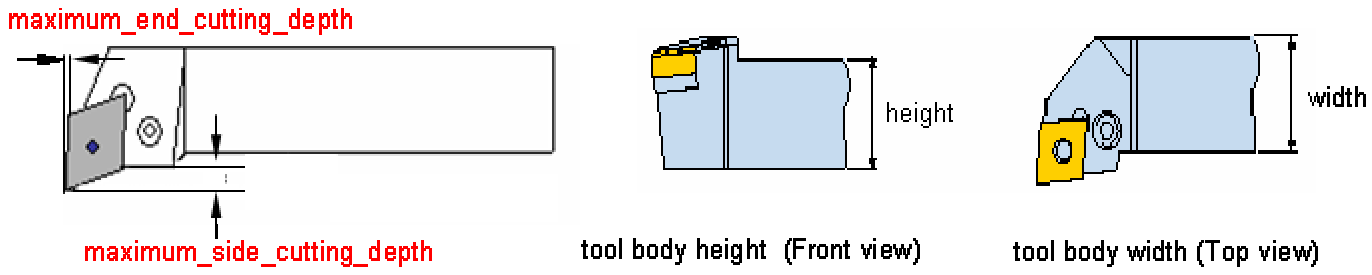


Figure 3: Some attributes of turning tool body.

dimension: The information specifying the dimensions of turning tool (see Section 4.2.2).

hand_of_tool: The attribute describing cutting direction of tool body (see Section 4.2.3).

maximum_side_cutting_depth: The maximum depth of cut that can be made with the side cutting edge.

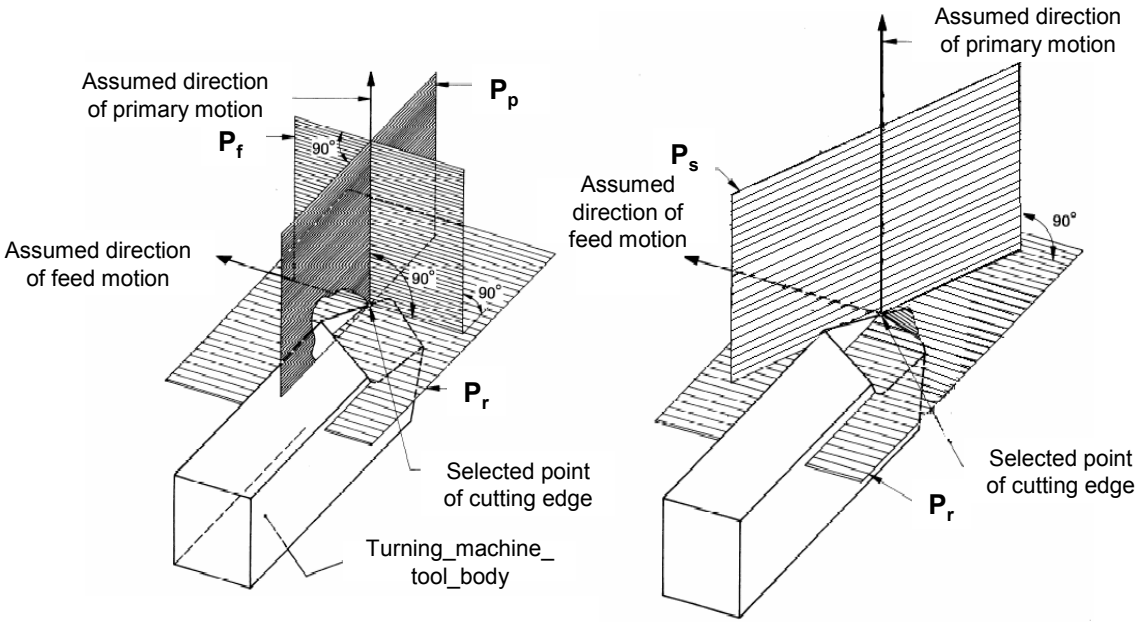
maximum_end_cutting_depth: The maximum depth of cut that can be made with end cutting edge.

tool_body_height: This attribute describes the height of the tool body.

tool_body_width: This attribute describes width of the tool body.

4.2.2 Turning tool dimension

This entity describes the dimensions of turning tool referenced from ISO 3002-1. To define some attributes for turning tool dimension, it is necessary to define the tool reference systems of planes. Figure 4 describes the tool reference systems of plane. There are 4 planes: tool reference plane (Pr), assumed working plane (Pf), tool cutting edge plane (Pr), tool back plane (Pp). The angles of turning tool are defined based on these planes.



P_r (tool reference plane) : A plane through the selected point on the cutting edge

P_f (assumed working plane) : A plane through the selected point on the cutting edge and perpendicular to the tool reference plane P_r

P_s (tool cutting edge plane) : A plane tangential to the cutting edge at the selected point and perpendicular to the tool reference plane P_r

P_p (tool back plane) : A plane through the selected point on the cutting edge and perpendicular both to the tool reference plane P_r and to the assumed working plane P_f

Figure 4. Tool reference systems of planes.

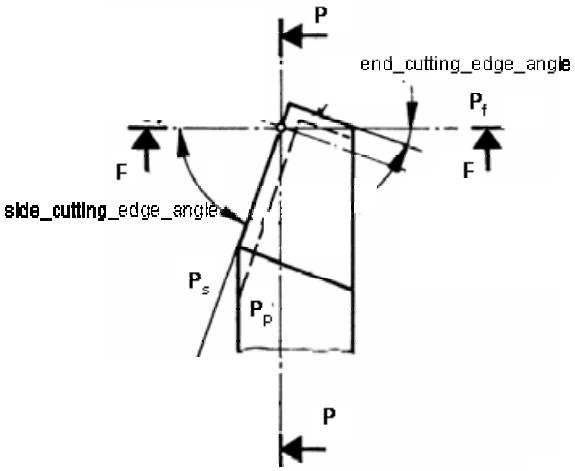


Figure 5. Side cutting edge angle and end cutting edge angle.

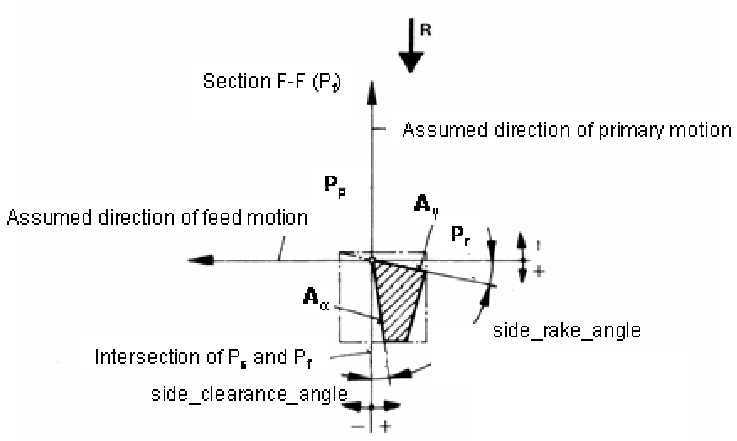


Figure 6. Side rake angle and side clearance angle.

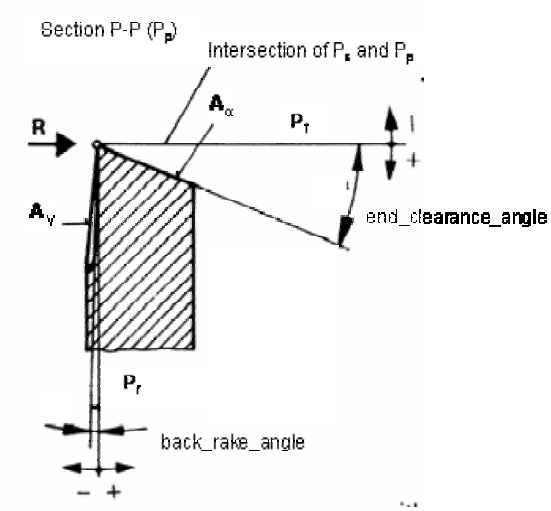


Figure 7. Back rake angle and end clearance angle.

```
ENTITY turning_tool_dimension;
    cutting_edge_length           : OPTIONAL length_measure;
    side_cutting_edge_angle       : OPTIONAL plane_angle_measure;
    end_cutting_edge_angle        : OPTIONAL plane_angle_measure;
    side_rake_angle               : OPTIONAL plane_angle_measure;
    back_rake_angle               : OPTIONAL plane_angle_measure;
    side_clearance_angle          : OPTIONAL plane_angle_measure;
    end_clearance_angle           : OPTIONAL plane_angle_measure;
    nose_radius                   : OPTIONAL length_measure;
    circle_diameter               : OPTIONAL length_measure;
END_ENTITY;
```

cutting_edge_length: This attribute describes the length of cutting edge.

side_cutting_edge_angle: The angle between the side cutting edge plane P_s and the assumed working plane P_f measured in the tool reference plane P_r (See Fig. 5). This attribute is equivalent to *major tool cutting edge angle* defined in Section 5.1 (Tool angles) of ISO 3002-1.

end_cutting_edge_angle: The angle between the end tool cutting edge plane P_s and the assumed working plane P_f measured in the tool reference plane P_r (See Fig. 5). This attribute is equivalent to *minor tool cutting edge angle* defined in Section 5.1 (Tool angles) of ISO 3002-1.

side_rake_angle: The angle between the face A_γ (the surface or surfaces over which the chip flows) and the tool reference plane P_r measured in the assumed working plane P_f (See Fig. 6). This attribute is equivalent to *tool side rake* defined in Section 5.1 (Tool angles) of ISO 3002-1.

back_rake_angle: The angle between the face A_γ (the surface or surfaces over which the chip flows) and the tool reference plane P_r measured in the tool back plane P_p (See Fig. 5). This attribute is equivalent to *tool back rake* defined in Section 5.1 (Tool angles) of ISO 3002-1.

side_clearance_angle: The angle between the flank A_α (the tool surface or surfaces over which the surface produces on the workpiece passes) and the tool cutting edge plane P_s, measured in the assumed working plane P_f (See Fig. 6). This attribute is equivalent to *tool side clearance* defined in Section 5.1 (Tool angles) of ISO 3002-1.

end_clearance_angle: The angle between the flank A_α (the tool surface or surfaces over which the surface produces on the workpiece passes) and the tool cutting edge plane P_s, measured in the tool back plane P_p (See Fig. 7). This attribute is equivalent to *tool back clearance* defined in Section 5.1 (Tool angles) of ISO 3002-1.

nose_radius: This attribute describes the radius of the curve where the end and side surfaces meet, as viewed from the face of the insert.

circle_diameter: This attribute describes an inscribed circle being tangent to all sides of an regular shaped insert.

4.2.3 Hand of tool type

This is to describe the location and shape of cutting edge on to the cutting component.

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

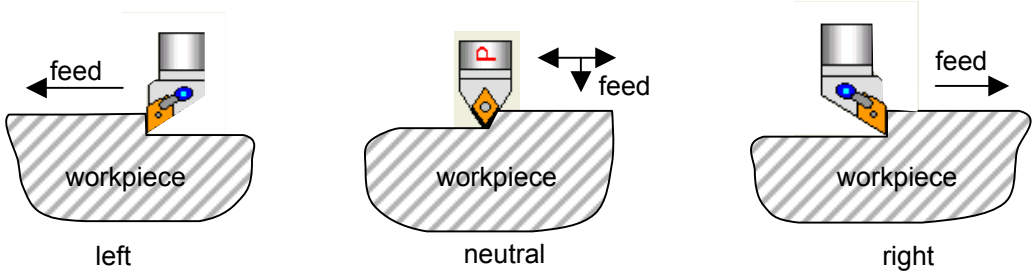


Figure 8. Hand of tool type.

4.3 Catalogue of turning tool

4.3.1 General turning tool

This entity is a subtype of the entity *turning_machine_tool_body*. This tool is used for machining outside or inside profile of feature.

```
ENTITY general_turning_tool
    SUBTYPE OF (turning_machine_tool_body);
END_ENTITY;
```

4.3.2 Turning threading tool

This entity is a subtype of the entity *turning_machine_tool_body*. This tool is used for machining *thread*.

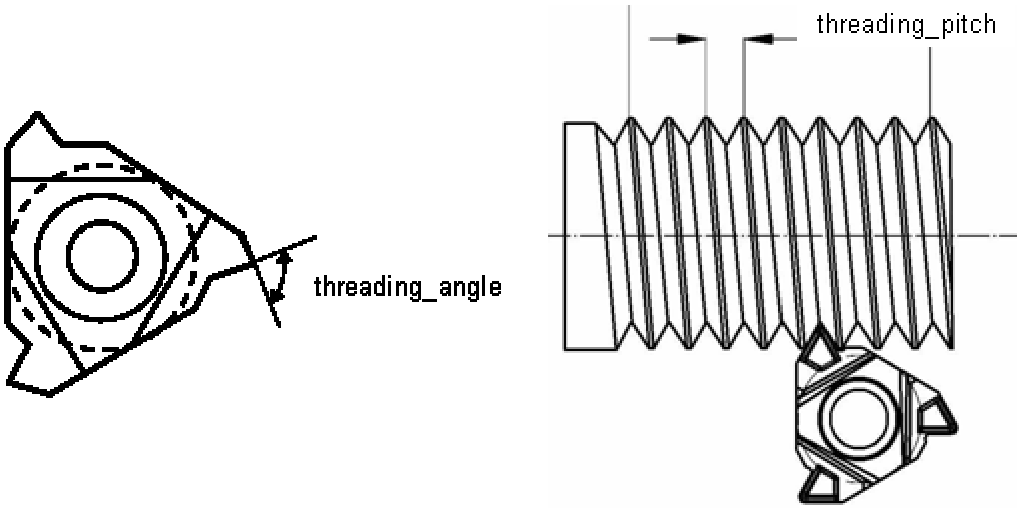


Figure 9. Threading insert.

```
ENTITY turning_threading_tool
    SUBTYPE OF (turning_machine_tool_body);
    threading_pitch    : length_measure;
    threading_angle    : OPTIONAL plane_angle_measure;
END_ENTITY;
```

threading_pitch: The value for the distance between corresponding points on adjacent threads, measured parallel with the thread axis. If omitted, the pitch of the thread insert is equal to that of thread feature.

threading_angle: This attribute defines angle of threading insert tip. If omitted, the default value is 60°

4.3.3 Grooving tool

This entity is a subtype of the entity *turning_machine_tool_body*. This tool may be used for machining operations such as *grooving*, *cutting_in* and cut off.

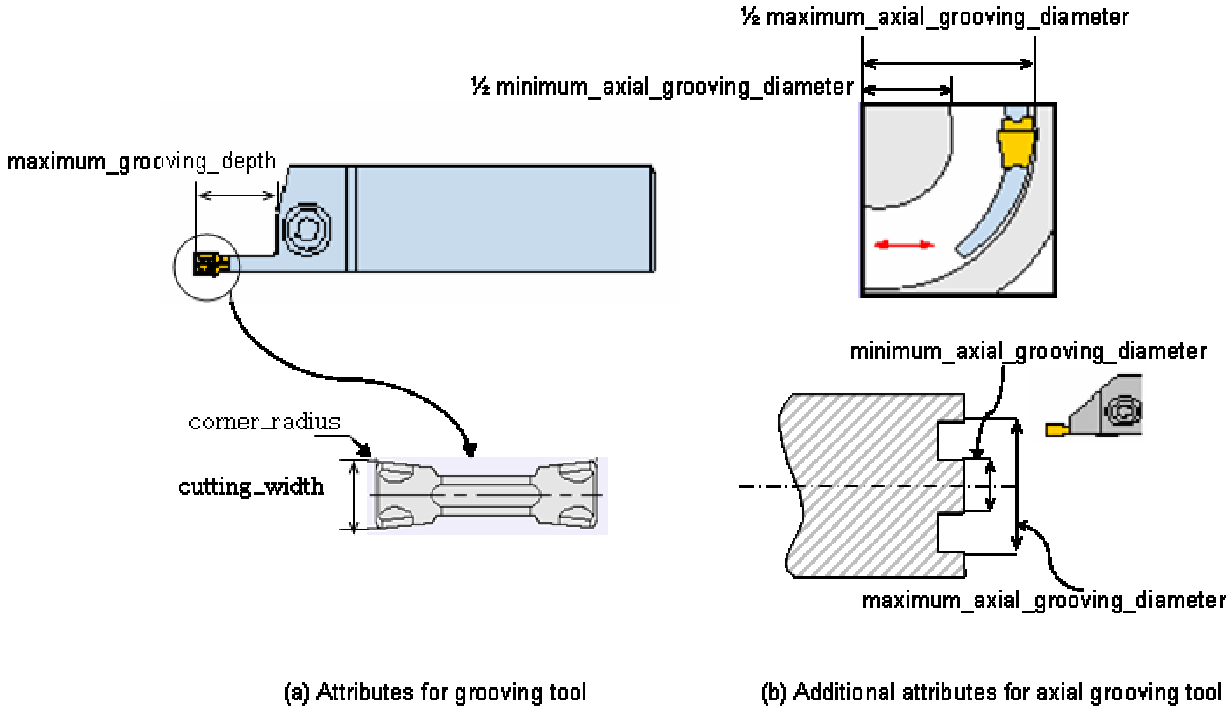


Figure 10. Grooving tool.

```
ENTITY grooving_tool
    SUBTYPE OF (turning_machine_tool_body);
    cutting_width                  : length_measure;
    maximum_grooving_depth         : length_measure
    corner_radius                  : OPTIONAL length_measure;
    maximum_axial_grooving_diameter : OPTIONAL length_measure;
    minimum_axial_grooving_diameter : OPTIONAL length_measure;
END_ENTITY;
```

cutting_width: The attribute defines width of grooving tip.

maximum_grooving_depth: This attribute defines the maximum grooving depth of grooving tool.

corner_radius: This attribute defines a corner radius of grooving insert.

maximum_axial_grooving_depth: This attribute defines the maximum diameter of groove that can be made by axial grooving operation without tool gouging.

minimum_axial_grooving_depth: This attribute defines the minimum diameter of groove that can be made by axial grooving operation without tool gouging.

4.3.4 Knurling tool

This entity is a subtype of the entity *turning_machine_tool_body*. This tool may be used for machining *knurl* feature.

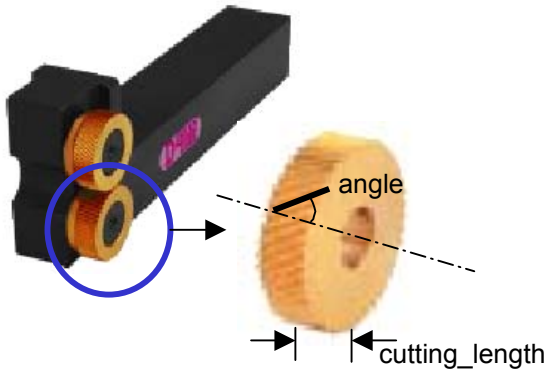


Figure 11. Knurling tool.

```
ENTITY knurling_tool
    SUBTYPE OF (turning_machine_tool_body);
    knurl_pattern       : knurl_pattern_type;
    cutting_length      : OPTIONAL length_measure;
    angle               : OPTIONAL plane_angle_measure;
    pitch               : OPTIONAL length_measure;
END_ENTITY;
```

knurl_pattern: The attribute defines a type of the knurl. Knurl pattern is one of straight, diagonal and diamond.

cutting_length: The attribute defines the cutting length of knurling tool.

angle: This attribute defines an angle the knurl pattern makes with the orientation axis of an applied to surface.

pitch: The value for the distance between corresponding points on adjacent pattern, measured parallel with the angle.

4.3.4.1 Knurl pattern

This is to describe the pattern of the *knurling_tool*. Knurl pattern can be one of straight, diagonal and diamond.

```
TYPE knurl_pattern_type = ENUMERATION OF (straight, diagonal, diamond);
END_TYPE;
```

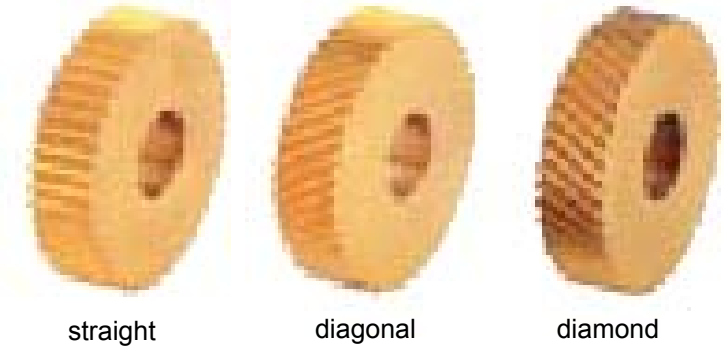


Figure 12. Knurl pattern type.

4.3.5 User defined turning tool

This entity describes user defined turning tool.

```
ENTITY user_defined_turning_tool
    SUBTYPE OF (turning_machine_tool_body);
    identifier:          label;
END_ENTITY;
```

identifier: This attribute defines the name of the tool. If the identifier is not unique, a match shall be made based upon the other attributes inherited from *turning_machine_tool_body*. If it is unique and the optional attributes are given but do not match the properties of the named tool, no tool shall be selected.

```
END_SCHEMA; (*turning_machine_tool_schema *)
```

Annex A:
(normative)

EXPRESS expanded listing

```
SCHEMA turning_machine_tool_schema;

(*
   Version : 09
   Date    : 19.07.2003
   Author  : ISO TC184/SC1/WG7
   Contact : Suk-Hwan Suh (shs@postech.ac.kr) or
             Heusinger (stefan.heusinger@isw.uni-stuttgart.de)
*)

(* ************************************************************************ *)
(* Types from machining_schema                  ISO 14649-10                *)
(* ************************************************************************ *)
REFERENCE FROM machining_schema (
    cutting_tool,
    direction,
    label,
    length_measure,
    machining_tool,
    material,
    plane_angle_measure,
    time_measure,
    tool_body);

USE FROM milling_machine_tool_schema

(* ********************************************************** *)
(*                   turning tool                             *)
(* ********************************************************** *)

ENTITY turning_machine_tool
    SUBTYPE OF (cutting_tool);
    overall_assembly_width    : OPTIONAL length_measure;
    minimum_cutting_diameter  : OPTIONAL length_measure;
END_ENTITY;

(* ********************************************************** *)
(*                   turning tool_body                        *)
(* ********************************************************** *)

ENTITY turning_machine_tool_body
    ABSTRACT SUPERTYPE OF (ONEOF(general_turning_tool, knurling_tool,
    turning_threading_tool, grooving_tool, user_defined_turning_tool))
    SUBTYPE OF (tool_body);
    dimension                  :  turning_tool_dimension;
    hand_of_tool               :  OPTIONAL hand_of_tool_type;
    maximum_side_cutting_depth :  OPTIONAL length_measure;
    maximum_end_cutting_depth  :  OPTIONAL length_measure;
    tool_body_height           :  OPTIONAL length_measure;
    tool_body_width            :  OPTIONAL length_measure;
END_ENTITY;
```

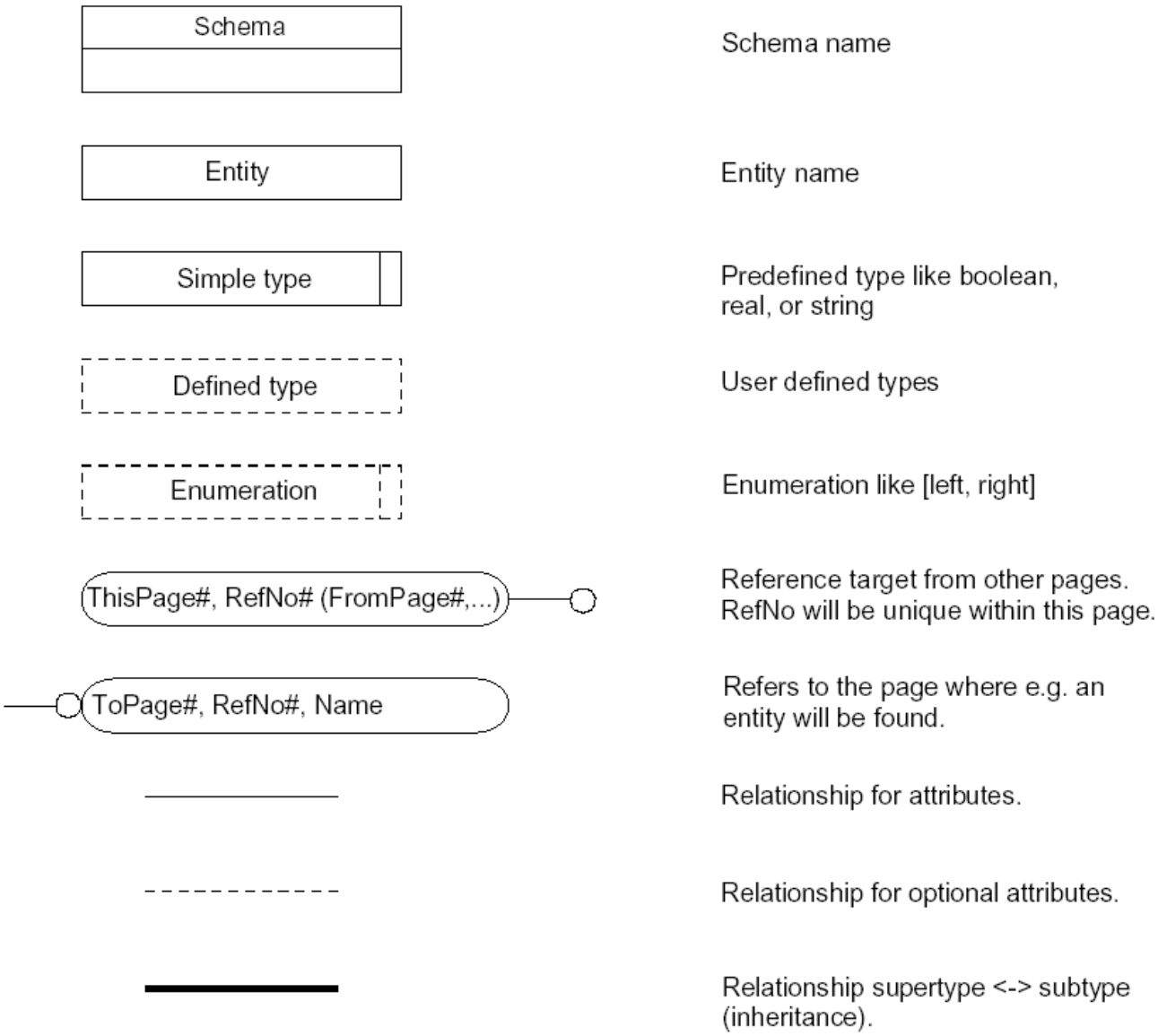
```
(* ************************************************************ *)
(*                    turning tool_dimension                    *)
(* ************************************************************ *)

ENTITY turning_tool_dimension;
    cutting_edge_length           : OPTIONAL length_measure;
    side_cutting_edge_angle       : OPTIONAL plane_angle_measure;
    end_cutting_edge_angle        : OPTIONAL plane_angle_measure;
    side_rake_angle               : OPTIONAL plane_angle_measure;
    back_rake_angle               : OPTIONAL plane_angle_measure;
    side_clearance_angle          : OPTIONAL plane_angle_measure;
    end_clearance_angle           : OPTIONAL plane_angle_measure;
    nose_radius                   : OPTIONAL length_measure;
    circle_diameter               : OPTIONAL length_measure;
END_ENTITY;


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

(* ************************************************************ *)
(*                    turning tool catalogue                    *)
(* ************************************************************ *)

(* ************************************************************ *)
(*                    general turning tool                      *)
(* ************************************************************ *)

ENTITY general_turning_tool
    SUBTYPE OF (turning_machine_tool_body);
END_ENTITY;

(* ************************************************************ *)
(*                    turning threading tool                    *)
(* ************************************************************ *)

ENTITY turning_threading_tool
    SUBTYPE OF (turning_machine_tool_body);
    threading_pitch    : length_measure;
    threading_angle    : OPTIONAL plane_angle_measure;
END_ENTITY;

(* ************************************************************ *)
(*                    grooving tool                             *)
(* ************************************************************ *)

ENTITY grooving_tool
    SUBTYPE OF (turning_machine_tool_body);
    cutting_width                   : length_measure;
    maximum_grooving_depth          : length_measure
    corner_radius                   : OPTIONAL length_measure;
    maximum_axial_grooving_diameter : OPTIONAL length_measure;
    minimum_axial_grooving_diameter : OPTIONAL length_measure;
END_ENTITY;


(* ************************************************************ *)
(*                    knurling tool                             *)
(* ************************************************************ *)
```

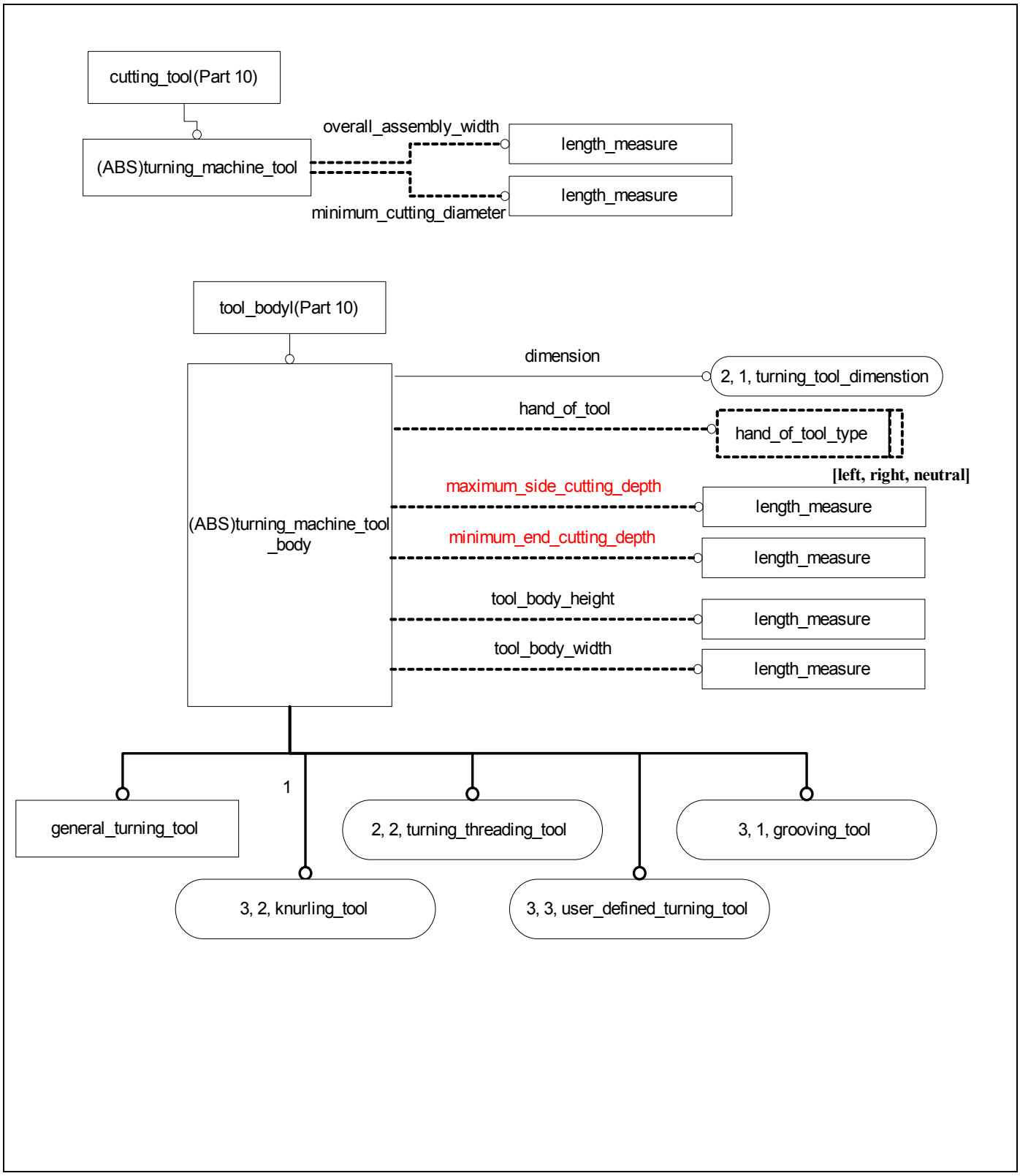
```
ENTITY knurling_tool
    SUBTYPE OF (turning_machine_tool_body);
    knurl_pattern       : knurl_pattern_type;
    cutting_length      : OPTIONAL length_measure;
    angle               : OPTIONAL plane_angle_measure;
    pitch               : OPTIONAL length_measure;
END_ENTITY;


TYPE knurl_pattern_type = ENUMERATION OF (straight, diagonal, diamond);
END_TYPE;

(* ********************************************************** *)
(*                    user defined turning tool                          *)
(* ********************************************************** *)

ENTITY user_defined_turning_tool
    SUBTYPE OF (turning_machine_tool_body);
    identifier:          label;
END_ENTITY;


END_SCHEMA; (*turning tool schema*)
```

Annex B:
(informative)

EXPRESS-G diagram

The following section shows the EXPRESS-G of Part 121: tools for turning. According to the notation of EXPRESS-G the used symbols and their respective meaning are listed in brief.





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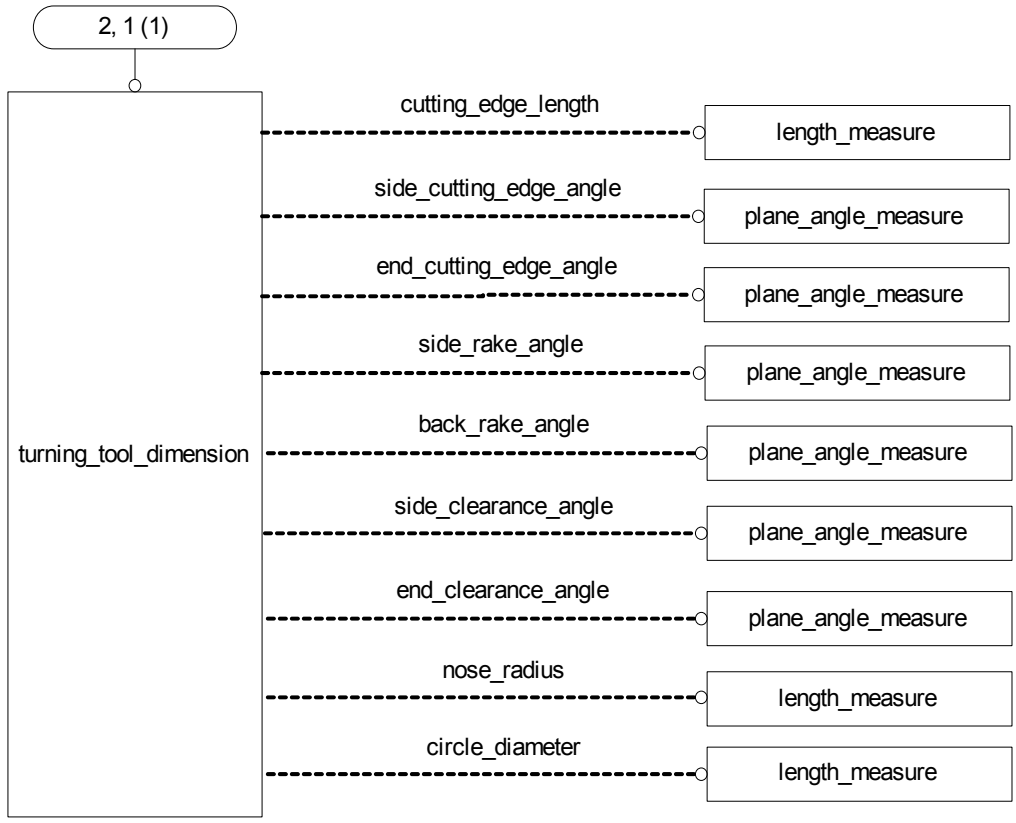

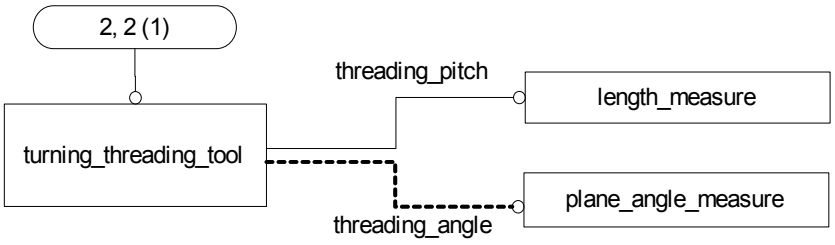

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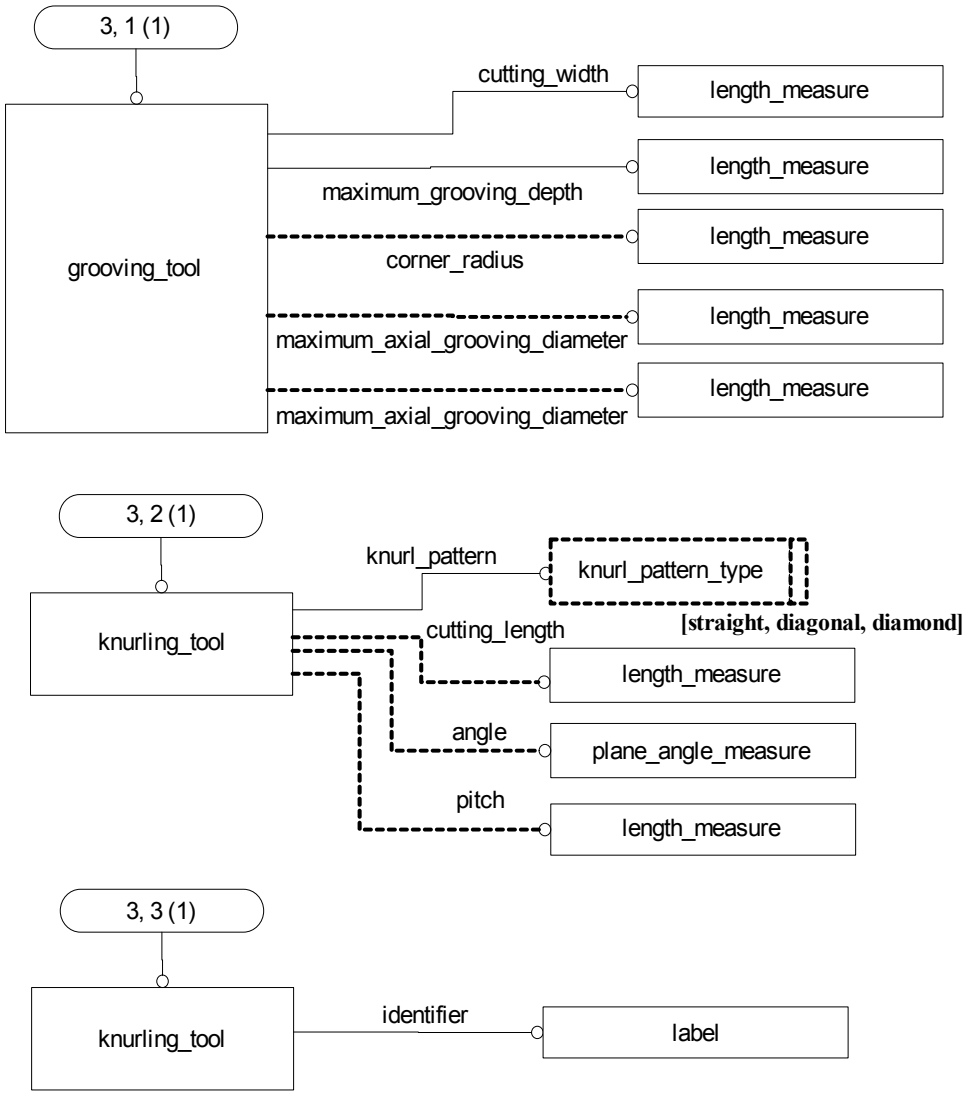

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