TECHNICAL SPECIFICATION

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

Part 201: Machine tool data for cutting processes

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

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

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Foreword

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

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

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

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

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

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order to decide whether it will be confirmed for a further three years, revised to become an International Standard, or withdrawn.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again after a further three years, at which time it must either be transformed into an International Standard or be withdrawn.

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

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

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

— *Part 1: Overview and fundamental principles*

— *Part 10: General process data*

— *Part 11: Process data for milling*

— *Part 12: Process data for turning*

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

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

— *Part 111: Tools for milling machines*

— *Part 121: Tools for turning machines*

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

Introduction

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

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

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

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

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

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

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

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

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

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

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

Part 201:
Machine tool data for cutting processes

1 Scope

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

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

Examples of manufacturing applications of this model are:

— part programming for CNC machining;

— process planning;

— a simulation of machining processes;

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

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

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

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 10303-105, *Industrial automation systems and integration — Product data representation and exchange — Part 105: Integrated application resource: Kinematics*

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

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

3 Terms and definitions

3.1 Terms defined in ISO 14649-1

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

— executable;

— machining operation;

— NC function;

— workingstep.

3.2 Terms defined in ISO 10303-105

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

— base;

— frame;

— joint;

— kinematics;

— link;

— link frame;

— mechanism;

— pair;

— placement.

3.3 Terms defined in ISO 10303-240

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

— process plan.

3.4 Other terms and definitions

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

3.4.1
multi-channel control
control of multiple machining operations simultaneously

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

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

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

4 Machine tool data for cutting processes

4.1 Header and references

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

```
USE FROM DATE_TIME_SCHEMA
  (calendar_date);

USE FROM GEOMETRY_SCHEMA
  (axis2_placement_3d);

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

USE FROM MACHINING_SCHEMA
  (project,
   rot_speed_measure,
   workplan);

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

USE FROM PRODUCT_DEFINITION_SCHEMA
  (product_definition);
```

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

USE FROM PRODUCT_PROPERTY_REPRESENTATION_SCHEMA
  (shape_representation);

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

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

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

4.2 General type definitions

4.2.1 Measure units

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

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

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

4.2.2 jerk_measure

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

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

4.2.3 rot_acceleration_measure

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

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

4.2.4 rot_jerk_measure

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

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

4.2.5 torque_measure

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

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

4.3 Machine tool

4.3.1 machine_tool

This entity is a supertype of machine_tool_specification and machine_tool_requirements.

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

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

4.3.2 machine_tool_specification

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

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

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

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

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

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

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

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

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

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

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

4.3.2.1 machine_class

This type is used for selecting a machine class.

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

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

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

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

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

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

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

4.3.3 device_id

This entity describes the device identification information.

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

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

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

serial_number : This attribute specifies the serial number.

manufacturer : This attribute specifies the name of the manufacturer.

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

4.3.4 locator

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

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

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

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

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

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

4.3.5 installation

This entity describes the installation and facility planning information.

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

weight : This attribute specifies the mass of the machine.

size : This attribute specifies the dimensions of the machine.

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

air_pressure_requirement : This attribute specifies the pressure of air supplied.

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

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

4.3.6 machine_size

This entity describes the overall dimensions of a machine.

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

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

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

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

4.3.7 electrical

This entity describes the properties of the supplied electrical power.

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

electric_phase : This attribute describes the number of phases.

electric_power : This attribute describes the maximum power consumption.

electrical_current : This attribute describes the maximum required amperage.

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

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

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

4.3.8 hydraulics

This entity describes the properties of a hydraulics system.

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

type_of_hydraulic_oil : This attribute describes the type of hydraulic oil.

pump_outlet_pressure : This attribute describes the pump outlet pressure.

capacity_of_hydraulics_tank : This attribute describes the capacity of hydraulic tank.

4.3.9 nc_controller

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

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

controller_model :	This attribute specifies the name or the identification designating the controller model.
controller_manufacturer :	This attribute specifies the name of the controller's manufacturer.
units :	This attribute specifies the units type of the NC controller.
maximum_number_of_simultaneous_control_axes :	This attribute specifies the number of axes controlled simultaneously by the NC controller.
maximum_total_number_of_control_feed_axes :	This attribute specifies the number of feed axes controlled by the NC controller.
maximum_total_number_of_control_spindles :	This attribute specifies the number of spindles controlled by the NC controller.
minimum_linear_increment :	This attribute specifies the minimum length controlled by the NC controller during machining.
minimum_angle_increment:	This attribute specifies the minimum angle controlled by the NC controller during machining.
maximum_number_of_multi_channel_control :	This attribute specifies the maximum number of channels which the NC controller can deal with during operation.
cycle_functions :	This attributes specifies a series of operation sequences used by part programs repeatedly as cycle functions. It represents possible cycle functions supported by the controller.
interpolation_functions :	This attributes specifies possible interpolation functions supported by the controller.
look_ahead :	This attribute specifies the maximum readable blocks to look ahead at NC data. If specified, adequate feedrate of each axis within the maximum allowable feedrate and acceleration/deceleration will be calculated.
adaptive_control:	This attribute specifies the type of adaptive control, such as feed rate, etc.
miscellaneous_controller_functions :	This attributes specifies a set of miscellaneous controller functions of the NC controller. Examples are toolpath accuracy compensation, and loader.
program_memory_size :	This attribute specifies total memory size available for storage of part programs in the NC controller.
cutting_feed_rate_override :	This attribute specifies the set of increase of feed rate that the user can change while the machine tool is working. It has several levels, usually in the range from 0 % to 150 %.
rapid_traverse_override :	This attribute specifies the set of increase of rate of rapid movement. The controller indicates the range of rapid movement. It has several levels, for example 0%, 10 %, 50 %, and 100 %, etc.

tool_compensation_functions: This attribute specifies possible compensation functions supported by the controller.

time_sampling: This attribute specifies the minimal time period between two consecutive (feedrate or position) control orders.

clock_frequency: This attributes specifies the clock rate of the CNC controller CPU.

4.3.9.1 units_type

This type is used for describing the units used in the NC controller.

```
TYPE units_type = ENUMERATION OF
  (INCH,
   INCH_AND_METRIC,
   METRIC);
END_TYPE;
```

INCH: NC controller deals with only US units for length measurement

INCH_AND_METRIC : NC controller deals with SI units and US units for length measurement

METRIC : NC controller deals with only SI units for length measurement

4.3.9.2 interpolation

This type is used for describing the functions that enable a machine tool to move axes along a specific path for multi-axis machine tools. A CNC system provides circular interpolation, linear interpolation, and other interpolation as interpolation functions.

```
TYPE interpolation = ENUMERATION OF
  (CIRCULAR,
   HELICAL,
   LINEAR,
   NURBS,
   OTHER);
END_TYPE;
```

CIRCULAR: NC controller provides circular interpolation functions when a tool path is generated.

HELICAL : NC controller provides helical interpolation functions when a tool path is generated.

LINEAR : NC controller provides linear interpolation functions when a tool path is generated.

NURBS : NC controller provides NURBS interpolation functions when a tool path is generated.

OTHER : NC controller provides additional interpolation functions when a tool path is generated.

4.3.9.3 tool_compensation

This type is used for describing the functions for compensation supported by NC controller. The compensation is an adjustment of tool measurements caused by installation of tool.

```
TYPE tool_compensation = ENUMERATION OF
  (TOOL_LENGTH,
   TOOL_RADIUS);
END_TYPE;
```

TOOL_LENGTH : NC controller provides compensation functions for the length of tools.

TOOL_RADIUS : NC controller provides compensation functions for the radius or diameter of tools.

4.3.10 environmental_evaluation

This entity is for evaluating the environmental effect of the machine tool in accordance with the standard machining process. Basically this entity describes the environmental effect of the machine and related operation as power used and the emissions.

```
ENTITY environmental_evaluation;
    evaluation_name              : label;
    power_in_idling              : OPTIONAL power_measure;
    time_for_warming_up          : OPTIONAL time_measure;
    power_for_standard_machining : OPTIONAL SET [1:?] OF
                                   standard_machining_process;
END_ENTITY;
```

evaluation_name : This attribute specifies the name of the environmental evaluation.

power_in_idling : This attribute specifies the power required when the machine is not operating.

time_for_warming_up : This attribute specifies the time spent from idle state to ready-to-machining state.

power_for_standard_machining : This attribute specifies the list of entities which describe the environmental effect of one or more standard machining processes.

4.3.11 standard_machining_process

This entity is for describing a standard machining process of a machine tool and evaluating power used and emissions of the process.

```
ENTITY standard_machining_process;
    process_description : text;
    type_of_machining   : label;
    power               : power_measure;
    electric_power      : power_measure;
    process_emission    : SET [1:?] OF emission_property;
END_ENTITY;
```

process_description : This attribute specifies the description of the standard machining processes. This generally includes process name, purpose of the process and feature of the workpiece.

type_of_machining : This attribute specifies the name of machining which identifies the machining operation in the process.

power : This attribute specifies the maximum power during the machining process.

electric_power : This attribute specifies the maximum electric power during the machining process.

process_emission : This attribute specifies the emissions produced during the machining process. Generally this attribute contains emissions that are environmentally harmful.

4.3.12 emission_property

This entity contains the type and weight of the emission which is produced during the machining operations.

```
ENTITY emission_property;
    emission_type : label;
    weight        : mass_measure;
END_ENTITY;
```

emission_type : This attribute specifies the substance name of the emission produced.

weight : This attribute specifies the weight of the emission.

4.3.13 machine_tool_requirements

This entity describes requirements for the machine tool.

```
ENTITY machine_tool_requirements
  SUBTYPE OF(machine_tool);
    number_of_tools_in_tool_magazine : OPTIONAL count_measure;
    machining                        : SET [1:?] OF machining_capability;
    spindles                         : OPTIONAL SET [1:?] OF
   spindle_capability;
    positioning                      : OPTIONAL positioning_capability;
    axis                             : OPTIONAL axis_capability;
    touch_probing                    : OPTIONAL measuring_capability;
    automatically_pallet_changeable  : BOOLEAN;
END_ENTITY;
```

number_of_tools_in_tool_magazine : This attribute specifies the number of tools in the tool magazine.

machining : This attribute specifies the machining capability of the machine tool.

spindles : This attribute specifies the spindle capability of the machine tool.

positioning : This attribute specifies the positioning capability of the machine tool.

axis : This attribute specifies the axis capability of the machine tool.

touch_probing : This attribute specifies the measuring capability of the machine tool.

automatically_pallet_changeable: This attribute specifies whether the machine tool has an automatic pallet changer.

4.3.14 project_physical_resource_association

This entity describes an association between a project and a machine_tool_requirements which the project requires for machine tools.

```
ENTITY project_physical_resource_association;
    project_of_resource : project;
    physical_resource   : machine_tool_requirements;
END_ENTITY;
```

project_of_resource : This attribute specifies a project of a machine tool.

physical_resource : This attribute specifies a machine_tool_requirements which the project requires for machine tools.

4.3.15 workplan_physical_resource_association

This entity describes an association between a workplan and a machine_tool_requirements which the workplan requires for machine tools.

```
ENTITY workplan_physical_resource_association;
    workplan_of_resource : workplan;
    physical_resource    : machine_tool_requirements;
END_ENTITY;
```

workplan_of_resource : This attribute specifies a workplan of a machine tool.

physical_resource : This attribute specifies a machine_tool_requirements which the workplan requires for machine tools.

4.3.16 machining_capability

This entity describes the machining capability of the machine tool.

```
ENTITY machining_capability;
    capability         : machining_capability_profile;
    machining_accuracy : OPTIONAL text;
    description        : OPTIONAL text;
    machining_size     : OPTIONAL machining_size;
END_ENTITY;
```

capability : This attribute specifies the main functions which the machine tool has.

machining_accuracy : This attribute specifies the description of the machining accuracy.

description : This attribute specifies the description of the machining capability.

machining_size : This attribute specifies the size of the workpiece which can be machined with the machine tool.

4.3.16.1 machining_capability_profile

This type is used for selecting a machine capability profile.

```
TYPE machining_capability_profile = ENUMERATION OF
  (BORING_CAPABILITY,
   DRILLING_CAPABILITY,
   GUNDRILL_CAPABILITY,
   MILLING_CAPABILITY,
   TURNING_CAPABILITY);
END_TYPE;
```

BORING_CAPABILITY : Capability for finishing holes of a part with a boring tool.

DRILLING_CAPABILITY : Capability for making holes of a part with a drilling tool.

GUNDRILL_CAPABILITY : Capability for machining deep (long) holes with a gundrill tool.

MILLING_CAPABILITY : Capability for cutting a part with a rotating tool.

TURNING_CAPABILITY : Capability for cutting a part by the rotation of the workpiece against stationary cutting tools.

4.3.17 machining_size

This entity describes the size of the workpiece which can be machined with the machine tool with reference to the axis directions of a machine tool.

```
ENTITY machining_size;
    description : OPTIONAL text;
    x           : length_measure;
    y           : length_measure;
    z           : length_measure;
END_ENTITY;
```

description : This attribute specifies the word or group of words used to provide information about the machining size.

x : This attribute specifies the length of the workpiece which can be machined with the machine tool.

y : This attribute specifies the width of the workpiece which can be machined with the machine tool.

z : This attribute specifies the height of the workpiece which can be machined with the machine tool.

4.3.18 spindle_capability

This entity describes the spindle capability of the machine tool.

```
ENTITY spindle_capability;
    spindle_name        : label;
    spindle_power       : power_measure;
    maximum_drive_speed : rot_speed_measure;
END_ENTITY;
```

spindle_name : This attribute specifies the name of the spindle.

spindle_power : This attribute specifies the maximum spindle power during continuous operation.

maximum_drive_speed : This attribute specifies the maximum spindle speed.

4.3.19 positioning_capability

This entity describes the positioning capability of the machine tool.

```
ENTITY positioning_capability;
    maximum_range_of_motion                   : LIST [1:?] OF range_of_motion;
    maximum_displacement_error_of_linear_axis : length_measure;
    maximum_repeatability_error_of_linear_axis: length_measure;
END_ENTITY;
```

maximum_range_of_motion : This attribute specifies the maximum programmable axis travel of each linear axis.

maximum_displacement_error_of_linear_axis: This attribute specifies the maximum displacement error of axis movements.

maximum_repeatability_error_of_linear_axis: This attribute specifies the maximum repeatability error of axis movements.

4.3.20 range_of_motion

This entity describes the properties of a range of motion.

```
ENTITY range_of_motion;
    axis_name    : label;
    motion_range : angle_or_length;
END_ENTITY;
```

axis_name: This attribute specifies the name of the axis.

motion_range : This attribute specifies the range of motion.

4.3.20.1 angle_or_length

This type is used for selecting plane_angle_measure or length_measure.

```
TYPE angle_or_length = SELECT
  (plane_angle_measure,
   length_measure);
END_TYPE;
```

4.3.21 axis_capability

This entity describes the specification of machine tool axes.

```
ENTITY axis_capability;
    number_of_axes              : count_measure;
    number_of_simultaneous_axes : count_measure;
END_ENTITY;
```

number_of_axes : This attribute specifies the number of axes.

number_of_simultaneous_axes : This attribute specifies the number of axes controlled by NC controller simultaneously. The number of simultaneous axes controlled must not be greater than the total number of axes.

4.3.22 measuring_capability

This entity describes the measuring capability of the machine tool.

```
ENTITY measuring_capability;
    measuring_accuracy : text;
    description        : OPTIONAL text;
END_ENTITY;
```

measuring_accuracy : This attribute specifies the accuracy of the measurement on the machine tool.

description : This attribute specifies the word or group of words used to provide information about the measuring capability.

4.4 Machine tool elements

4.4.1 machine_tool_element

This entity describes the properties of the machine tool elements of which a machine tool is composed.

NOTE The geometry of the machine_tool_element is represented in shape_representation which is connected to this entity instance via element_link_association and kinematic_link_representation. See 4.5.1 for details about this referenced structure.

```
ENTITY machine_tool_element;
    name         : label;
    description  : OPTIONAL text;
    weight       : OPTIONAL mass_measure;
    capabilities : OPTIONAL SET [1:?] OF element_capability;
END_ENTITY;
```

name : This attribute specifies the word, or group of words, that identifies the machine tool element.

description : This attribute specifies the word or group of words used to provide information about the machine tool element.

weight : This attribute specifies the numeric value that represents the mass of the machine tool element.

capabilities : This attribute specifies capabilities which the machine tool element has.

4.4.2 machine_element_relationship

This entity describes the properties of a relationship between machine elements.

```
ENTITY machine_element_relationship;
    class          : label;
    former_element : machine_tool_element;
    latter_element : machine_tool_element;
END_ENTITY;
```

former_element : This attribute specifies the former machine element of the relationship.

latter_element : This attribute specifies the latter machine element of the relationship.

class : This attribute specifies the classification of the relationship.

4.4.3 element_capability

This entity describes the types of a machine element capability.

```
ENTITY element_capability
  ABSTRACT SUPERTYPE OF (ONEOF(machine_tool_axis, work_table,
                         spindle, tool_handling_unit, coolant, sensor, chuck,
                        collet, bar_feeder, tailstock));
    description : OPTIONAL text;
END_ENTITY;
```

description : This attribute specifies the word or group of words used to provide information about the capability of the machine tool element.

4.4.4 machine_tool_axis

This entity describes the properties of a machine axis.

```
ENTITY machine_tool_axis
  SUPERTYPE OF (ONEOF(linear_axis, rotary_axis))
  SUBTYPE OF(element_capability);
    axis_name : label;
END_ENTITY;
```

axis_name : This attribute specifies the word, or group of words, that identifies the axis.

4.4.5 linear_axis

This entity describes the properties of a linear axis.

```
ENTITY linear_axis
  SUBTYPE OF(machine_tool_axis);
    minimum_range_of_motion   : length_measure;
    maximum_range_of_motion   : length_measure;
    displacement_error        : length_measure;
    repeatability_error       : length_measure;
    rapid_traverse_feed_rate  : velocity_measure;
    minimum_cutting_feed_rate : velocity_measure;
    maximum_cutting_feed_rate : velocity_measure;
    maximum_acceleration      : OPTIONAL acceleration_measure;
    maximum_deceleration      : OPTIONAL acceleration_measure;
    maximum_jerk              : OPTIONAL jerk_measure;
END_ENTITY;
```

minimum_range_of_motion : This attribute specifies the minimum programmable axis travel.

maximum_range_of_motion : This attribute specifies the maximum programmable axis travel.

displacement_error : This attribute specifies the maximum displacement error.

repeatability_error : This attribute specifies the maximum repeatability error.

rapid_traverse_feed_rate : This attribute specifies the rapid traverse speed.

minimum_cutting_feed_rate : This attribute specifies the minimum programmable cutting feed rate.

maximum_cutting_feed_rate : This attribute specifies the maximum programmable cutting feed rate.

maximum_acceleration : This attribute specifies the maximum acceleration of the axis.

maximum_deceleration : This attribute specifies the maximum deceleration of the axis.

maximum_jerk : This attribute specifies the maximum jerk of the axis.

4.4.6 rotary_axis

This entity describes the properties of a rotary axis.

```
ENTITY rotary_axis
  ABSTRACT SUPERTYPE OF (ONEOF(continuous_rotary, indexing, limited_swing))
  SUBTYPE OF(machine_tool_axis);
    displacement_angle_error           : plane_angle_measure;
    repeatability_angle_error          : plane_angle_measure;
    rapid_traverse_rotation_feed_rate  : rot_speed_measure;
    minimum_cutting_rotation_feed_rate : rot_speed_measure;
    maximum_cutting_rotation_feed_rate : rot_speed_measure;
    maximum_rotation_acceleration      : OPTIONAL rot_acceleration_measure;
    maximum_rotation_deceleration      : OPTIONAL rot_acceleration_measure;
    maximum_rotation_jerk              : OPTIONAL rot_jerk_measure;
END_ENTITY;
```

displacement_angle_error : This attribute specifies the maximum displacement angle error.

repeatability_angle_error : This attribute specifies the maximum repeatability angle error.

rapid_traverse_rotation_feed_rate : This attribute specifies the rapid traverse rotation speed.

minimum_cutting_rotation_feed_rate : This attribute specifies the minimum programmable cutting rotation feed rate.

maximum_cutting_rotation_feed_rate : This attribute specifies the maximum programmable cutting rotation feed rate.

maximum_rotation_acceleration : This attribute specifies the maximum rotation acceleration of the axis.

maximum_rotation_deceleration : This attribute specifies the maximum rotation deceleration of the axis.

maximum_rotation_jerk : This attribute specifies the maximum rotation jerk of the axis.

4.4.7 continuous_rotary

This entity describes the properties of a continuous rotary axis.

```
ENTITY continuous_rotary
  SUBTYPE OF(rotary_axis);
END_ENTITY;
```

4.4.8 indexing

This entity describes the properties of an indexing rotary axis.

```
ENTITY indexing
  SUBTYPE OF(rotary_axis);
    index_increment : plane_angle_measure;
END_ENTITY;
```

index_increment : This attribute specifies the increment motion by an index.

4.4.9 limited_swing

This entity describes the properties of a limited swing rotary axis.

```
ENTITY limited_swing
  SUBTYPE OF(rotary_axis);
    minimum_angle_of_motion : plane_angle_measure;
    maximum_angle_of_motion : plane_angle_measure;
    axis_travel_limit       : BOOLEAN;
END_ENTITY;
```

minimum_angle_of_motion : This attribute specifies the minimum programmable angle of motion.

maximum_angle_of_motion : This attribute specifies the maximum programmable angle of motion.

axis_travel_limit : This attribute specifies whether or not the axis has a travel limit.

4.4.10 work_table

This entity describes the properties of a work holding table.

```
ENTITY work_table
  ABSTRACT SUPERTYPE OF (ONEOF(circular_work_table, rectangular_work_table)
                         ANDOR pallet)
  SUBTYPE OF(element_capability);
    rotatable        : BOOLEAN;
    workpiece_weight : OPTIONAL mass_measure;
    fixture_style    : OPTIONAL fixture_style;
    chuck            : OPTIONAL chuck;
    t_slot           : OPTIONAL t_slot;
END_ENTITY;
```

rotatable : This attribute specifies whether the work holding table is rotatable.

workpiece_weight : This attribute specifies maximum workpiece weight.

fixture_style : This attribute specifies a designation of the fixture mechanism provided by the work holding table.

chuck : This attribute specifies properties of a chuck on the work holding table.

t_slot : This attribute specifies properties of T_slots on the work holding table.

4.4.10.1 fixture_style

This type is used for selecting the designation of the fixture mechanism.

```
TYPE fixture_style = ENUMERATION OF
  (CHUCK_FIXTURE,
   HOLE,
   T_SLOT_FIXTURE,
   VACUUM);
END_TYPE;
```

CHUCK_FIXTURE : Chuck.

HOLE : Threaded hole pattern.

T_SLOT_FIXTURE : T-slots.

VACUUM : Vacuum.

4.4.11 circular_work_table

This entity describes the properties of a round machine table.

```
ENTITY circular_work_table
  SUBTYPE OF(work_table);
    table_diameter : length_measure;
END_ENTITY;
```

table_diameter : This attribute specifies the diameter of a round machine table.

4.4.12 rectangular_work_table

This entity describes the properties of a rectangular work table.

```
ENTITY rectangular_work_table
  SUBTYPE OF(work_table);
    table_width  : length_measure;
    table_length : length_measure;
END_ENTITY;
```

table_width : This attribute specifies the size of a rectangular machine table in the X-direction.

table_length : This attribute specifies the size of a rectangular machine table in the Y-direction.

4.4.13 pallet

This entity describes the properties of a pallet.

```
ENTITY pallet
  SUBTYPE OF(work_table);
    random_access              : BOOLEAN;
    table_width                : length_measure;
    table_length               : length_measure;
    number_of_pallets           : count_measure;
    storage_configuration      : OPTIONAL pallet_storage_configuration;
    pallet_change_time_minimum : OPTIONAL time_measure;
    pallet_change_time_maximum : OPTIONAL time_measure;
    pallet_type                : OPTIONAL STRING;
END_ENTITY;
```

random_access : This attribute specifies whether the pallet can be stored in any of the empty slots after the next one has been loaded into the machine.

table_width : This attribute specifies the size of the pallet in the X-direction.

table_length : This attribute specifies the size of the pallet in the Y-direction.

number_of_pallets : This attribute specifies number of pallets.

storage_configuration : This attribute specifies the type of pallet store configuration.

pallet_change_time_minimum : This attribute specifies minimum pallet change time (typically for the nearest pallet).

pallet_change_time_maximum : This attribute specifies maximum pallet change time (typically for the furthest pallet).

pallet_type : This attribute specifies designation pallet type.

4.4.13.1 pallet_storage_configuration

This type is used for selecting the type of pallet store configuration.

```
TYPE pallet_storage_configuration = ENUMERATION OF
  (CAROUSEL,
   CAROUSEL_2_PLACE,
   CHAIN,
   FIXED_2_PLACE,
   MULTI_STOREY,
   STRAIGHT_LINE);
END_TYPE;
```

CAROUSEL : Carousel type store.

CAROUSEL_2_PLACE : Carousel two-place store.

CHAIN : Chain type store.

FIXED_2_PLACE : Fixed two-place store.

MULTI_STOREY : Multi-storey pallet store.

STRAIGHT_LINE : Straight-line pallet store.

4.4.14 t_slot

This entity describes the properties of T-slots on a work table or a pallet.

```
ENTITY t_slot;
    number_of_t_slots              : count_measure;
    t_slot_size                   : length_measure;
    distance_between_t_slot_centres : length_measure;
END_ENTITY;
```

number_of_t_slots : This attribute specifies the number of T-slots.

t_slot_size : This attribute specifies the size of T-slots.

distance_between_t_slot_centres : This attribute specifies the distance between T-slot centres.

4.4.15 spindle

This entity describes the properties of a spindle. A spindle is an axis rotating with a tool or workpiece. This entity is the supertype of tool spindle and work spindle. All spindle entities are derived from this supertype. The specification of the spindle is defined by its physical property including speed, length, or thread diameter.

```
ENTITY spindle
  SUPERTYPE OF (ONEOF(tool_spindle, work_spindle))
  SUBTYPE OF(element_capability);
    spindle_power                  : power_measure;
    spindle_name                   : label;
    spindle_manufacturer           : OPTIONAL label;
    manufacturer_model_designation : OPTIONAL label;
    range                          : LIST [1:?] OF spindle_range;
END_ENTITY;
```

spindle_power: This attribute specifies the maximum power of the spindle.

spindle_name: This attribute specifies the name of the spindle.

spindle_manufacturer: This attribute specifies the name of the company that manufactured the spindle.

manufacturer_model_designation: This attribute specifies the name of the spindle model.

range: This attribute specifies possible limits on spindle range. If the spindle is a gear spindle, an index of list is corresponds to the gear selection. Otherwise the size of the list is one.

4.4.16 tool_spindle

This entity describes the properties of a tool spindle. A tool spindle is a spindle for rotating a cutting tool. Tapered spindle, straight spindle, and threaded spindle are derived from this entity. These subtypes are determined by the shape of the spindle.

```
ENTITY tool_spindle
  ABSTRACT SUPERTYPE OF (ONEOF(tapered_spindle, straight_spindle,
                               threaded_spindle))
  SUBTYPE OF(spindle);
    spindle_tool_holder_style_designation : label;
    coolant_through_spindle               : BOOLEAN;
END_ENTITY;
```

spindle_tool_holder_style_designation : This attribute describes the tool holder style.

coolant_through_spindle : This attribute specifies whether the coolant is used through the spindle.

4.4.17 tapered_spindle

This entity describes the properties of a tapered spindle.

```
ENTITY tapered_spindle
  SUBTYPE OF(tool_spindle);
    spindle_taper_designation : label;
END_ENTITY;
```

spindle_taper_designation : This attribute specifies the bore of a tapered spindle.

4.4.18 straight_spindle

This entity describes the properties of a straight spindle.

```
ENTITY straight_spindle
  SUBTYPE OF(tool_spindle);
    spindle_bore_depth    : length_measure;
    spindle_bore_diameter : length_measure;
END_ENTITY;
```

spindle_bore_depth: This attribute specifies the depth of the bore.

spindle_bore_diameter: This attribute specifies the diameter of the bore.

4.4.19 threaded_spindle

This entity describes the properties of a threaded spindle.

```
ENTITY threaded_spindle
  SUBTYPE OF(tool_spindle);
    spindle_thread_diameter : length_measure;
    spindle_thread_pitch    : length_measure;
    spindle_thread_form     : label;
END_ENTITY;
```

spindle_thread_diameter : This attribute specifies the diameter of the bore.

spindle_thread_pitch : This attribute specifies the length which represents the distance between one groove and the next groove in a threaded spindle.

spindle_thread_form : This attribute specifies the shape or other attributes of the thread

4.4.20 work_spindle

This entity describes the properties of a work spindle. Work spindle is a spindle which is for rotating the workpiece.

```
ENTITY work_spindle
  SUBTYPE OF(spindle);
    spindle_nose_designation : label;
    spindle_bore_diameter    : length_measure;
    round_bar_stock_diameter : OPTIONAL length_measure;
    through_hole_diameter    : OPTIONAL length_measure;
    hex_bar_stock_capacity   : OPTIONAL REAL;
    chuck                    : OPTIONAL chuck;
END_ENTITY;
```

spindle_nose_designation : This attribute specifies the spindle nose. Spindle nose is located at the front of the spindle for attaching a chuck or other machine tool element. This attribute contains information about whether the nose type is threaded, tapered, cam-lock or another type.

spindle_bore_diameter : This attribute specifies the diameter of the spindle bore.

round_bar_stock_diameter : This attribute specifies the maximum diameter of workpeice.

through_hole_diameter : This attribute specifies the diameter of the through hole.

hex_bar_stock_capacity : This attribute specifies the maximum length of a side in hex bar.

chuck : This attribute specifies the chuck in a work spindle.

4.4.21 spindle_range

This entity describes the lower and upper limit of the spindle range. It consists of rotating speed and torque of the spindle.

```
ENTITY spindle_range;
    minimum_drive_speed  : rot_speed_measure;
    maximum_drive_speed  : rot_speed_measure;
    minimum_drive_torque : torque_measure;
    maximum_drive_torque : torque_measure;
END_ENTITY;
```

minimum_drive_speed : This attribute specifies the minimum drive speed of the spindle during the operation.

maximum_drive_speed : This attribute specifies the maximum drive speed of the spindle during the operation.

minimum_drive_torque : This attribute specifies the minimum drive torque of the spindle during the operation.

maximum_drive_torque : This attribute specifies the maximum drive torque of the spindle during the operation.

4.4.22 tool_handling_unit

This entity describes the properties of the tool handling unit that is one of turret, tool changer and tool magazine.

```
ENTITY tool_handling_unit
  ABSTRACT SUPERTYPE OF (ONEOF(turret, tool_changer, tool_magazine))
  SUBTYPE OF(element_capability);
END_ENTITY;
```

4.4.23 turret

This entity describes the properties of a turret.

```
ENTITY turret
  SUBTYPE OF(tool_handling_unit);
    spindle_name                    : OPTIONAL SET [1:?] OF label;
    number_of_fixed_tools           : count_measure;
    number_of_rotating_tools        : count_measure;
    cut_to_cut_min_turret_index_time : OPTIONAL time_measure;
    cut_to_cut_max_turret_index_time : OPTIONAL time_measure;
    turret_contents                 : OPTIONAL SET [1:?] OF tool_assembly;
END_ENTITY;
```

spindle_name : This attribute specifies the word, or group of words, that identifies the spindle(s) served by a turret.

number_of_fixed_tools : This attribute specifies the number of fixed tool positions.

number_of_rotating_tools : This attribute specifies the number of rotating tool positions.

cut_to_cut_min_turret_index_time : This attribute specifies the minimum cut-to-cut turret index time (typically for the nearest tool).

cut_to_cut_max_turret_index_time : This attribute specifies maximum cut-to-cut turret index time (typically for the furthest tool).

turret_contents : This attribute specifies the tool assemblies in the turret.

4.4.24 tool_assembly

This entity describes the properties of a tool assembly that contains a cutting tool and its tool holder(s).

```
ENTITY tool_assembly;
    tool_number : identifier;
    tool_type   : label;
    tool_size   : OPTIONAL STRING;
END_ENTITY;
```

tool_number : This attribute specifies the tool number that identifies the tool assembly.

tool_type : This attribute specifies the tool type of the tool assembly.

tool_size : This attribute specifies the tool size of the tool assembly.

4.4.25 tool_changer

This entity describes the properties of a tool changer that does not contain a tool magazine.

```
ENTITY tool_changer
  SUBTYPE OF(tool_handling_unit);
    spindle_name                    : label;
    cut_to_cut_min_tool_change_time : OPTIONAL time_measure;
    cut_to_cut_max_tool_change_time : OPTIONAL time_measure;
END_ENTITY;
```

spindle_name : This attribute specifies the word, or group of words, that identifies the spindle(s) served by a tool changer.

cut_to_cut_min_tool_change_time : This attribute specifies minimum cut-to-cut tool change time (typically for the nearest tool).

cut_to_cut_max_tool_change_time : This attribute specifies maximum cut-to-cut tool change time (typically for the furthest tool).

4.4.26 tool_magazine

This entity describes the properties of a tool store magazine.

```
ENTITY tool_magazine
  SUBTYPE OF(tool_handling_unit);
    number_of_tools        : count_measure;
    random_access          : BOOLEAN;
    diameter_full          : length_measure;
    diameter_empty         : length_measure;
    tool_length            : length_measure;
```

```
    tool_weight            : mass_measure;
    storage_configuration  : OPTIONAL Tool_storage_configuration;
    tool_magazine_contents : OPTIONAL SET [1:?] OF tool_assembly;
END_ENTITY;
```

number_of_tools : This attribute specifies the number of tools that a tool magazine can store.

random_access : This attribute specifies whether the tool can be stored in any of the empty slots after the next one has been loaded into the machine spindle.

diameter_full : This attribute specifies the maximum diameter tool if adjacent positions are occupied.

diameter_empty : This attribute specifies the maximum diameter tool if adjacent positions are empty.

tool_length : This attribute specifies the maximum tool length in a tool magazine.

tool_weight : This attribute specifies the maximum tool weight in a tool magazine.

storage_configuration : This attribute specifies the type of tool store configuration.

tool_magazine_contents : This attribute specifies tool assemblies in a tool magazine.

4.4.26.1 tool_storage_configuration

This type is used for selecting the type of tool store configuration (see ISO 10791-9).

```
TYPE tool_storage_configuration = ENUMERATION OF
  (BI_DIRECTIONAL,
   BOX_MATRIX,
   UNI_DIRECTIONAL);
END_TYPE;
```

BI_DIRECTIONAL : Describes a tool change system of a tool magazine that can move in both directions to bring the tools to the loading position.

BOX_MATRIX : Describes a tool change system of a tool magazine that stores the tools in a matrix arrangement where loading and unloading is done by moving the pick up device to the appropriate tool box.

UNI_DIRECTIONAL : Describes a tool change system of a tool magazine that can move only in one direction to bring the tools to the loading position.

4.4.27 coolant

This entity describes the properties of a process coolant system.

```
ENTITY coolant
  SUBTYPE OF(element_capability);
    coolant_type             : coolant_type;
    means_of_delivery        : OPTIONAL means_of_coolant_delivery;
    capacity_of_coolant_tank : OPTIONAL volume_measure;
    coolant_weight           : OPTIONAL mass_measure;
END_ENTITY;
```

coolant_type : This attribute specifies the type of coolant used by the machine.

means_of_delivery : This attribute specifies the means of coolant delivery.

capacity_of_coolant_tank : This attribute specifies the capacity of the coolant tank.

coolant_weight : This attribute specifies the weight of coolant in the coolant tank.

4.4.27.1 coolant_type

This type is used for selecting the type of coolant delivery.

```
TYPE coolant_type = ENUMERATION OF
  (AIR,
   FLOOD,
   MICRO,
   MIST,
   NONE);
END_TYPE;
```

AIR : Using (cool) air.

FLOOD : Flood coolant, high volume of coolant at low velocity.

MICRO : Extremely low volume of lubricant as a high-velocity aerosol.

MIST : Low volume of liquid coolant delivered as a high-velocity aerosol.

NONE : No coolant, or dry machining.

4.4.27.2 means_of_coolant_delivery

This type is used for selecting the means of coolant delivery.

```
TYPE means_of_coolant_delivery = ENUMERATION OF
  (EXTERNAL,
   THRU_SPINDLE,
   THRU_TURRET);
END_TYPE;
```

EXTERNAL : Delivery of coolant neither through the spindle nor turret.

THRU_SPINDLE : Delivery of coolant through the spindle.

THRU_TURRET : Delivery of coolant through the turret.

4.4.28 sensor

This entity describes the properties of an additional sensing device.

```
ENTITY sensor
  ABSTRACT SUPERTYPE OF (ONEOF(tool_setting, tool_breakage, part_probe))
  SUBTYPE OF(element_capability);
    device_id : device_id;
END_ENTITY;
```

device_id : This attribute specifies identification information of the sensor.

4.4.29 tool_setting

This entity describes the properties of tool setting station.

```
ENTITY tool_setting
  SUBTYPE OF(sensor);
    probe_type       : probe_type;
    measuring_radius : BOOLEAN;
    measuring_length : BOOLEAN;
    measure_time     : time_measure;
END_ENTITY;
```

probe_type: This attribute specifies the probe type of tool setting.

measuring_radius: This attribute specifies whether the tool setting station can measure tool radius.

measuring_length: This attribute specifies whether the tool setting station can measure tool offset/length.

measure_time: This attribute specifies the time required to measure tool parameters.

4.4.29.1 probe_type

This type is used for selecting the probe type.

```
TYPE probe_type = ENUMERATION OF
  (NULLING,
   PROPORTIONAL,
   SWITCHING);
END_TYPE;
```

NULLING: Probe that, in reference to a measure object, gives a signal that causes the machine to be driven to a position that will null the probe reading.

PROPORTIONAL: Probe that gives a signal proportional to a displacement of the probe from its free position.

SWITCHING: Probe that gives a binary signal as a result of contact with or in proximity to an object.

4.4.30 tool_breakage

This entity describes the properties of a tool breakage sensor.

```
ENTITY tool_breakage
  SUBTYPE OF(sensor);
END_ENTITY;
```

4.4.31 part_probe

This entity describes the properties of a part probe.

```
ENTITY part_probe
  SUBTYPE OF(sensor);
    probe_type     : probe_type;
    dimensionality : sensor_dimensionality;
    setting_time   : time_measure;
END_ENTITY;
```

probe_type: This attribute specifies the probe type of part probe.

dimensionality: This attribute specifies the maximum dimensionality of the measurement tasks that can be performed.

setting_time: This attribute specifies the setting time of a proportional probe.

4.4.31.1 sensor_dimensionality

This type is used for selecting the maximum dimensionality of the measurement tasks that can be performed.

```
TYPE sensor_dimensionality = ENUMERATION OF
  (ONE_D,
   TWO_D,
   THREE_D);
END_TYPE;
```

ONE_D: Allows only 1-D measurements.

TWO_D: Allows only 2-D measurements.

THREE_D: Allows 3-D measurements.

4.4.32 chuck

This entity describes the properties of a chuck.

```
ENTITY chuck
  SUBTYPE OF(element_capability);
    minimum_part_diameter : length_measure;
    maximum_part_diameter : length_measure;
    number_of_jaws        : count_measure;
END_ENTITY;
```

minimum_part_diameter : This attribute specifies the minimum allowed value for the diameter of the workpiece to be held by the chuck.

maximum_part_diameter : This attribute specifies the maximum allowed value for the diameter of the workpiece to be held by the chuck.

number_of_jaws : This attribute specifies the number of the jaws in the chuck.

4.4.33 collet

This entity describes the properties of a collet.

```
ENTITY collet
  SUBTYPE OF(element_capability);
    collet_type           : label;
    minimum_part_diameter : length_measure;
    maximum_part_diameter : length_measure;
END_ENTITY;
```

collet_type : This attribute specifies the name of the tool that identifies the characteristics of the collet.

minimum_part_diameter : This attribute specifies the minimum diameter of the tool or workpiece to be held by the collet. It provides a limit for workpieces that are not large enough to be held.

maximum_part_diameter : This attribute specifies the maximum diameter of the tool or workpiece to be hold by the collet. It provides a limit for workpieces that are not small enough to be held.

4.4.34 bar_feeder

This entity describes the properties of a bar feeder.

```
ENTITY bar_feeder
  SUBTYPE OF(element_capability);
    minimum_stock_diameter : length_measure;
    maximum_stock_diameter : length_measure;
    maximum_stock_length   : length_measure;
END_ENTITY;
```

minimum_stock_diameter : This attribute specifies the minimum diameter of the stock to be fed to a lathe. It provides a limit for stock size that is not large enough to be fed.

maximum_stock_diameter : This attribute specifies the maximum diameter of the stock to be fed to a lathe. It provides a limit for stock size that is not small enough to be fed.

maximum_stock_length : This attribute specifies the maximum length of the stock to be fed to a lathe. It provides a limit for stock size that is not short enough to be fed.

4.4.35 tailstock

This entity describes the properties of a tail stock.

```
ENTITY tailstock
  SUBTYPE OF(element_capability);
    spindle_name                      : label;
    taper                             : label;
    maximum_workpiece_weight_of_quill : mass_measure;
END_ENTITY;
```

spindle_name : This attribute specifies the name of the tailstock.

taper : This attribute describes the shape of the taper.

maximum_workpiece_weight_of_quill : This attribute specifies the maximum weight of the workpiece to be held by a tailstock. It provides a limit for workpiece weight that is not light enough to be fed.

4.5 Kinematics

4.5.1 General

The kinematic model of the machine tools is based on ISO 10303-105 kinematics. In ISO 10303-105, kinematic structures are represented by graphs where the kinematic links are represented by the vertices of the graph, and the joints are represented by the edges. The following entities are imported from ISO 10303-105 to represent the kinematic structure of the machine tools:

— cylindrical_pair;

— cylindrical_pair_range;

— kinematic_joint;

— kinematic_link;

— kinematic_link_representation;

— kinematic_link_representation_association;

— kinematic_link_representation_relation;

— kinematic_pair;

— kinematic_property_definition;

— kinematic_structure;

— mechanism;

— pair_actuator;

— prismatic_pair;

— prismatic_pair_range;

— revolute_pair;

— revolute_pair_range;

— rotational_range_measure;

— simple_pair_range;

— spherical_pair;

— spherical_pair_range;

— su_parameters;

— translational_range_measure;

— unlimited_range.

NOTE 1 The detailed description of the kinematic model is in ISO 10303-105.

The geometry of the machine_tool_element is represented in shape_representation which is connected to the machine_tool_element instance via element_link_association, kinematic_link, kinematic_link_representation_relation, kinematic_link_representation and kinematic_link_representation_association.

NOTE 2 Figure 1 shows this reference structure in EXPRESS-G diagram.

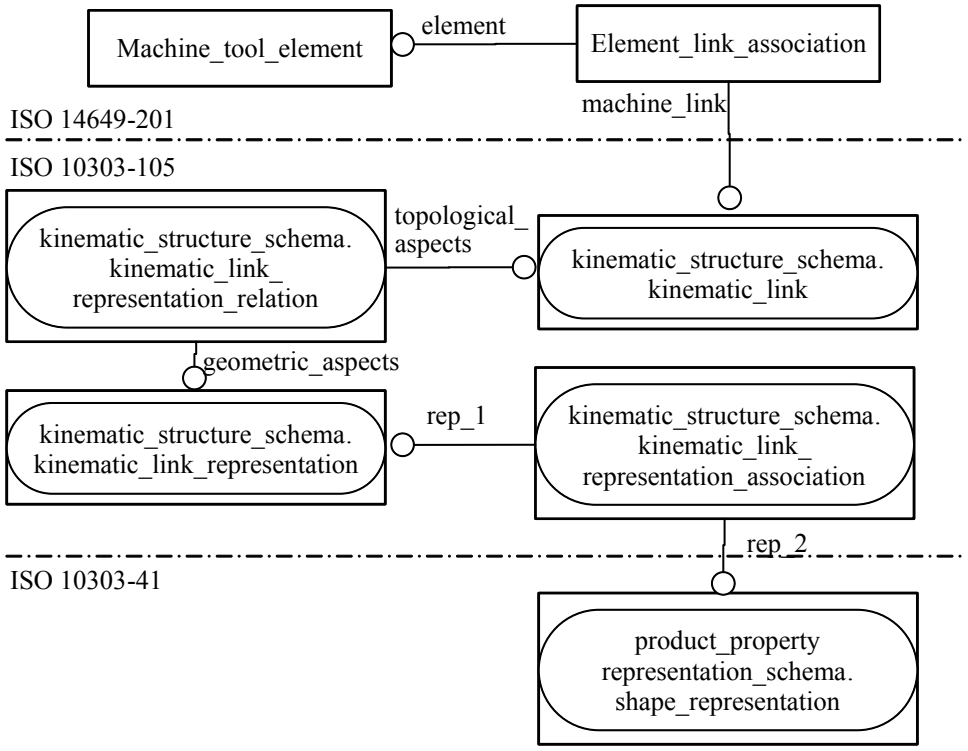


Figure 1 — Referencing mechanism from machine_tool_element to shape_representation

4.5.2 machine_kinematic_association

This entity describes an association between the Machine_tool and the mechanism which represents its kinematic structure.

```
ENTITY machine_kinematic_association;
    machine    : machine_tool_specification;
    kinematics : mechanism;
END_ENTITY;
```

machine : This attribute specifies the machine_tool which has the kinematic structure.

kinematics : This attribute specifies a mechanism which represents the kinematic structure of the machine tool.

4.5.3 element_link_association

This entity describes an association between the machine_tool_element and the kinematic_link which is the element of kinematic structure in the mechanism of the machine tool.

```
ENTITY element_link_association;
    element      : machine_tool_element;
    machine_link : kinematic_link;
END_ENTITY;
```

element: This attribute specifies a machine_tool_element which is the movable element of the machine tool.

machine_link: This attribute specifies a kinematic_link which is the element of kinematic structure in the mechanism of the machine tool.

Annex A
(normative)

EXPRESS expanded listing

This annex shows the EXPRESS listing of this part of ISO 14649.

```
SCHEMA CUTTING_PROCESS_MACHINE_TOOL_SCHEMA;

(*
   Version : 1
   Date    : 04.01.2011
   Author  : ISO TC184/SC1/WG7
   Contact : Fumiki Tanaka <ftanaka@ssi.ist.hokudai.ac.jp>

*)

  USE FROM DATE_TIME_SCHEMA
    (calendar_date);

  USE FROM GEOMETRY_SCHEMA
    (axis2_placement_3d);

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

  USE FROM MACHINING_SCHEMA
    (project,
     rot_speed_measure,
     workplan);

  USE FROM MEASURE_SCHEMA
    (acceleration_measure,
     count_measure,
     electric_current_measure,
```

```
   length_measure,
   mass_measure,
   plane_angle_measure,
   power_measure,
   pressure_measure,
   ratio_measure,
   time_measure,
   velocity_measure,
   volume_measure);

USE FROM PRODUCT_DEFINITION_SCHEMA
  (product_definition);

USE FROM PRODUCT_PROPERTY_DEFINITION_SCHEMA
  (characterized_definition,
   characterized_object,
   characterized_product_definition);

USE FROM PRODUCT_PROPERTY_REPRESENTATION_SCHEMA
  (shape_representation);

USE FROM SUPPORT_RESOURCE_SCHEMA
  (identifier,
   label,
   text);

TYPE angle_or_length = SELECT
  (plane_angle_measure,
   length_measure);
END_TYPE;

TYPE jerk_measure = REAL;
END_TYPE;

TYPE rot_acceleration_measure = REAL;
END_TYPE;

TYPE rot_jerk_measure = REAL;
END_TYPE;

TYPE torque_measure = REAL;
END_TYPE;

TYPE coolant_type = ENUMERATION OF
  (AIR,
   FLOOD,
   MICRO,
   MIST,
   NONE);
END_TYPE;

TYPE fixture_style = ENUMERATION OF
  (CHUCK_FIXTURE,
   HOLE,
   T_SLOT_FIXTURE,
   VACUUM);
END_TYPE;

TYPE interpolation = ENUMERATION OF
  (CIRCULAR,
   HELICAL,
```

```
   LINEAR,
   NURBS,
   OTHER);
END_TYPE;

TYPE machining_capability_profile = ENUMERATION OF
  (BORING_CAPABILITY,
   DRILLING_CAPABILITY,
   GUNDRILL_CAPABILITY,
   MILLING_CAPABILITY,
   TURNING_CAPABILITY);
END_TYPE;

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

TYPE means_of_coolant_delivery = ENUMERATION OF
  (EXTERNAL,
   THRU_SPINDLE,
   THRU_TURRET);
END_TYPE;

TYPE pallet_storage_configuration = ENUMERATION OF
  (CAROUSEL,
   CAROUSEL_2_PLACE,
   CHAIN,
   FIXED_2_PLACE,
   MULTI_STOREY,
   STRAIGHT_LINE);
END_TYPE;

TYPE probe_type = ENUMERATION OF
  (NULLING,
   PROPORTIONAL,
   SWITCHING);
END_TYPE;

TYPE sensor_dimensionality = ENUMERATION OF
  (ONE_D,
   TWO_D,
   THREE_D);
END_TYPE;

TYPE tool_compensation = ENUMERATION OF
  (TOOL_LENGTH,
   TOOL_RADIUS);
END_TYPE;

TYPE tool_storage_configuration = ENUMERATION OF
  (BI_DIRECTIONAL,
   BOX_MATRIX,
   UNI_DIRECTIONAL);
END_TYPE;

TYPE units_type = ENUMERATION OF
```

```
  (INCH,
   INCH_AND_METRIC,
   METRIC);
END_TYPE;

ENTITY axis_capability;
    number_of_axes              : count_measure;
    number_of_simultanious_axes : count_measure;
END_ENTITY;

ENTITY bar_feeder
  SUBTYPE OF(element_capability);
    minimum_stock_diameter : length_measure;
    maximum_stock_diameter : length_measure;
    maximum_stock_length   : length_measure;
END_ENTITY;

ENTITY chuck
  SUBTYPE OF(element_capability);
    minimum_part_diameter : length_measure;
    maximum_part_diameter : length_measure;
    number_of_jaws        : count_measure;
END_ENTITY;

ENTITY circular_work_table
  SUBTYPE OF(work_table);
    table_diameter : length_measure;
END_ENTITY;

ENTITY collet
  SUBTYPE OF(element_capability);
    collet_type           : label;
    minimum_part_diameter : length_measure;
    maximum_part_diameter : length_measure;
END_ENTITY;

ENTITY continuous_rotary
  SUBTYPE OF(rotary_axis);
END_ENTITY;

ENTITY coolant
  SUBTYPE OF(element_capability);
    coolant_type             : coolant_type;
    means_of_delivery        : OPTIONAL means_of_coolant_delivery;
    capacity_of_coolant_tank : OPTIONAL volume_measure;
    coolant_weight           : OPTIONAL mass_measure;
END_ENTITY;

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

ENTITY electrical;
    electric_phase       : INTEGER;
    electric_power       : power_measure;
    electrical_current   : electric_current_measure;
    electrical_frequency : STRING;
```

```
    electrical_grounding : STRING;
    electrical_voltage   : REAL;
END_ENTITY;

ENTITY element_capability
  ABSTRACT SUPERTYPE OF (ONEOF(machine_tool_axis, work_table, spindle,
                               tool_handling_unit, coolant, sensor, chuck,
collet,
                               bar_feeder, tailstock ));
    description : OPTIONAL text;
END_ENTITY;

ENTITY element_link_association;
    element      : machine_tool_element;
    machine_link : kinematic_link;
END_ENTITY;

ENTITY emission_property;
    emission_type : label;
    weight        : mass_measure;
END_ENTITY;

ENTITY environmental_evaluation;
    evaluation_name              : label;
    power_in_idling              : OPTIONAL power_measure;
    time_for_warming_up          : OPTIONAL time_measure;
    power_for_standard_machining : OPTIONAL SET [1:?] OF
                                   standard_machining_process;
END_ENTITY;

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

ENTITY indexing
  SUBTYPE OF(rotary_axis);
    index_increment : plane_angle_measure;
END_ENTITY;

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

ENTITY limited_swing
  SUBTYPE OF(rotary_axis);
    minimum_angle_of_motion : plane_angle_measure;
    maximum_angle_of_motion : plane_angle_measure;
    axis_travel_limit       : BOOLEAN;
END_ENTITY;

ENTITY linear_axis
  SUBTYPE OF(machine_tool_axis);
    minimum_range_of_motion   : length_measure;
    maximum_range_of_motion   : length_measure;
```

```
    displacement_error        : length_measure;
    repeatability_error       : length_measure;
    rapid_traverse_feed_rate  : velocity_measure;
    minimum_cutting_feed_rate : velocity_measure;
    maximum_cutting_feed_rate : velocity_measure;
    maximum_acceleration      : OPTIONAL acceleration_measure;
    maximum_deceleration      : OPTIONAL acceleration_measure;
    maximum_jerk              : OPTIONAL jerk_measure;
END_ENTITY;

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

ENTITY machine_element_relationship;
    class          : label;
    former_element : machine_tool_element;
    latter_element : machine_tool_element;
END_ENTITY;

ENTITY machine_kinematic_association;
    machine    : machine_tool_specification;
    kinematics : mechanism;
END_ENTITY;

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

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

ENTITY machine_tool_axis
  SUPERTYPE OF (ONEOF(linear_axis, rotary_axis))
  SUBTYPE OF(element_capability);
    axis_name : label;
END_ENTITY;

ENTITY machine_tool_element;
    name         : label;
    description  : OPTIONAL text;
    weight       : OPTIONAL mass_measure;
    capabilities : OPTIONAL SET [1:?] OF element_capability;
END_ENTITY;

ENTITY machine_tool_requirements
  SUBTYPE OF(machine_tool);
    number_of_tools_in_tool_magazine : OPTIONAL count_measure;
    machining                        : SET [1:?] OF machining_capability;
    spindles                         : OPTIONAL SET [1:?] OF
spindle_capability;
    positioning                      : OPTIONAL positioning_capability;
    axis                             : OPTIONAL axis_capability;
```

```
    touch_probing                    : OPTIONAL measuring_capability;
    automatically_pallet_changeable  : BOOLEAN;
END_ENTITY;

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

ENTITY machining_capability;
    capability         : machining_capability_profile;
    machining_accuracy : OPTIONAL text;
    description        : OPTIONAL text;
    machining_size     : OPTIONAL machining_size;
END_ENTITY;

ENTITY machining_size;
    description : OPTIONAL text;
    x           : length_measure;
    y           : length_measure;
    z           : length_measure;
END_ENTITY;

ENTITY measuring_capability;
    measuring_accuracy : text;
    description        : OPTIONAL text;
END_ENTITY;

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

```
    time_sampling                                : OPTIONAL time_measure;
    clock_frequency                              : OPTIONAL count_measure;
END_ENTITY;

ENTITY pallet
  SUBTYPE OF(work_table);
    random_access              : BOOLEAN;
    table_width                : length_measure;
    table_length               : length_measure;
    number_of_pallet           : count_measure;
    storage_configuration      : OPTIONAL pallet_storage_configuration;
    pallet_change_time_minimum : OPTIONAL time_measure;
    pallet_change_time_maximum : OPTIONAL time_measure;
    pallet_type                : OPTIONAL STRING;
END_ENTITY;

ENTITY part_probe
  SUBTYPE OF(sensor);
    probe_type     : probe_type;
    dimensionality : sensor_dimensionality;
    setting_time   : time_measure;
END_ENTITY;

ENTITY positioning_capability;
    maximum_range_of_motion                   : LIST [1:?] OF
 range_of_motion;
    maximum_displacement_error_of_linear_axis : length_measure;
    maximum_repeatability_error_of_linear_axis: length_measure;
END_ENTITY;

ENTITY project_physical_resource_association;
    project_of_resource : project;
    physical_resource   : machine_tool_requirements;
END_ENTITY;

ENTITY range_of_motion;
    axis_name    : label;
    motion_range : angle_or_length;
END_ENTITY;

ENTITY rectangular_work_table
  SUBTYPE OF(work_table);
    table_width  : length_measure;
    table_length : length_measure;
END_ENTITY;

ENTITY rotary_axis
  ABSTRACT SUPERTYPE OF (ONEOF(continuous_rotary, indexing, limited_swing))
  SUBTYPE OF(machine_tool_axis);
    displacement_angle_error           : plane_angle_measure;
    repeatability_angle_error          : plane_angle_measure;
    rapid_traverse_rotation_feed_rate  : rot_speed_measure;
    minimum_cutting_rotation_feed_rate : rot_speed_measure;
    maximum_cutting_rotation_feed_rate : rot_speed_measure;
    maximum_rotation_acceleration      : OPTIONAL rot_acceleration_measure;
    maximum_rotation_deceleration      : OPTIONAL rot_acceleration_measure;
    maximum_rotation_jerk              : OPTIONAL rot_jerk_measure;
END_ENTITY;
```

```
ENTITY sensor
  ABSTRACT SUPERTYPE OF (ONEOF(tool_setting, tool_breakage, part_probe))
  SUBTYPE OF(element_capability);
    device_id : device_id;
END_ENTITY;

ENTITY spindle
  SUPERTYPE OF (ONEOF(tool_spindle, work_spindle))
  SUBTYPE OF(element_capability);
    spindle_power                  : power_measure;
    spindle_name                   : label;
    spindle_manufacturer           : OPTIONAL label;
    manufacturer_model_designation : OPTIONAL label;
    range                          : LIST [1:?] OF spindle_range;
END_ENTITY;

ENTITY spindle_capability;
    spindle_name        : label;
    spindle_power       : power_measure;
    maximum_drive_speed : rot_speed_measure;
END_ENTITY;

ENTITY spindle_range;
    minimum_drive_speed  : rot_speed_measure;
    maximum_drive_speed  : rot_speed_measure;
    minimum_drive_torque : torque_measure;
    maximum_drive_torque : torque_measure;
END_ENTITY;

ENTITY standard_machining_process;
    process_description : text;
    type_of_machining   : label;
    power               : power_measure;
    electric_power      : power_measure;
    process_emission    : SET [1:?] OF emission_property;
END_ENTITY;

ENTITY straight_spindle
  SUBTYPE OF(tool_spindle);
    spindle_bore_depth    : length_measure;
    spindle_bore_diameter : length_measure;
END_ENTITY;

ENTITY t_slot;
    number_of_t_slots               : count_measure;
    t_slots_size                    : length_measure;
    distance_between_t_slot_centres : length_measure;
END_ENTITY;

ENTITY tailstock
  SUBTYPE OF(element_capability);
    spindle_name                      : label;
    taper                             : label;
    maximum_workpiece_weight_of_quill : mass_measure;
END_ENTITY;

ENTITY tapered_spindle
  SUBTYPE OF(tool_spindle);
    spindle_taper_designation : label;
END_ENTITY;
```

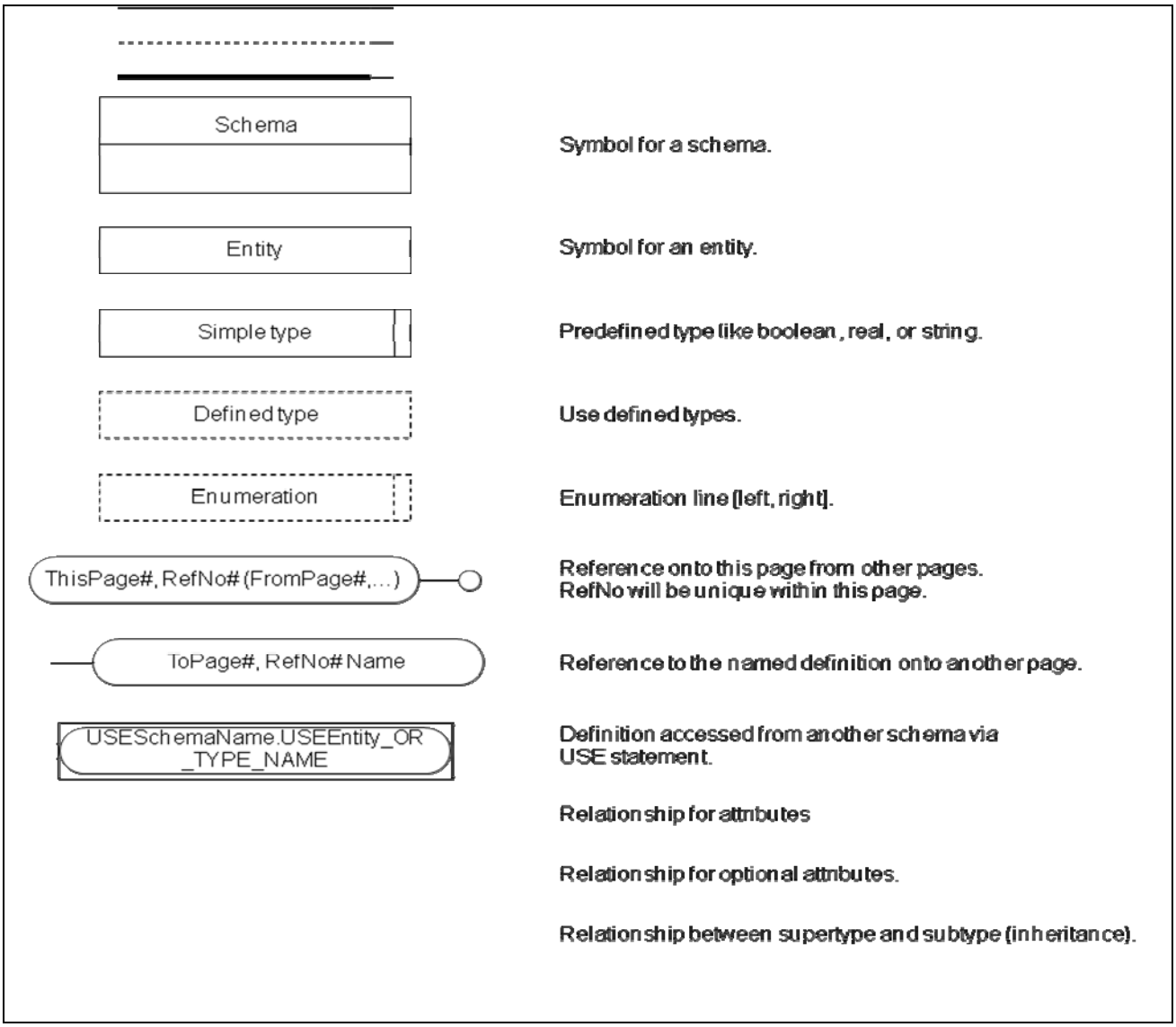
```
ENTITY threaded_spindle
  SUBTYPE OF(tool_spindle);
    spindle_thread_diameter : length_measure;
    spindle_thread_pitch    : length_measure;
    spindle_thread_form     : label;
END_ENTITY;

ENTITY tool_assembly;
    tool_number : identifier;
    tool_type   : label;
    tool_size   : OPTIONAL STRING;
END_ENTITY;

ENTITY tool_breakage
  SUBTYPE OF(sensor);
END_ENTITY;

ENTITY tool_changer
  SUBTYPE OF(tool_handling_unit);
    spindle_name                    : label;
    cut_to_cut_min_tool_change_time : OPTIONAL time_measure;
    cut_to_cut_max_tool_change_time : OPTIONAL time_measure;
END_ENTITY;

ENTITY tool_handling_unit
  ABSTRACT SUPERTYPE OF (ONEOF(turret, tool_changer, tool_magazine))
  SUBTYPE OF(element_capability);
END_ENTITY;

ENTITY tool_magazine
  SUBTYPE OF(tool_handling_unit);
    number_of_tools        : count_measure;
    random_access          : BOOLEAN;
    diameter_full          : length_measure;
    diameter_empty         : length_measure;
    tool_length            : length_measure;
    tool_weight            : mass_measure;
    storage_configuration  : OPTIONAL Tool_storage_configuration;
    tool_magazine_contents : OPTIONAL SET [1:?] OF tool_assembly;
END_ENTITY;

ENTITY tool_setting
  SUBTYPE OF(sensor);
    probe_type       : probe_type;
    measuring_radius : BOOLEAN;
    measuring_length : BOOLEAN;
    measure_time     : time_measure;
END_ENTITY;

ENTITY tool_spindle
  ABSTRACT SUPERTYPE OF (ONEOF(tapered_spindle, straight_spindle,
                               threaded_spindle))
  SUBTYPE OF(spindle);
    spindle_tool_holder_style_designation : label;
    coolant_through_spindle               : BOOLEAN;
END_ENTITY;

ENTITY turret
  SUBTYPE OF(tool_handling_unit);
    spindle_name                    : OPTIONAL SET [1:?] OF label;
    number_of_fixed_tools           : count_measure;
```

```
    number_of_rotating_tools         : count_measure;
    cut_to_cut_min_turret_index_time : OPTIONAL time_measure;
    cut_to_cut_max_turret_index_time : OPTIONAL time_measure;
    turret_contents                  : OPTIONAL SET [1:?] OF tool_assembly;
  END_ENTITY;

  ENTITY workplan_physical_resource_association;
    workplan_of_resource : workplan;
    physical_resource    : machine_tool_requirements;
  END_ENTITY;

  ENTITY work_spindle
    SUBTYPE OF(spindle);
    spindle_nose_designation : label;
    spindle_bore_diameter    : length_measure;
    round_bar_stock_diameter : OPTIONAL length_measure;
    through_hole_diameter    : OPTIONAL length_measure;
    hex_bar_stock_capacity   : OPTIONAL REAL;
    chuck                    : OPTIONAL chuck;
  END_ENTITY;

  ENTITY work_table
    ABSTRACT SUPERTYPE OF (ONEOF(circular_work_table, rectangular_work_table)
                           ANDOR pallet)
    SUBTYPE OF(element_capability);
    rotatable        : BOOLEAN;
    workpiece_weight : OPTIONAL mass_measure;
    fixture_style    : OPTIONAL fixture_style;
    chuck            : OPTIONAL chuck;
    t_slot           : OPTIONAL t_slot;
  END_ENTITY;
END_SCHEMA; (* cutting_process_machine_tool_schema *)
```

Annex B
(informative)

EXPRESS-G diagram

This annex shows the EXPRESS-G figures of this part of ISO 14649. The symbols used and their respective meaning are listed in brief, in accordance with the notation of EXPRESS-G.



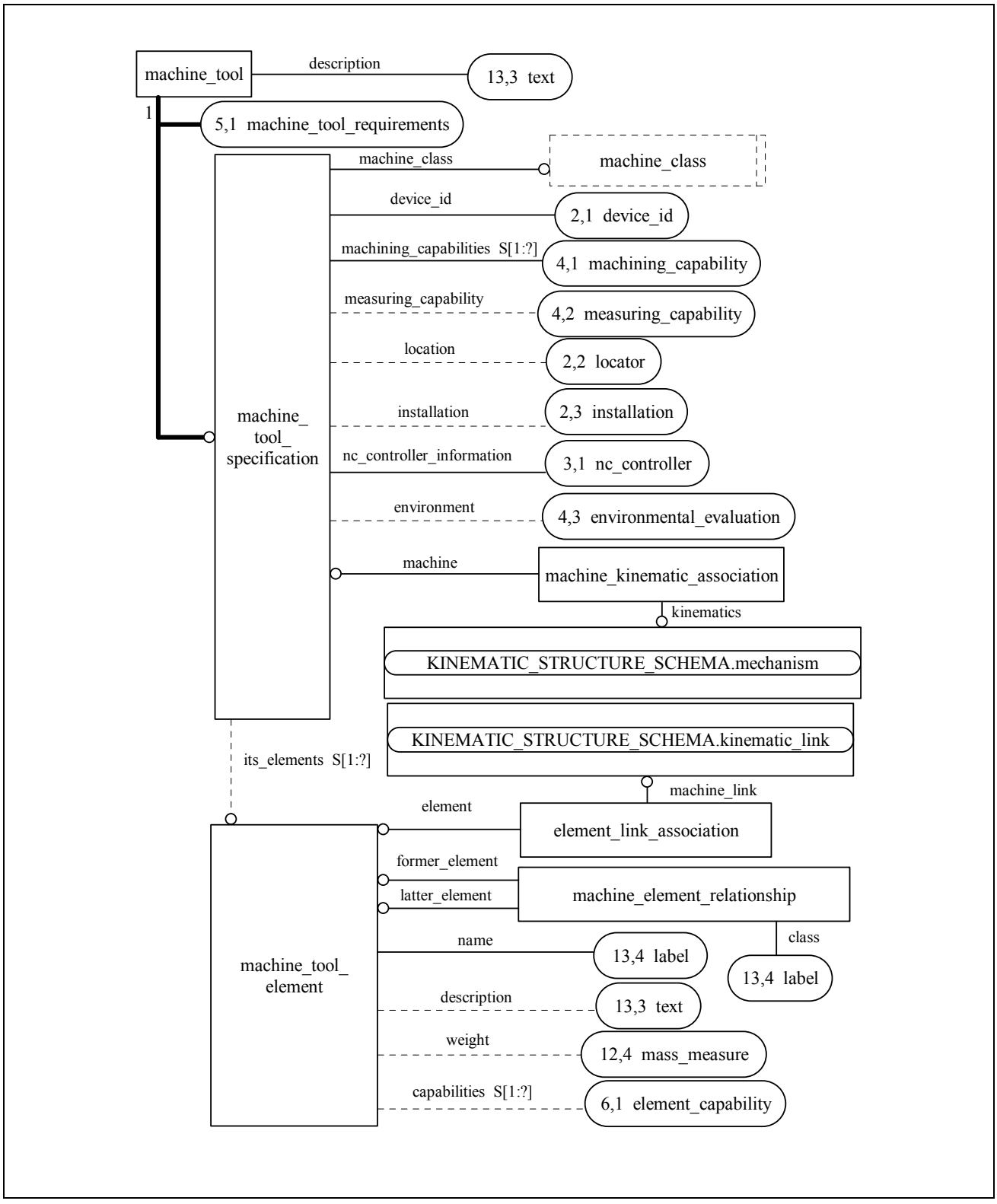


Figure B.1 — EXPRESS-G diagram (1 of 13)

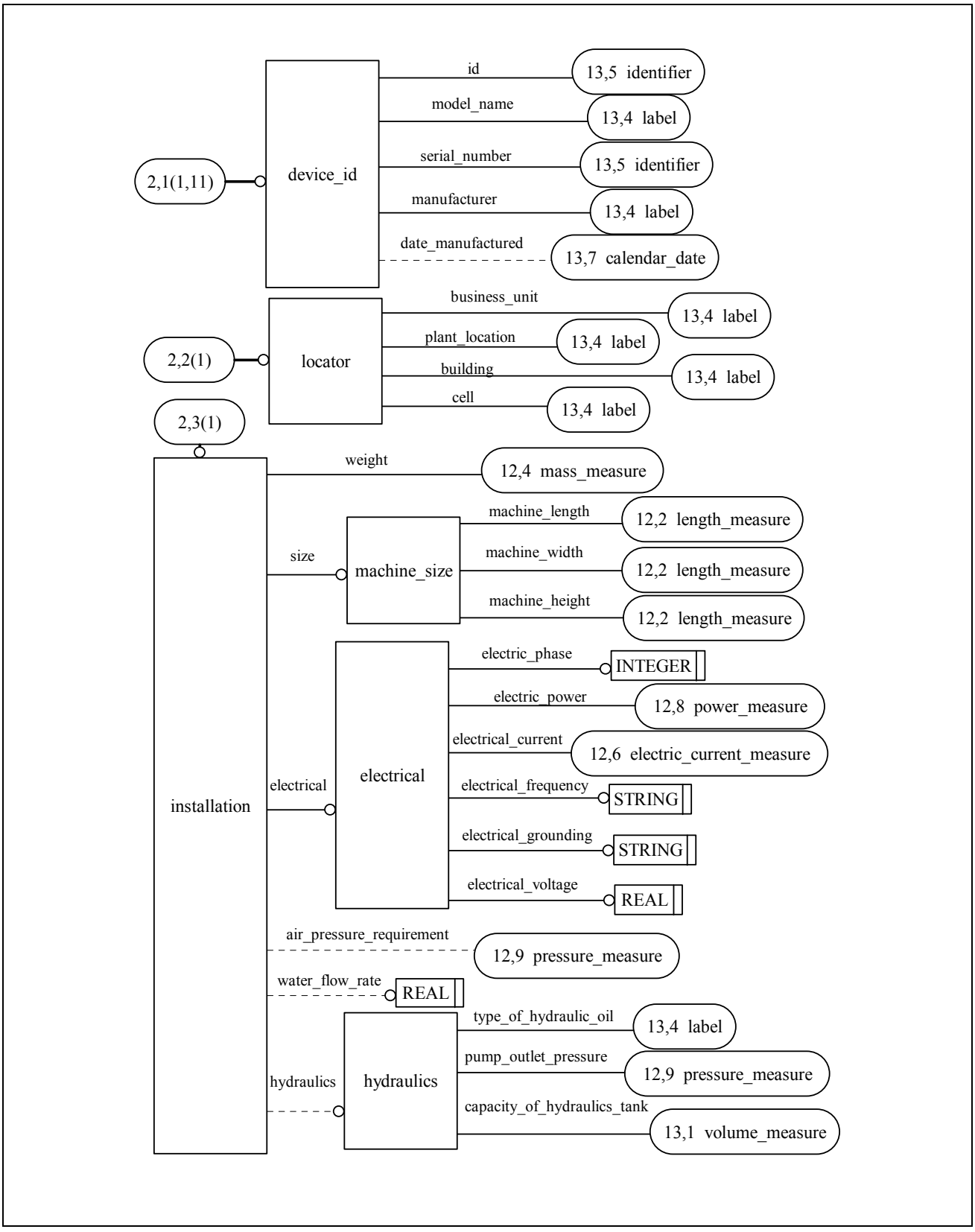


Figure B.2 — EXPRESS-G diagram (2 of 13)

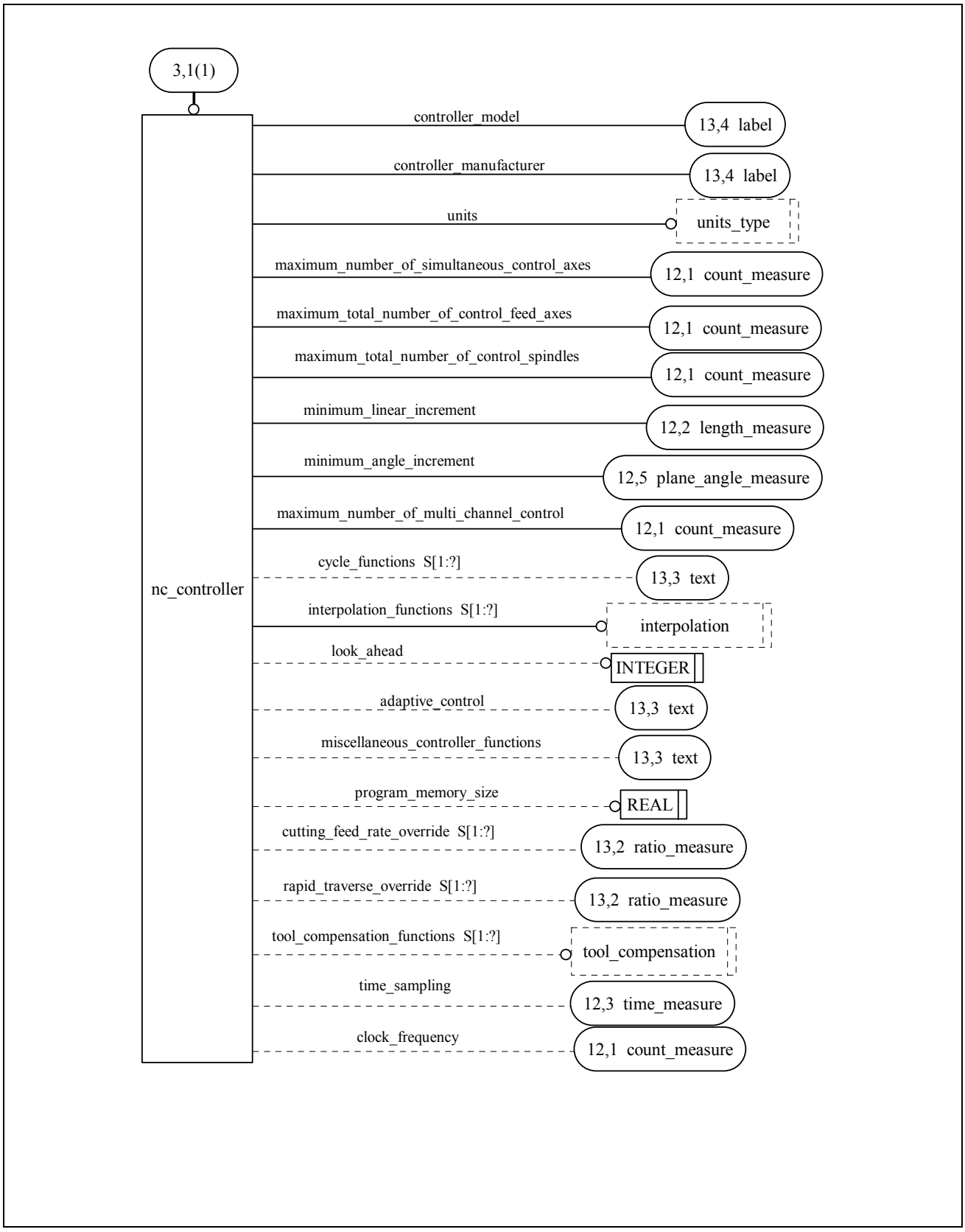


Figure B.3 — EXPRESS-G diagram (3 of 13)

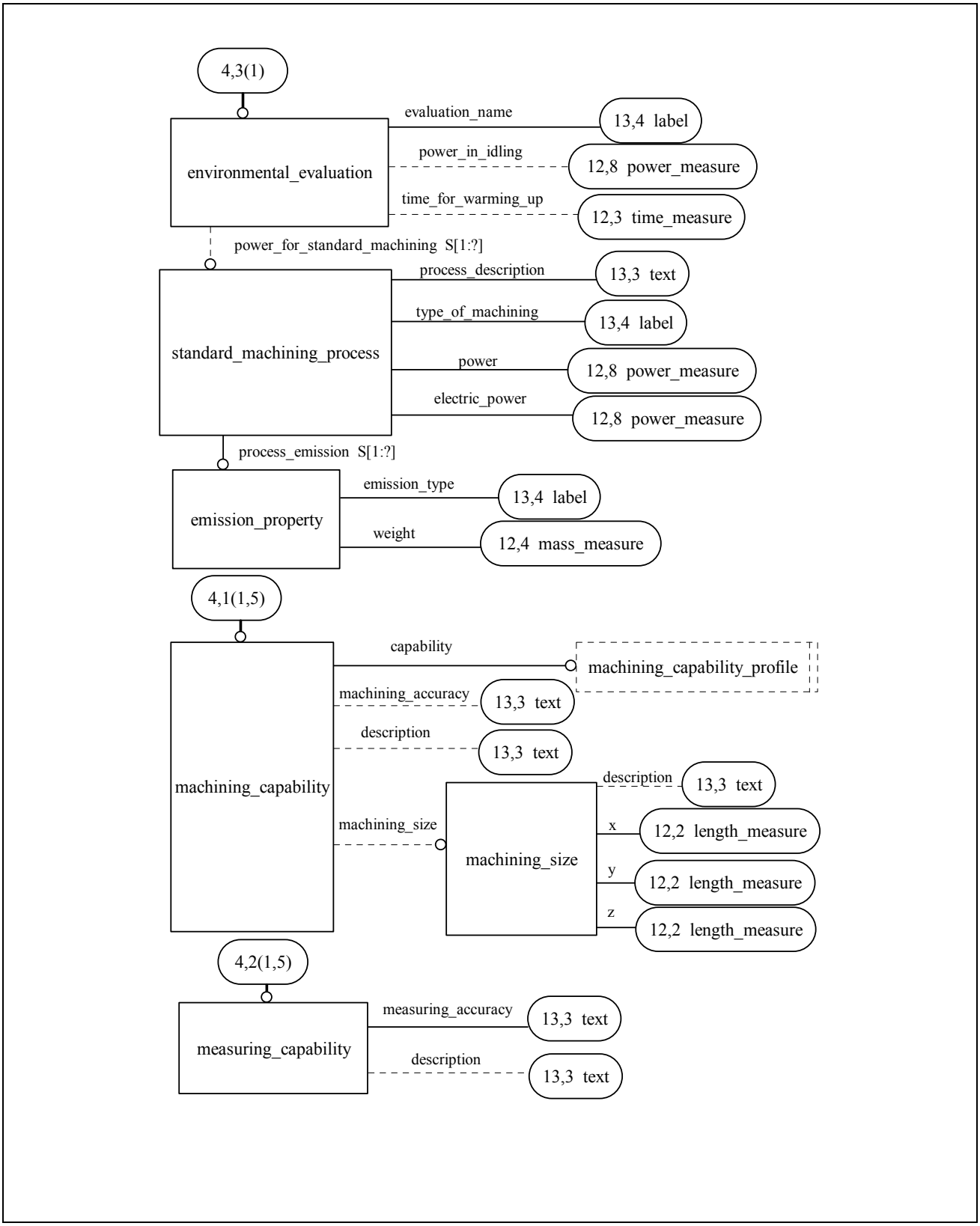


Figure B.4 — EXPRESS-G diagram (4 of 13)

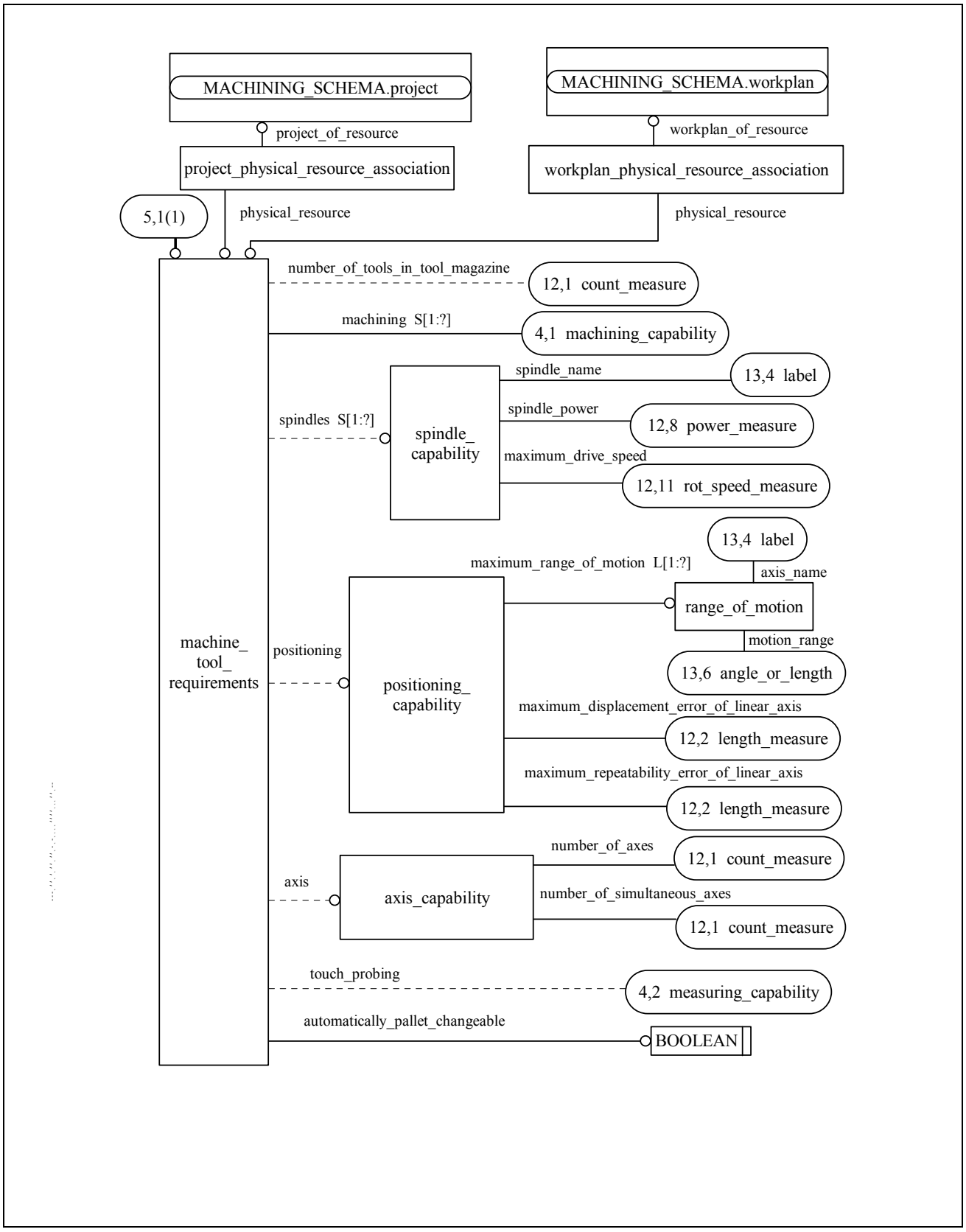


Figure B.5 — EXPRESS-G diagram (5 of 13)

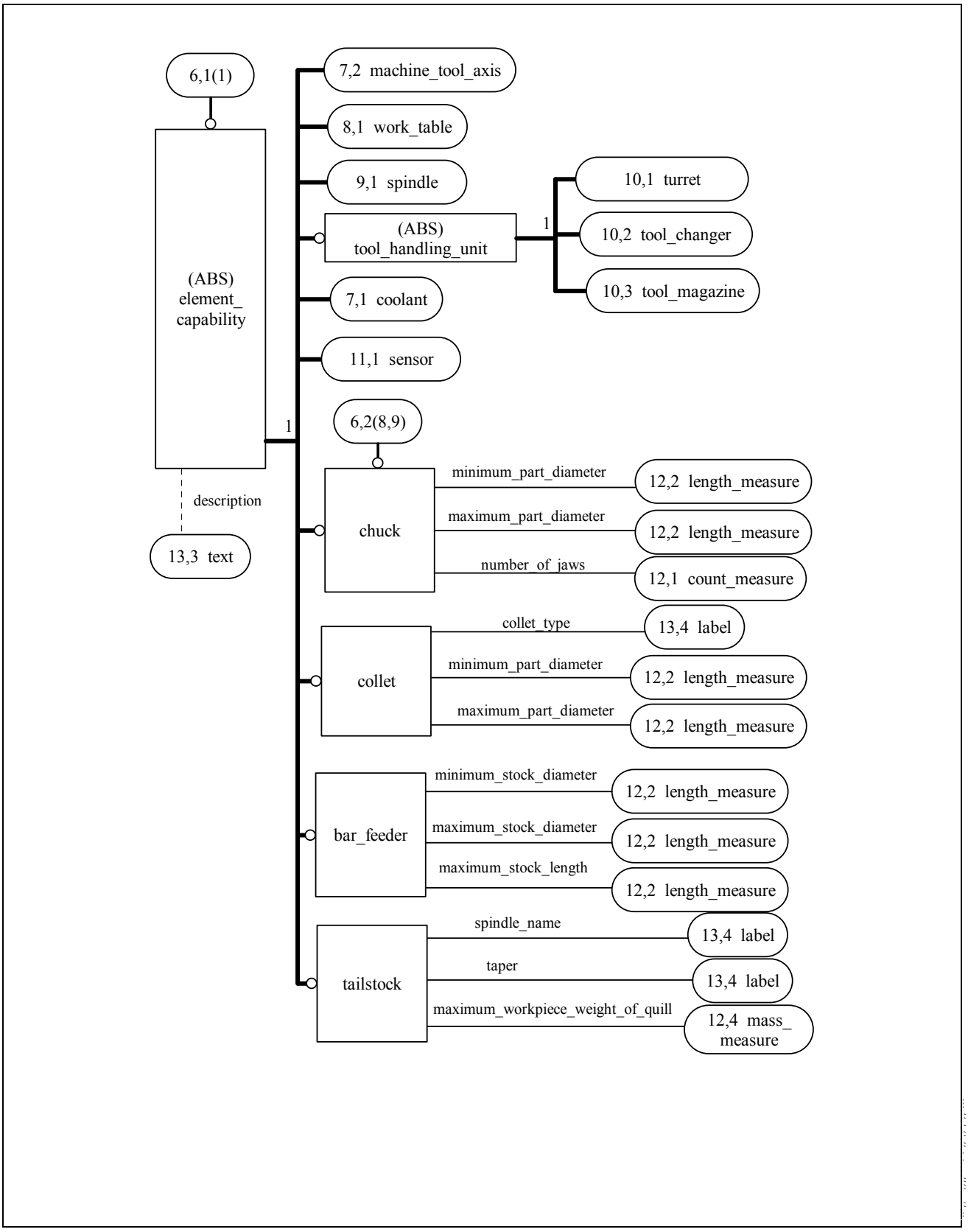


Figure B.6 — EXPRESS-G diagram (6 of 13)

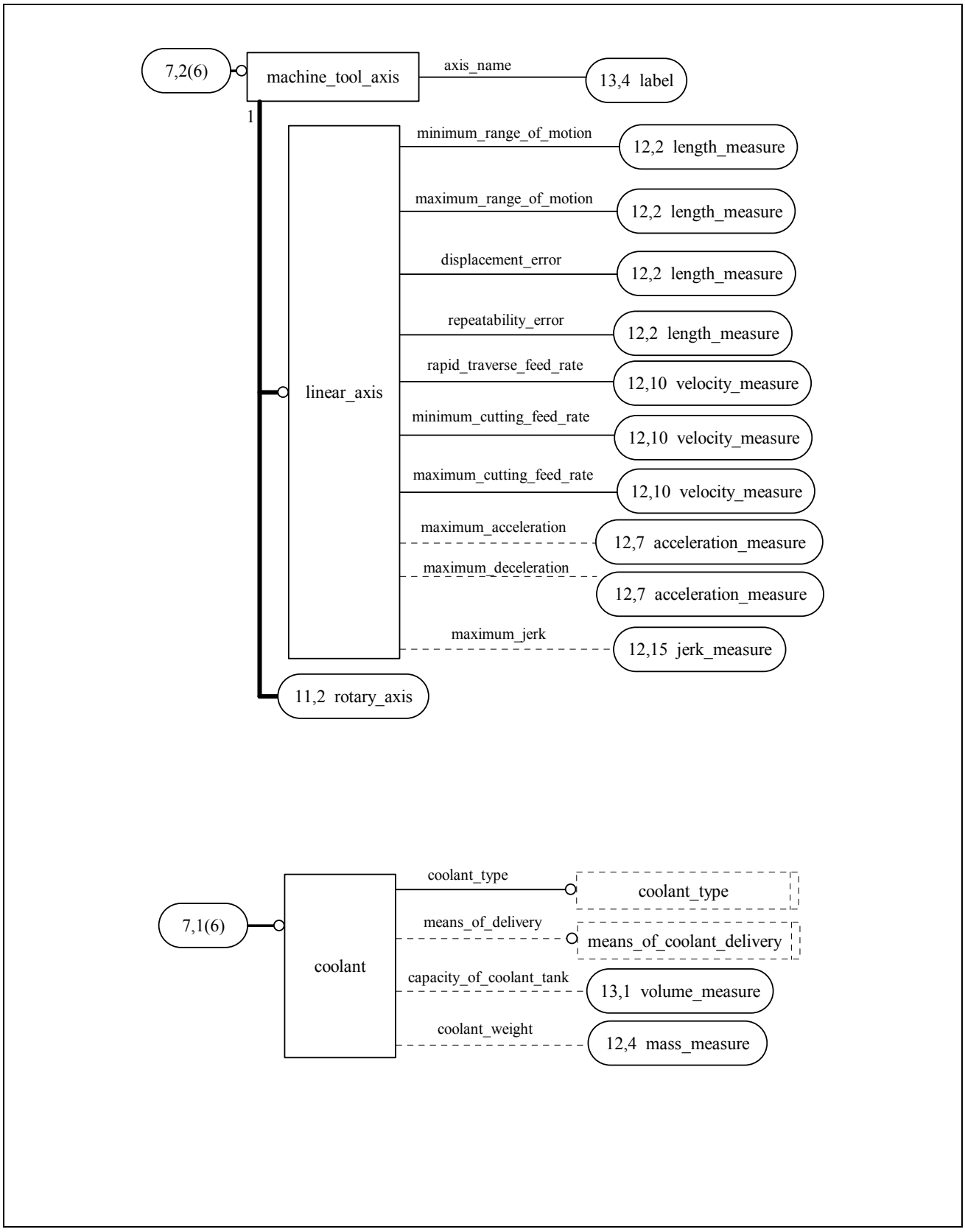


Figure B.7 — EXPRESS-G diagram (7 of 13)

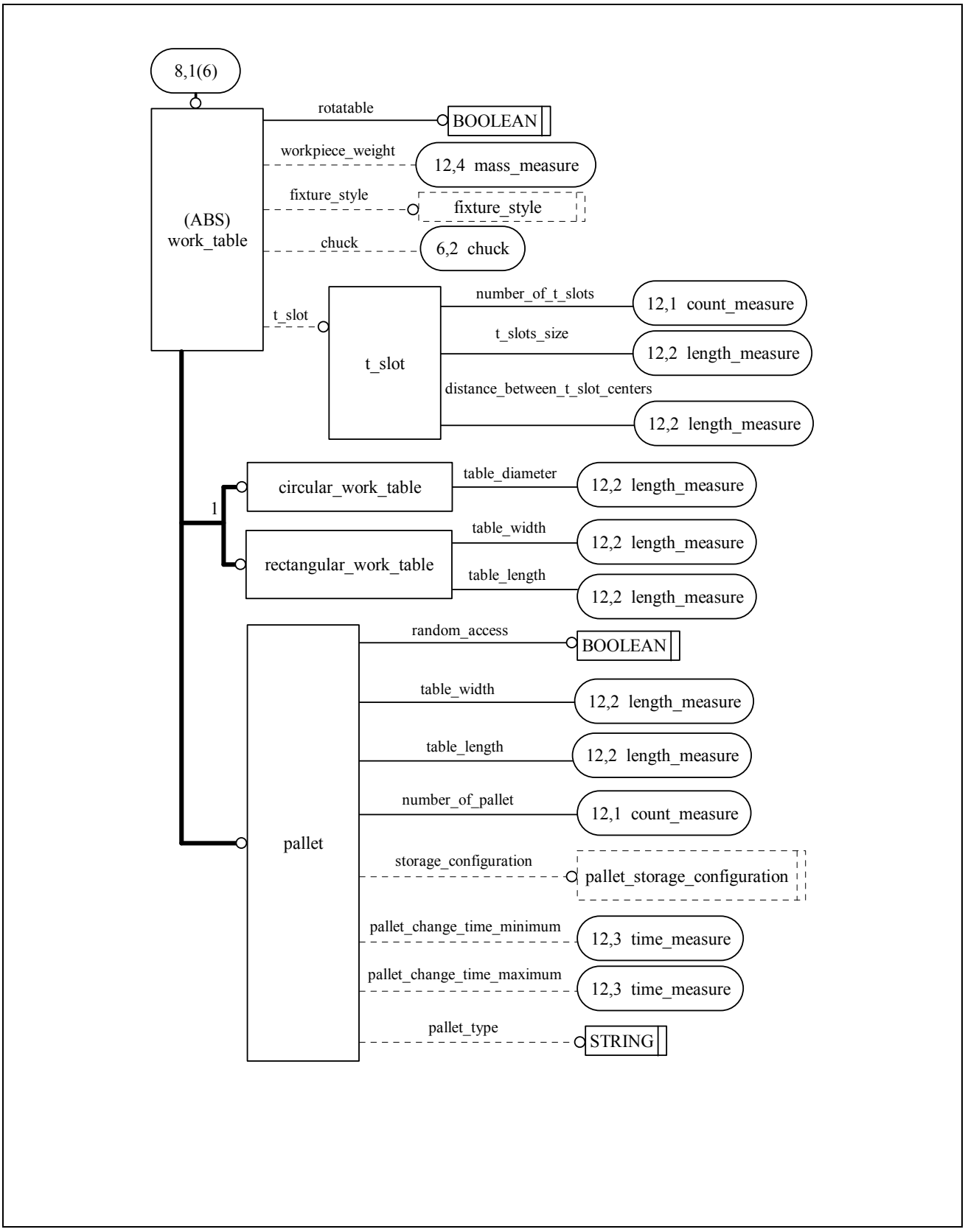


Figure B.8 — EXPRESS-G diagram (8 of 13)

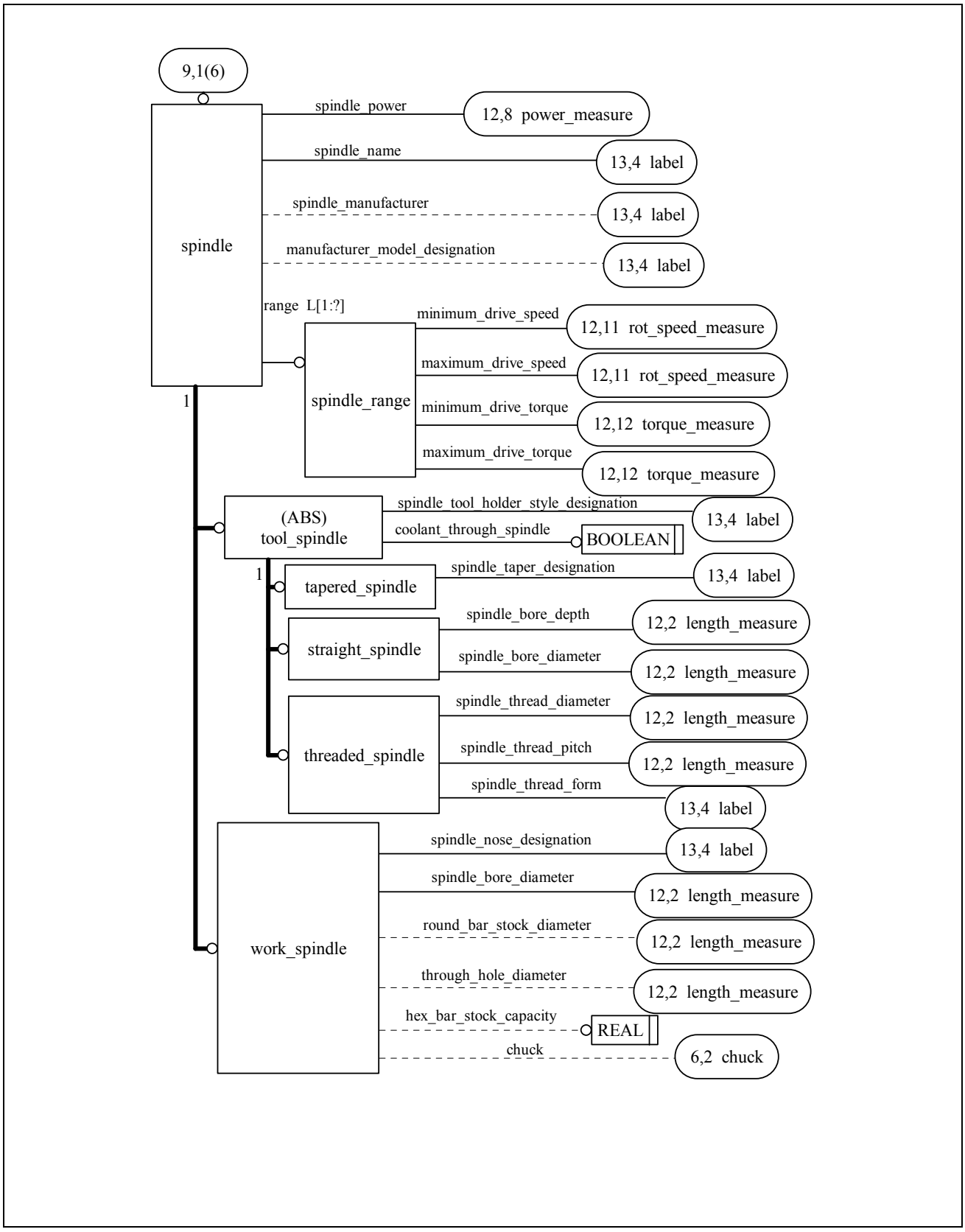


Figure B.9 — EXPRESS-G diagram (9 of 13)

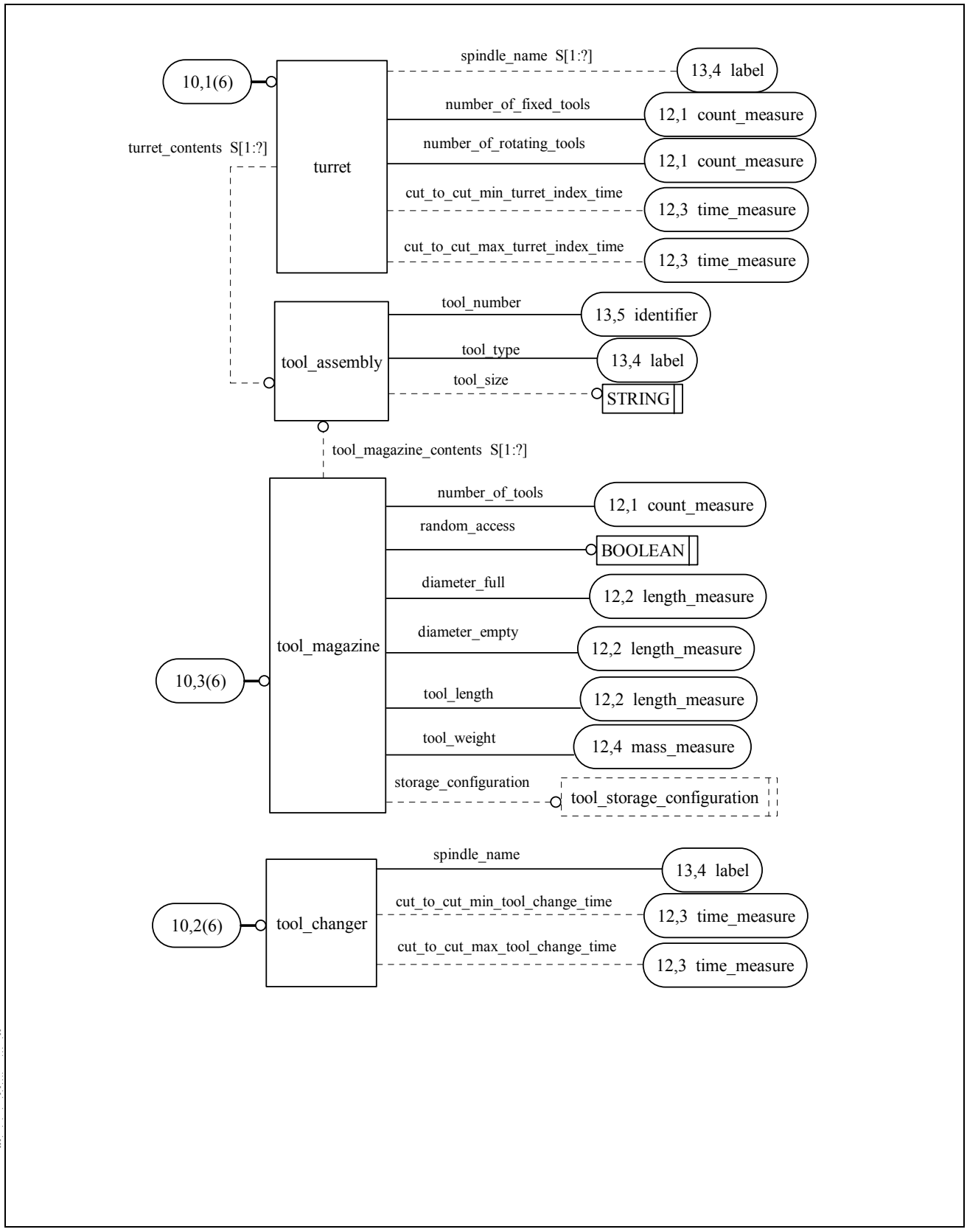


Figure B.10 — EXPRESS-G diagram (10 of 13)

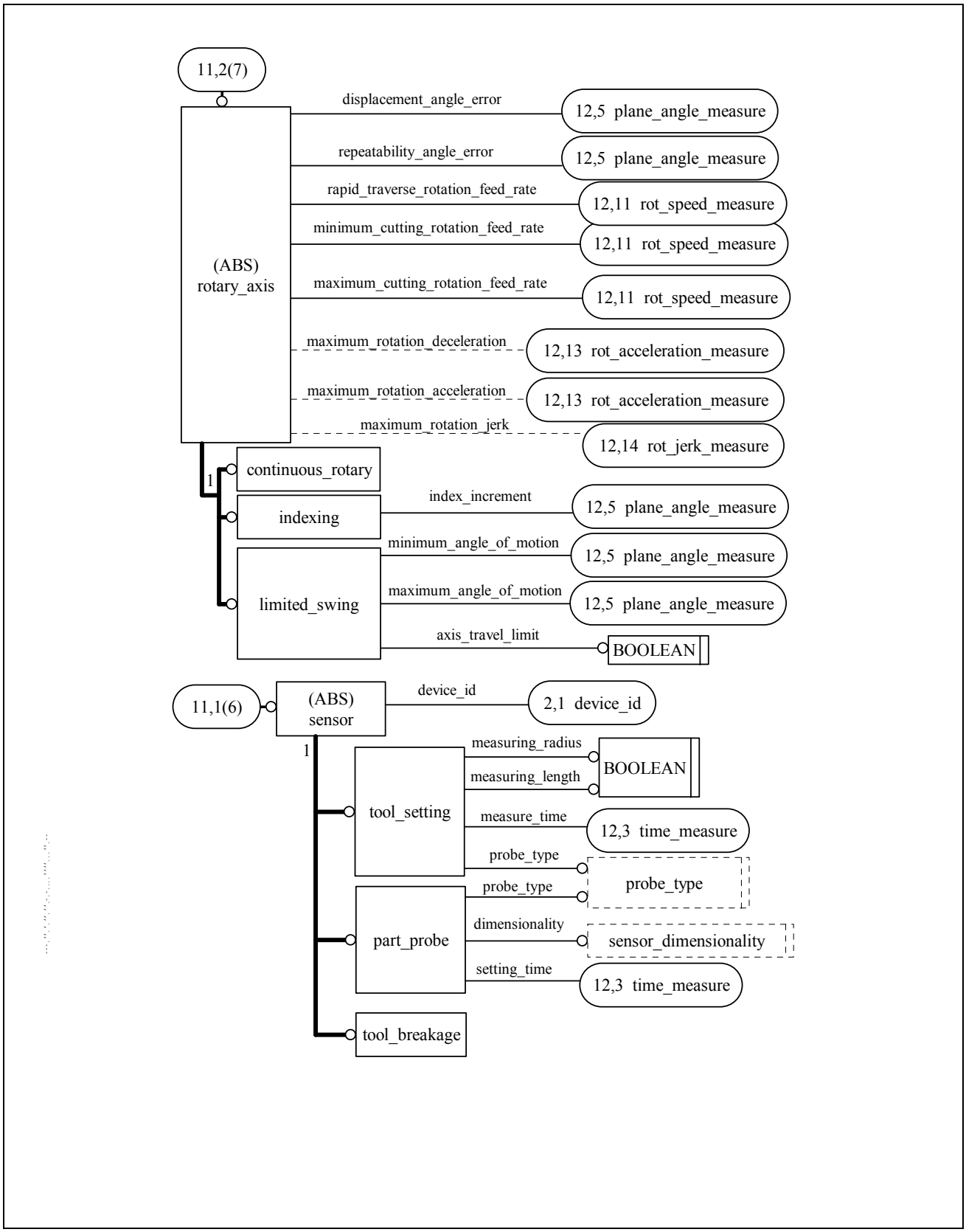


Figure B.11 — EXPRESS-G diagram (11 of 13)

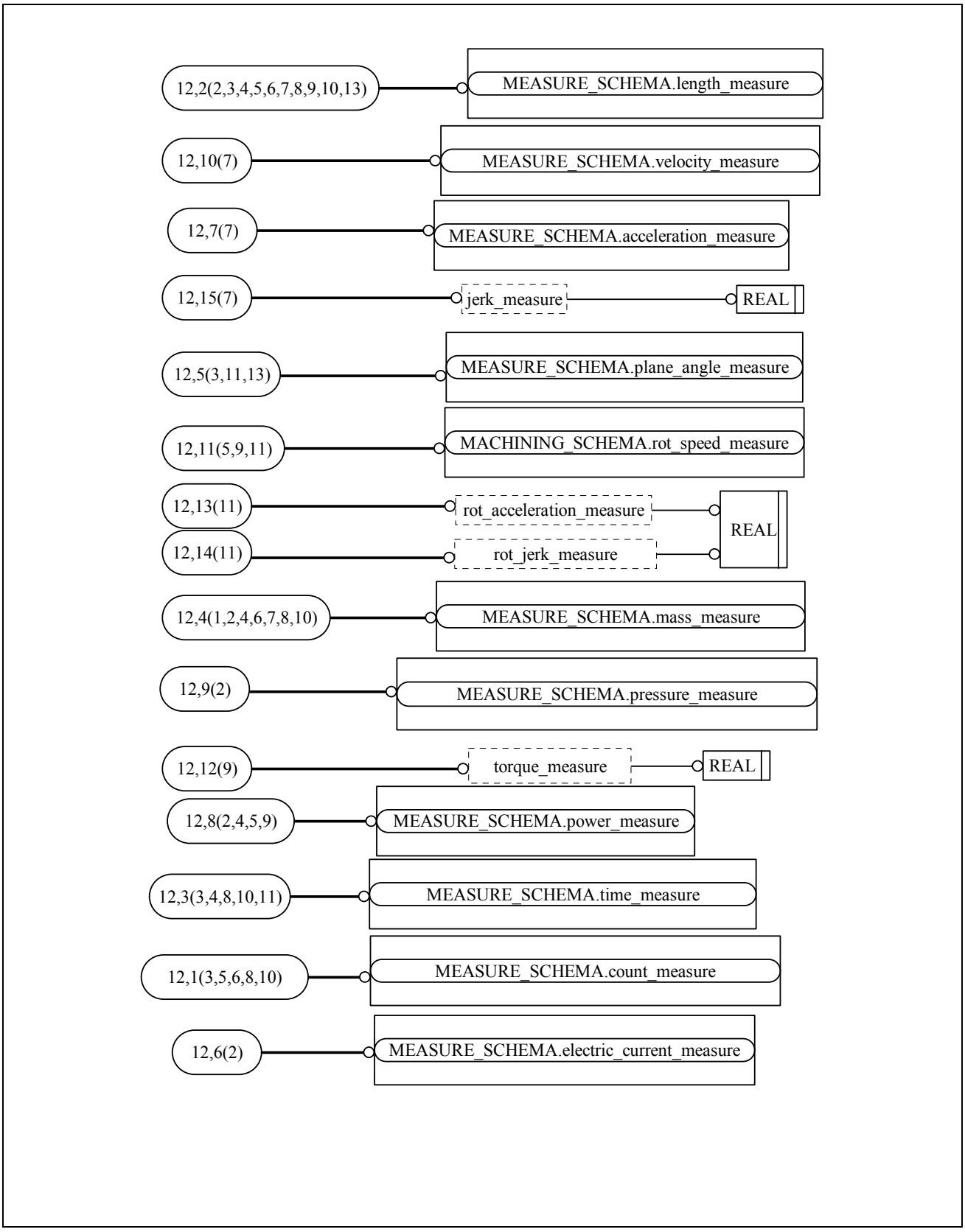


Figure B.12 — EXPRESS-G diagram (12 of 13)

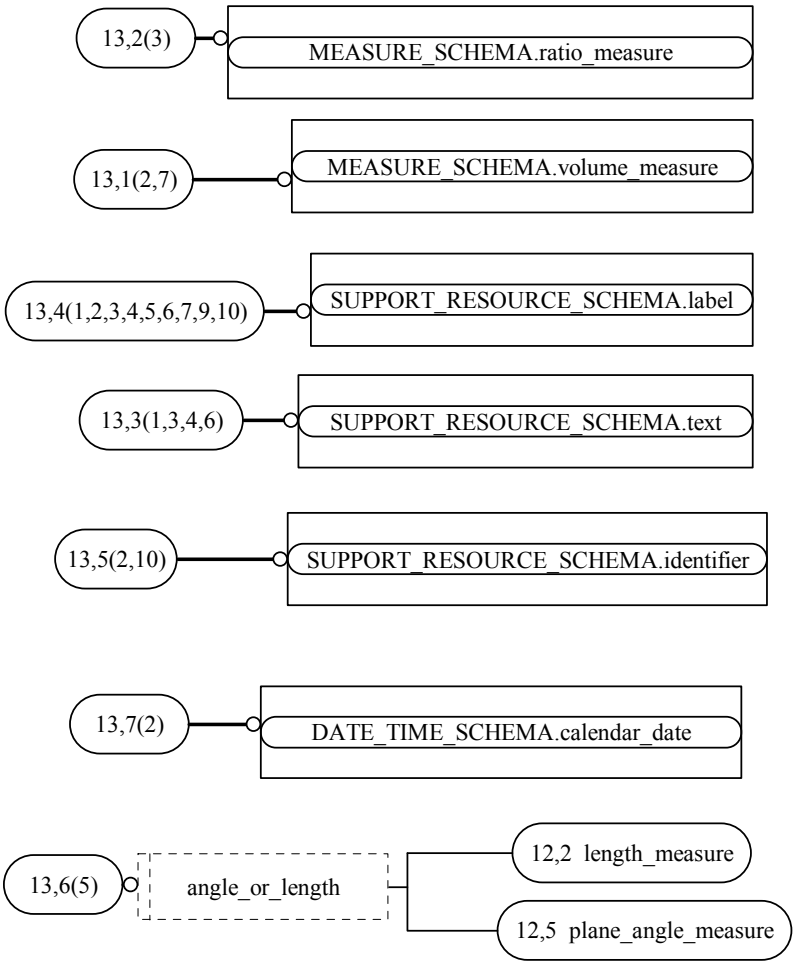


Figure B.13 — EXPRESS-G diagram (13 of 13)

Annex C
(informative)

Multi-tasking machine example

C.1 General

This annex shows the examples of machine tool specification data and machine tool requirement data for a multi-tasking machine tool.

C.2 Machine tool specification data for multi-tasking machine tool

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION((''),'2;1');
FILE_NAME('turn_spec',  '2011-04-30T20:17:50',  ('Tanaka'),  ('JMTBA'),
'The EXPRESS Data Manager Version 5.00.0305.03 : 9 Feb 2011', '  ', '  ');
FILE_SCHEMA(('CUTTING_PROCESS_MACHINE_TOOL_SCHEMA'));
ENDSEC;

DATA;
#1= MACHINE_TOOL_SPECIFICATION('Multi tasking machine specification data for sample',
      .MULTI_TASKING_MACHINE.,#2,(#5,#6,#7),$,#8,#9,#13,$,(#19,#23,#26,#29,#32
      ,#35,#38,#41,#47,#53,#58,#61,#65,#68,#71,#74));
#2= DEVICE_ID('X06-6438','MX1600','37-19621201','KOMMA',#3);
#3= CALENDAR_DATE(2011,30,4);
#5= MACHINING_CAPABILITY(.TURNING_CAPABILITY.,$,$,$);
#6= MACHINING_CAPABILITY(.MILLING_CAPABILITY.,$,$,$);
#7= MACHINING_CAPABILITY(.DRILLING_CAPABILITY.,$,$,$);
#8= LOCATOR('A-001','B02','C33','D05');
#9= INSTALLATION(11000.,#10,#11,3500000.,500.,#12);
#10= MACHINE_SIZE(2470.,4850.,2805.);
#11= ELECTRICAL(3,22000.,60000.,'50/60Hz','TT',200.);
#12= HYDRAULICS('water solubility/no water solubility',3500000.,750.);
#13= NC_CONTROLLER('31i-A','Jmtba co.',.METRIC.,4.,20.,6.,0.001,0.0001,2.,
      ('Canned cycle for drilling and turning', 'Multiple repetitive canned cycle','Multiple repetitive canned cycle II'),
      (.CIRCULAR.,.LINEAR.,.OTHER.),1024,$,$,$,(0.,0.5,1.,1.5,2.),(0.2,0.5,1.),(.TOOL_LENGTH.,.TOOL_RADIUS.
),$,$);
#19= MACHINE_TOOL_ELEMENT('X1 Linear axis',$,$,(#21));
#21= LINEAR_AXIS($,'X1',0.,565.,0.003,0.001,600.,0.2,500.,$,$,$);
#23= MACHINE_TOOL_ELEMENT('X2 Linear axis',$,$,(#24));
#24= LINEAR_AXIS($,'X2',0.,187.,0.003,0.001,400.,0.2,300.,$,$,$);
#26= MACHINE_TOOL_ELEMENT('Y Linear axis',$,$,(#27));
#27= LINEAR_AXIS($,'Y',0.,170.,0.003,0.001,433.,0.2,400.,$,$,$);
#29= MACHINE_TOOL_ELEMENT('Z1 Linear axis',$,$,(#30));
#30= LINEAR_AXIS($,'Z1',0.,1050.,0.003,0.001,600.,0.2,500.,$,$,$);
#32= MACHINE_TOOL_ELEMENT('Z2 Linear axis',$,$,(#33));
#33= LINEAR_AXIS($,'Z2',0.,1050.,0.003,0.001,600.,0.2,500.,$,$,$);
#35= MACHINE_TOOL_ELEMENT('Z3 Linear axis',$,$,(#36));
#36= LINEAR_AXIS($,'Z3',0.,1050.,0.003,0.001,500.,0.2,400.,$,$,$);
#38= MACHINE_TOOL_ELEMENT('B Rotary axis',$,$,(#39));
#39= CONTINUOUS_ROTARY($,'B',0.1,0.05,1.,0.02,0.2,$,$,$);
#41= MACHINE_TOOL_ELEMENT('C1 Rotary axis',$,$,(#42,#44));
```

```
#42= CONTINUOUS_ROTARY($,'C1',0.1,0.05,1.,0.02,0.2,$,$,$);
#44= WORK_SPINDLE($,15000.,'First Main spindle','KOMMA','JM010',(#46),'A2-5',100.,$,$,$,$);
#46= SPINDLE_RANGE(0.2,36000.,3.,200.);
#47= MACHINE_TOOL_ELEMENT('C2 Rotary axis',$,$,(#48,#50));
#48= CONTINUOUS_ROTARY($,'C2',0.1,0.05,1.,0.02,0.2,$,$,$);
#50= WORK_SPINDLE($,15000.,'Second Main spindle','KOMMA','JM010',(#52),'A2-5',100.,$,$,$,$);
#52= SPINDLE_RANGE(0.2,36000.,3.,200.);
#53= MACHINE_TOOL_ELEMENT('spindle',$,$,(#54));
#54= TAPERED_SPINDLE($,15000.,'Main spindle','Jmtba Co.','JM010',(#56),'BT40',.T.,'7/24 taper');
#56= SPINDLE_RANGE(0.2,200.,3.,200.);
#58= MACHINE_TOOL_ELEMENT('tool_magazine',$,$,(#59));
#59= TOOL_MAGAZINE($,40.,.T.,90.,120.,300.,8.,.BI_DIRECTIONAL.,$);
#61= MACHINE_TOOL_ELEMENT('turret',$,$,(#62));
#62= TURRET($,('turret'),12.,0.,$,$,$);
#65= MACHINE_TOOL_ELEMENT('Tailstock',$,$,(#66));
#66= TAILSTOCK($,'First Main spindle','MT#4',100.);
#68= MACHINE_TOOL_ELEMENT('coolant',$,$,(#69));
#69= COOLANT($,.FLOOD.,.THRU_SPINDLE.,0.75,$);
#71= MACHINE_TOOL_ELEMENT('coolant',$,$,(#72));
#72= COOLANT($,.FLOOD.,.THRU_SPINDLE.,0.75,$);
#74= MACHINE_TOOL_ELEMENT('tool_breakage',$,$,(#75));
#75= TOOL_BREAKAGE($,#76);
#76= DEVICE_ID('H06-6447','YST-100','71-19941126','Jmt electron Co.',#77);
#77= CALENDAR_DATE(2011,30,4);
ENDSEC;
END-ISO-10303-21;
```

C.3 Machine tool requirement data for multi-tasking machine tool

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION((''),'2;1');
FILE_NAME('turn_req',  '2011-04-30T20:17:50',  ('Tanaka'),  ('JMTBA'),
'The EXPRESS Data Manager Version 5.00.0305.03 : 9 Feb 2011', '  ', '  ');
FILE_SCHEMA(('CUTTING_PROCESS_MACHINE_TOOL_SCHEMA'));
ENDSEC;

DATA;
#1= MACHINE_TOOL_REQUIREMENTS('Multi tasking machine requirement data for sample',40.,(#3,#4,#5),
      (#7,#8),#9,#14,$,.F.);
#3= MACHINING_CAPABILITY(.TURNING_CAPABILITY.,$,$,$);
#4= MACHINING_CAPABILITY(.MILLING_CAPABILITY.,$,$,$);
#5= MACHINING_CAPABILITY(.DRILLING_CAPABILITY.,$,$,$);
#7= SPINDLE_CAPABILITY('First main spindle',36000.,100.);
#8= SPINDLE_CAPABILITY('Second main spindle',36000.,100.);
#9= POSITIONING_CAPABILITY((#11,#12,#13),0.003,0.001);
#11= RANGE_OF_MOTION('X',LENGTH_MEASURE(565));
#12= RANGE_OF_MOTION('Y',LENGTH_MEASURE(170));
#13= RANGE_OF_MOTION('Z',LENGTH_MEASURE(1050));
#14= AXIS_CAPABILITY(9.,4.);
ENDSEC;
END-ISO-10303-21;
```

Annex D
(informative)

Machining centre example

D.1 General

This annex shows the examples of machine tool specification data and machine tool requirement data for a machining centre.

D.2 Machine tool specification data for machining centre

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION((''),'2;1');
FILE_NAME('mill_spec',  '2011-04-30T20:17:50',  ('Tanaka'),  ('JMTBA'),
'The EXPRESS Data Manager Version 5.00.0305.03 : 9 Feb 2011', '  ', '  ');
FILE_SCHEMA(('CUTTING_PROCESS_MACHINE_TOOL_SCHEMA'));
ENDSEC;

DATA;
#1= MACHINE_TOOL_SPECIFICATION('Machining Centre specification data for
sample',.MACHINING_CENTRE.,#2,
      (#5,#6,#7),$,#8,#9,#13,$,(#17,#21,#24,#27,#30,#33,#37,#42,#45,#48));
#2= DEVICE_ID('X06-6436','STY-5000','37-19621201','Jmtba Co.',#3);
#3= CALENDAR_DATE(2010,30,4);
#5= MACHINING_CAPABILITY(.MILLING_CAPABILITY.,$,$,$);
#6= MACHINING_CAPABILITY(.DRILLING_CAPABILITY.,$,$,$);
#7= MACHINING_CAPABILITY(.BORING_CAPABILITY.,$,$,$);
#8= LOCATOR('A-001','B02','C33','D05');
#9= INSTALLATION(12000.,#10,#11,3500000.,500.,#12);
#10= MACHINE_SIZE(4500.,2800.,3100.);
#11= ELECTRICAL(3,22000.,60000.,'50/60Hz','TT',200.);
#12= HYDRAULICS('water solubility/no water solubility',3500000.,750.);
#13= NC_CONTROLLER('XSM-401','Jmtba Co.',.INCH_AND_METRIC.,4.,4.,1.,  0.001,0.001,1.,
       ('Canned cycle cancel','Drilling cycle'),(.CIRCULAR.,.LINEAR.),$,$,$,$,$,$,
       (.TOOL_LENGTH.,.TOOL_RADIUS.),$,$);
#17= MACHINE_TOOL_ELEMENT('X Linear axis',$,$,(#19));
#19= LINEAR_AXIS($,'X',0.,725.,0.003,0.001,800.,0.2,500.,$,$,$);
#21= MACHINE_TOOL_ELEMENT('Y Linear axis',$,$,(#22));
#22= LINEAR_AXIS($,'Y',0.,500.,0.003,0.001,800.,0.2,500.,$,$,$);
#24= MACHINE_TOOL_ELEMENT('Z Linear axis',$,$,(#25));
#25= LINEAR_AXIS($,'Z',0.,500.,0.003,0.001,800.,0.2,500.,$,$,$);
#27= MACHINE_TOOL_ELEMENT('B Rotary axis',$,$,(#28));
#28= CONTINUOUS_ROTARY($,'B',0.1,0.05,1.,0.02,0.2,$,$,$);
#30= MACHINE_TOOL_ELEMENT('coolant',$,$,(#31));
#31= COOLANT($,.FLOOD.,.THRU_SPINDLE.,0.75,$);
#33= MACHINE_TOOL_ELEMENT('pallet',$,$,(#34));
#34= (CIRCULAR_WORK_TABLE(485.)ELEMENT_CAPABILITY($)PALLET(.T.,400.,400.,2.,$,45.,45.,$)
       WORK_TABLE(.F.,300.,.T_SLOT_FIXTURE.,$,#35));
#35= T_SLOT(5.,15.,80.);
#37= MACHINE_TOOL_ELEMENT('spindle',$,$,(#38));
#38= TAPERED_SPINDLE($,15000.,'Main spindle','Jmtba Co.','JM010',(#40),'BT40',.T.,'7/24 taper');
```

```
#40= SPINDLE_RANGE(0.2,200.,3.,200.);
#42= MACHINE_TOOL_ELEMENT('tool_magazine',$,$,(#43));
#43= TOOL_MAGAZINE($,36.,.T.,70.,140.,300.,8.,.BI_DIRECTIONAL.,$);
#45= MACHINE_TOOL_ELEMENT('tool_changer',$,$,(#46));
#46= TOOL_CHANGER($,'Main spindle',7.,20.);
#48= MACHINE_TOOL_ELEMENT('tool_breakage',$,$,(#49));
#49= TOOL_BREAKAGE($,#50);
#50= DEVICE_ID('H06-6447','YST-100','71-19941126','Jmt electron Co.',#51);
#51= CALENDAR_DATE(2010,30,4);
ENDSEC;
END-ISO-10303-21;
```

D.3 Machine tool requirement data for machining centre

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION((''),'2;1');
FILE_NAME('mill_req',  '2011-04-30T20:17:50',  ('Tanaka'),  ('JMTBA'),
'The EXPRESS Data Manager Version 5.00.0305.03 : 9 Feb 2011', '  ', '  ');
FILE_SCHEMA(('CUTTING_PROCESS_MACHINE_TOOL_SCHEMA'));
ENDSEC;

DATA;
#1= MACHINE_TOOL_REQUIREMENTS('Machining Centre requirement data for sample',36.,(#3,#4,#5),(#7),#8,
      #13,$,.T.);
#3= MACHINING_CAPABILITY(.MILLING_CAPABILITY.,$,$,$);
#4= MACHINING_CAPABILITY(.DRILLING_CAPABILITY.,$,$,$);
#5= MACHINING_CAPABILITY(.BORING_CAPABILITY.,$,$,$);
#7= SPINDLE_CAPABILITY('main spindle',15000.,200.);
#8= POSITIONING_CAPABILITY((#10,#11,#12),0.003,0.001);
#10= RANGE_OF_MOTION('X',LENGTH_MEASURE(725));
#11= RANGE_OF_MOTION('Y',LENGTH_MEASURE(500));
#12= RANGE_OF_MOTION('Z',LENGTH_MEASURE(500));
#13= AXIS_CAPABILITY(4.,4.);
ENDSEC;
END-ISO-10303-21;
```

Annex E
(informative)

Parallel mechanism machining centre example

E.1 General

This annex shows the examples of machine tool specification data and machine tool requirement data for a parallel mechanism machining centre.

E.2 Machine tool specification data for Parallel mechanism machining centre

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION((''),'2;1');
FILE_NAME('mill_spec',  '2011-04-30T20:17:50',  ('Tanaka'),  ('JMTBA'),
'The EXPRESS Data Manager Version 5.00.0305.03 : 9 Feb 2011', '  ', '  ');
FILE_SCHEMA(('CUTTING_PROCESS_MACHINE_TOOL_SCHEMA'));
ENDSEC;

DATA;
DATA;
#1= MACHINE_TOOL_SPECIFICATION('Parallel mechanism 5 axis Machining Centre specification data for sample'
    ,.MACHINING_CENTRE.,#2,(#5,#6,#7),$,#8,#9,#13,$,(#19,#22,#25,#28,#31,#34,#37,#40,#43,#47,#52,#55,#58));
#2= DEVICE_ID('Verne','VERNE','PKM-004','FATRONIK',#3);
#3= CALENDAR_DATE(2004,15,5);
#5= MACHINING_CAPABILITY(.MILLING_CAPABILITY.,$,$,$);
#6= MACHINING_CAPABILITY(.DRILLING_CAPABILITY.,$,$,$);
#7= MACHINING_CAPABILITY(.BORING_CAPABILITY.,$,$,$);
#8= LOCATOR('ECN','Nantes','H','PUR');
#9= INSTALLATION(17000.,#10,#11,6000000.,$,#12);
#10= MACHINE_SIZE(3200.,6000.,4200.);
#11= ELECTRICAL(3,90000.,130.,'50Hz','TT',380.);
#12= HYDRAULICS('',4000000.,450.);
#13= NC_CONTROLLER('840D','Siemens',.INCH_AND_METRIC.,5.,5.,1.,0.001,0.001,2.,
      ('drilling','boring','tapping','hole grids','pocket milling', 'slot milling','contour
milling','inspection','fillet','chamfer','thread'),
      (.CIRCULAR.,.LINEAR.,.NURBS.,.HELICAL.),250,$,$,$,(0.,1.5),$,(.TOOL_LENGTH.,.TOOL_RADIUS.),0.00
3,
      4.0000000E8);
#19= MACHINE_TOOL_ELEMENT('V1Linear axis',$,$,(#21));
#21= LINEAR_AXIS($,'V1',0.,800.,0.002,0.001,83.3,0.,0.83,15.,15.,120.);
#22= MACHINE_TOOL_ELEMENT('V2Linear axis',$,$,(#24));
#24= LINEAR_AXIS($,'V2',0.,800.,0.002,0.001,83.3,0.,0.83,15.,15.,120.);
#25= MACHINE_TOOL_ELEMENT('V3Linear axis',$,$,(#27));
#27= LINEAR_AXIS($,'V3',0.,800.,0.002,0.001,83.3,0.,0.83,15.,15.,120.);
#28= MACHINE_TOOL_ELEMENT('B Rotary axis',$,$,(#30));
#30= CONTINUOUS_ROTARY($,'B',0.083,0.083,0.37,0.,0.37,$,$,$);
#31= MACHINE_TOOL_ELEMENT('C Rotary axis',$,$,(#33));
#33= CONTINUOUS_ROTARY($,'C',0.067,0.067,0.56,0.,0.56,$,$,$);
#34= MACHINE_TOOL_ELEMENT('coolant',$,$,(#36));
#36= COOLANT($,.FLOOD.,.THRU_SPINDLE.,$,$);
#37= MACHINE_TOOL_ELEMENT('coolant',$,$,(#39));
```

```
#39= COOLANT($,.MIST.,.EXTERNAL.,$,$);
#40= MACHINE_TOOL_ELEMENT('coolant',$,$,(#42));
#42= COOLANT($,.MICRO.,.EXTERNAL.,$,$);
#43= MACHINE_TOOL_ELEMENT('circular_work_table',$,$,(#45));
#45= CIRCULAR_WORK_TABLE($,.T.,300.,.T_SLOT_FIXTURE.,$,#46,800.);
#46= T_SLOT(8.,17.,100.);
#47= MACHINE_TOOL_ELEMENT('spindle',$,$,(#49));
#49= TAPERED_SPINDLE($,41000.,'Main spindle','GMN','HCS 170 24000-41',(#51),'HSK A 63',.T.,'HSK');
#51= SPINDLE_RANGE(0.,400.,5.,56.);
#52= MACHINE_TOOL_ELEMENT('tool_magazine',$,$,(#54));
#54= TOOL_MAGAZINE($,20.,.F.,100.,130.,300.,10.,.BI_DIRECTIONAL.,$);
#55= MACHINE_TOOL_ELEMENT('tool_changer',$,$,(#57));
#57= TOOL_CHANGER($,'Main spindle',$,$);
#58= MACHINE_TOOL_ELEMENT('part_probe',$,$,(#60));
#60= PART_PROBE($,#61,.SWITCHING.,.THREE_D.,60.);
#61= DEVICE_ID('hkd0001','hkd','hsc0001','IRCCyN',$);
ENDSEC;
END-ISO-10303-21;
```

E.3 Machine tool requirement data for Parallel mechanism machining centre

```
ISO-10303-21;
HEADER;
FILE_DESCRIPTION((''),'2;1');
FILE_NAME('mill_spec',  '2011-04-30T20:17:50',  ('Tanaka'),  ('JMTBA'),
'The EXPRESS Data Manager Version 5.00.0305.03 : 9 Feb 2011', '  ', '  ');
FILE_SCHEMA(('CUTTING_PROCESS_MACHINE_TOOL_SCHEMA'));
ENDSEC;

DATA;
#1= MACHINE_TOOL_REQUIREMENTS('Parallel mechanism 5 axis Machining Centre requirement data for sample'
    ,20.,(#3,#4,#5),(#7),#8,#13,$,.F.);
#3= MACHINING_CAPABILITY(.MILLING_CAPABILITY.,$,$,$);
#4= MACHINING_CAPABILITY(.DRILLING_CAPABILITY.,$,$,$);
#5= MACHINING_CAPABILITY(.BORING_CAPABILITY.,$,$,$);
#7= SPINDLE_CAPABILITY('main spindle',40000.,400.);
#8= POSITIONING_CAPABILITY((#10,#11,#12),0.01,0.01);
#10= RANGE_OF_MOTION('V1',LENGTH_MEASURE(800.));
#11= RANGE_OF_MOTION('V2',LENGTH_MEASURE(800.));
#12= RANGE_OF_MOTION('V3',LENGTH_MEASURE(700.));
#13= AXIS_CAPABILITY(5.,5.);
ENDSEC;
END-ISO-10303-21;
```

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[12] ISO 80000 (all parts), *Quantities and units*

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