DRAFT

Information Technology for Machine Tools

Part 2

Data Specification for Properties of Machine Tools for Milling and Turning

ASME B5.59-2
Version 9c
June, 2005

ASME B5/TC56 Committee

Tentative
Subject to Revision

Modifications to the previous draft are highlighted yellow. Issues that require continued attention of the committee before finalization are highlighted blue. The ~~crossed out~~ sections were removed by the committee but are retained in the draft for future reference.

Foreword

The ASME B5.59 series of Standards defines electronic data formats and information models for machine tool data. The Standards facilitate the collection, archiving, use, and exchange of machine tool data within and in-between organizations and applications throughout the life-cycle of a machine. Applications that may require machine tool data include: process planning, resource allocation, E-commerce, NC programming, simulation, accounting, maintenance, performance verification/tracking, and quality control.

The B5.59-2 standard defines an electronic data format and associated information model for properties of machine tools for milling and turning. The focus is on properties that describe the performance and capabilities of a machine at an arbitrary instance in the machine's life-cycle, e.g., during specification, after acceptance testing, or at any time during operation.

The B5.59-2 Standard is part of a series of standards. The first Standard of this series, B5.59-1 "Data Specification for Machine Tool Performance Tests" addresses the results and properties of machine tool performance tests: the test procedure, the test conditions, the test equipment used, the measurement setup, the measurement data, and the estimated performance parameters.

The B5.59 series of Standards does not address the safety of machine tools, machine tool operation, and performance testing.

Suggestions for the improvement of this standard are welcome. They should be addressed to The American Society of Mechanical Engineers, Attn: Secretary, B5 Main Committee, Three Park Avenue, New York, NY 10016-5990.

This standard was approved as an American National Standard on ?, ?

Content

1 Introductory Notes

1.1 Scope

This standard defines an electronic data format and associated information model for properties of machine tools for milling and turning. The focus is on properties that describe the performance and capabilities of a machine at an arbitrary instance in the machine's life-cycle, e.g., during specification, after acceptance testing, or at any time during operation. The Standard facilitates the exchange, archiving, and use of unambiguous machine tool data. The specified information model can serve as a basis for generating database schemas and database calls.

The level of detail in the data format and information model is high. This standard does not define which machine properties are important for a specific application, nor their respective recommended values. Therefore, the standard does not prescribe the presence of the listed elements in a data exchange. The actual subset of the elements exchanged will depend on the application. The listed properties are expected to be adequate for many applications, but are not intended to supplant more complete descriptions that may be required for special applications. The standard allows for the addition of user-defined information elements.

The focus of this Standard is on properties that address the performance and capabilities of the machine tool. The definition of a property, and any additional information on usage and assessment, is deferred to the appropriate standard. Many listed properties are described in the following standards on machine tool performance:

- ASME/ANSI B5.54 "Methods for Performance Evaluation of Computer Numerically Controlled Machining Centers" (2005),
- ASME/ANSI B5.57 "Methods for Performance Evaluation of Computer Numerically Controlled Lathes and Turning Centers" (1998),
- ISO 230 "Test Code for Machine Tools", Parts 1 (1996), 2 (1999), 3 (2001), 4 (2005), 6 (2002), 7 (200?), and 8 (200?).

The listed machine tool performance data includes 1) the performance parameters found in the performance specification forms of the ANSI B5.54 and B5.57 standards on machine tool performance and 2) a summary of the geometric errors of the machine, e.g., for building compensation tables or to simulate machine errors.

1.2 Modeling language and implementation methods

An information model provides a sharable, stable, and organized structure of information requirements. It is developed to preserve independence from both usage and implementation. The selection of an implementation method is heavily dependent on the target environment where the application system resides. Currently, the implementation methods used by the manufacturing community include:

1) data transfer via a working form, which is a structured, in-memory representation of data,
2) data transfer via an exchange file, which is a file with a predefined structure or format, and
3) data transfer using a database management system.

This standard focuses on the implementation of an information model for data transfer via exchange files, in this case using the XML language (eXtensible Markup Language). Extracting

the underlying information model from this specification is straightforward and can be used for other purposes, e.g., to define a database. In this Standard the information model is not defined using a formal modeling language. However, the Standard has been designed to enable a straightforward definition of the model using an XML-schema or EXPRESS. The EXPRESS modeling language was developed as part of the International Organization for Standardization (ISO) 10303 Standard for the Exchange of Product Model Data (STEP), an effort to develop a mechanism for digitally representing the physical and functional characteristics of a product throughout the product's life cycle.

1.3 XML

XML is an eXtensible Markup Language that by virtue of user defined tags allows precise encoding of structured information. Structured information contains both data and an indication of the meaning of the data (metadata - data about the data). The markup in XML defines the meaning of the data. The role of the markup is therefore different from that in HTML (Hypertext Markup Language). In HTML the markup defines a view of the data, i.e., it instructs the browser how to display the data. XML relies on application programs or style sheets to manipulate, edit, and present the data. This separation of the data from the presentation and the process allows for applications that can be built more quickly, are easier to maintain, and can provide multiple views of data from any source.

XML is derived from the Standard Generalized Markup Language (SGML). Both languages use textual markup (tags) to describe data so that other applications or tools can correctly read the information and process it. XML is valuable to Internet and intranet environments because it provides interoperability using a flexible, open, standards-based format for structured information.

XML is a text-based format. The structure of an XML document is simple:

```
<?xml version="1.0"?>

<!-- This is a comment -->

<MACHINE>
   <MANUFACTURER>Xyz</MANUFACTURER>
   <MODEL>AbC</MODEL>
   <SERIAL_NUMBER>123</SERIAL_NUMBER>
   <OTHER DESCRIPTION=”Location information” />
</MACHINE>
```

An XML source is made up of XML elements, each of which consists of a start tag <ELEMENT_NAME>, a matching end-tag </ELEMENT_NAME>, and the information between the two tags (referred to as the content). An element can contain other elements and attributes. Attributes are name-value pairs that occur inside start-tags after the element name. The respective value is enclosed by quotes, e.g., DESCRIPTION = “Location information”. The example defines an element named “MACHINE” that contains 4 elements: MANUFACTURER, MODEL, SERIAL_NUMBER, and OTHER. The ‘/’ character in the OTHER element indicates that this element is empty. Comments begin with <!-- and end with -->. Note that in XML the names of elements and attributes are case sensitive.

XML documents that conform to this specification adhere to the following conventions:

- All entities of the underlying information model are encoded as elements.

- Element names equal the names of the respective entities, including capitalization. This specification uses uppercase for all the characters of an element name. The "_" character is used to separate multiple words in a name.
- Elements either contain other elements or a value. ~~No attributes are used.~~
- Acronyms in tag names are represented by one word
- Enumeration values equal the values defined in this specification, including capitalization.
- The values of a boolean variable equal "true" or "false".
- ID values cannot contain a white space character
- A white space character separates multiple values in a data string or text.
- An infinite, overflow or underflow value is denoted by INF.
- A missing value in a list of values is denoted by NaN.

1.4 Units

The use of a particular system of units is site-specific. However, use of mixed units will complicate the exchange and storage of data. Therefore, data is presented in the units specified below. It is assumed that the application software will make the desired conversions to and from these units.

Table 1. Units used in the data specification.

Property	Unit
Acceleration	mm/s^2 or °/s^2
Pressure	N/mm^2
Angle	Decimal degrees (°)
Angular error	µm/m
Chip area	mm^2
Coefficient of thermal expansion	mm/(mm·°C)
Compliance	mm/N or °/(N·mm)
Current	A
Data buffer size	kilobyte
Data transfer speed	kilobits/s
Elapsed time	s
Feed rate	mm/min or °/min
Flow rate	L/min
Frequency	Hz
Force	N
Length	mm
Mass	kg
Moment (Torque)	N·mm
Position	mm
Power	W

Property	Unit
Relative humidity	%
Spindle speed	rev/min
Temperature	°C
Voltage	V
Volume	L

1.5 Compensation and correction of measurement data

Measurement data exchanged in accordance to this standard is assumed to have been compensated for known systematic errors in instrumentation, reference artifacts, and setup that are unrelated to the specified machine property. The respective compensations are to be performed according to the procedures and accuracy requirements outlined in the standards where the respective tests are described. Furthermore, any machine error compensation functions are assumed to be active unless specified otherwise

1.6 Notations and conventions

As indicated in Section 1.3, an element contains either element(s) or a value. In this Standard, elements that contain other elements are defined using tables such as Table 2 below. The first header line of the table contains the number of the table, the element name, and its definition. The second column of the table lists the elements contained in the header element. A definition of each element is presented in the fifth column. The third column indicates how often this element occurs. Here the notation "m-n" indicates that an element occurs a minimum of m times and a maximum of n times. "1-?" indicates that the element can occur multiple times. The notation "0-1" is used to indicate an optional element. The fourth column indicates the data type of the respective element content. The various data types are defined in Section 2.1. Elements whose content is restricted to a limited set of values are denoted as an "enumeration". The respective values and their definitions are listed in the table indicated by the first column (Table 3 in this example). The notation "multi-element" in the fourth column denotes that an element contains other elements. In that case the first column contains the table number where the respective element content is defined.

Table 2. Example of a table used to define an element that contains other elements.

# 1	**<MACHINE_TOOL> :** Properties of a machine tool			
#	**Tag**	**Quantity**	**Type**	**Definition**
2	<DEVICE_ID>	1	multi-element	Identification information
	<DATE>	1	date	Local date when the current list of machine properties was generated
3	<MACHINE_CLASS>	0-1	enumeration	Classification of the machine based on its main function
4	<LOCATOR>	0-1	multi-element	Location and ownership information of the machine within a company
5	<AXES>	0-1	multi-element	Properties of the machine axes

# 1	**<MACHINE_TOOL> :** Properties of a machine tool			
#	**Tag**	**Quantity**	**Type**	**Definition**

Table 3. Example of a table used to define an element whose value equals an enumeration.

# 3	**<MACHINE_CLASS>:** Classification of machine type based on its main function
Value	**Definition**
TURNING_MACHINE	Machine tool in which the principle movement is the rotation of the workpiece against the stationary cutting tool(s) and where cutting energy is provided by the workpiece rotation.
NC_TURNING_MACHINE	Numerically controlled turning machine
TURNING_CENTER	Numerically controlled turning machine equipped with power-driven tool(s) and the capacity to orientate the work-holding spindle around its axis. This machine may include additional features such as programmable tool changing from a magazine

1.7 User-defined information elements

The properties listed in this standard are expected to be adequate for many applications, but are not intended to supplant more complete descriptions. Therefore, this standard provides two mechanisms for adding user-defined information:

- Each element that consists of one or more elements, can contain one or more <OTHER> elements whose content is user defined. The <OTHER> elements trail the elements specified in this standard. It is recommended to include an attribute DESCRIPTION in the <OTHER> element. The value of the attribute equals a string describing the content of the supplied user-defined information.

- Elements whose value space is defined as an enumeration, can contain user-defined enumeration values if the table defining the enumeration contains an empty row (Table 3 for example). A user-defined enumeration value must be preceded by “OTHER_”. Valid user-defined enumeration values are for example, OTHER_OPTION_1 or OTHER_ABCDEF. It is recommended to include an attribute DESCRIPTION in the element. The value of the attribute equals a string describing the meaning of the user-defined enumeration value.

1.8 Definitions

This section defines various terms used in this Standard that are not defined in the referenced ASME B5.54, ASME B5.57, or ISO 230 standards.

Element: within XML an element is a container for a distinct semantic class of document content

Machine coordinate system: coordinate system of the machine according to ISO 841. No offsets for workpiece location or tooling are applied. The coordinate system is a right-handed

rectangular system with the three principle axes labeled X, Y and Z, with rotary axes about each of these axes labeled A, B and C, respectively. The coordinate system considers the workpiece stationary and defines the motions of the tool relative to this workpiece (ISO 841)

Schema: within XML, a schema is a set of predefined rules describing a given class of XML documents by constraining and documenting the meaning, usage, and relationships of their constituent parts: datatypes, elements and their content, and attributes and their values. Thus a schema defines the elements that can appear within a given XML document, along with the attributes that can be associated with a given element. It also defines structural information about the XML document, such as which elements are child elements of others, the sequence in which the child elements can appear, and the number of child elements. Schemas may also provide for the specification of additional document information, such as normalization and defaulting of attribute and element values.

Tag: descriptive markup used by XML delimiting the start and end of an element, including its generic identifier and any attributes.

XML: Extensible Markup Language, a simplified subset of the Standard Generalized Markup Language (SGML, ISO 8879) which provides a file format for representing data, a schema for describing data structure, and a mechanism for extending and annotating HTML with semantic information.

1.9 Referenced documents

The following is a list of publications referenced in this Standard.

ANSI B5.54: Methods for Performance Evaluation of Computer Numerically Controlled Machining Centers, (2005)

ANSI B5.57: Methods for Performance Evaluation of Computer Numerically Controlled Lathes and Turning Centers, (1998)

EIA-267-C: Axis and Motion Nomenclature for Numerically Controlled Machines, (1990)

ISO 230-1: Test Code for Machine Tools -- Part 1: Geometric Accuracy of Machines Operating Under No-Load or Finishing Conditions, (1996)

ISO 230-2: Test Code for Machine Tools – Part 2: Determination of Accuracy and Repeatability of Positioning Numerically Controlled Axes, (1999)

ISO 230-3: Test Code for Machine Tools – Part 3: Determination of Thermal Effects, (2001)

ISO 230-4: Test Code for Machine Tools – Part 4: Circular Tests for Numerically Controlled Machine Tools, (2005)

ISO 230-6: Test Code for Machine Tools – Part 6: Determination of Positioning Accuracy on Body and Face Diagonals (Diagonal Displacement Tests), (2002)

ISO 230-7: Test Code for Machine Tools – Part 7: Geometric Accuracy of Axes of Rotation, (2005)

ISO 230-8: Test Code for Machine Tools – Part 8: Determination of Vibration Values, (200?)

ISO 841: Industrial automation systems and integration -- Numerical control of machines -- Coordinate system and motion nomenclature, (2001)

ISO 8601: Data elements and interchange formats -- Information interchange -- Representation of dates and times,, (2000)

ISO 8879: Information processing -- Text and office systems -- Standard Generalized Markup Language (SGML), (1986)

ISO 10303-11: Industrial automation systems and integration -- Product data representation and exchange -- Part 11: Description methods: The EXPRESS language reference manual, (2004)

ISO 10791-9: Test conditions for machining centers -- Part 9: Evaluation of the operating times of tool change and pallet change, (2001)

XML 1.0: Extensible Markup Language (XML) 1.0 (Third Edition), World Wide Web Consortium, http://www.w3.org, (2004)

XML Schema Part 0: Primer, Part 1: Structures, Part2: Data Types, Second Edition, World Wide Web Consortium, http://www.w3.org, (2004).

2 Data Types and Elements

2.1 Data types

An element that conforms to this standard either contains other elements, in which case it is denoted as "multi-element", or data of one of the following types:

boolean: Indicates an element whose value space equals “true” or “false”. This data type equals the boolean primitive data type defined in the W3C XML Schema.

date: Calendar date using the international standard date notation (ISO 8601). It is typically presented as:

YYYY-MM-DD

where YYYY is the year, MM is the month of the year between 01 (January) and 12 (December), and DD is the day of the month between 01 and 31. This data type equals the date primitive data type defined in the W3C XML Schema.

For example, to indicate May the 31st, 1999, one would write: 1999-05-31.

enumeration: Indicates an element whose value space is constrained to a limited set of values.

float: IEEE single-precision 32-bit floating point type. The value space of float includes the following special values: positive and negative zero, positive and negative infinity (“INF”) and not-a-number (“NaN”). The float data type equals the float primitive data type as defined in the W3C XML Schema.

Example values for float are: -1E4, 1267.43233, 12.78e-2, 12, NaN, and INF

gyear: Calendar year represented as a 4 digit number (i.e., 2002 as opposed to 02). the gyear data type equals the gyear primitive data type as defined in the W3C XML Schema

integer: IEEE 32-bit whole number consisting of a finite-length sequence of decimal digits with an optional leading sign. If the sign is omitted, "+" is assumed. The integer data type equals the integer derived data type as defined in the W3C XML Schema.

Example values for integer are: -1, 0, 123456, and +1000

string: A finite-length sequence of characters that match the Char production from the XML 1.0 standard. Within XML, strings are not enclosed by quotes. ~~A string contains a maximum of 80 characters.~~ This data type equals the string primitive data type defined in the W3C XML Schema.

string_axis: A string with the name of a machine tool axis. The string consists of an optional character followed by an optional single digit number (see EIA 267 and ISO 841).

Example values for string_axis are: A, B, X, Y, W, 1, and X2

~~**text:** A string whose length is not limited.~~

list_of_float: A finite length sequence of space delimited float values.

An example value for list_of_float is: 1 0.2 3E-4

anyURI A Uniform Resource Identifier Reference (URI), i.e., a string of characters for identifying an abstract or physical resource. Examples of resources are an electronic document, an image, or a service. An anyURI value can be absolute or relative. The anyURI type equals the anyURI primitive data type as defined in the W3C XML Schema.

An example value for anyURI is: http://www.example.com/doc.htm

2.2 Generic Elements

# 1	**<MACHINE_TOOL> :** Properties of a machine tool			
#	**Tag**	**Quantity**	**Type**	**Definition**
2	<DEVICE_ID>	1	multi-element	Identification information of the specified machine tool
3	<INFORMATION_STATUS>	0-1	enumeration	Classification of the listed information
	<DATE>	1	date	Local date when the current list of machine properties was generated
4	<LOCATOR>	0-1	multi-element	Location and ownership information of the machine within a company
5	<MACHINE_CLASS>	0-1	enumeration	Classification of the machine based on its main function
6	<SPINDLE_ORIENTATION>	0-1	enumeration	Orientation of the work spindle
7	<CONFIGURATION>	0-?	multi-element	Machine configuration
9	<WORK_ZONE>	0-1	multi-element	Properties of the machine work zone available for cutting operations
10	<AXES>	0-1	multi-element	Properties of the machine axes
17	<SPINDLES>	0-1	multi-element	Properties of the machine spindle(s)
23	<TOOL_HANDLING>	0-?	multi-element	Properties of devices used to handle cutting tools
36	<PALLET>	0-?	multi-element	Properties of the pallet system
33	<TABLE>	0-?	multi-element	Properties of the work table
31	<TAILSTOCK>	0-?	multi-element	Properties of the tailstock associated with a a workholding spindle
38	<CONTROLLER>	0-1	multi-element	Properties of the machine controller
39	<SENSORS>	0-?	multi-element	Properties of additional sensing devices
45	<ENVIRONMENT>	0-1	multi-element	Properties of the machine environment
48	<INSTALLATION>	0-1	multi-element	Installation and facility planning information
55	<COOLANT>	0-1	multi-element	Properties of the process coolant system
59	<AUXILIARY>	0-?	multi-element	Properties of auxiliary equipment
	<THERMAL_STABILIZATION>	0-1	string	Information on the method used to stabilize the temperature of the machine.
61	<PERFORMANCE>	0-?	multi-element	Performance data
135	<MACHINE_ERRORS>	0-1	multi-element	Summary of the machine errors
	<SPECIAL_FEATURE>	0-?		Generic entity for any special features or capabilities of the machine
	<IMAGE>	0-?	anyURI	URI to drawings or images of the machine
	<COMMENTS>	0-1	string	General comments related to the machine
	~~<ADDITIONAL_INFORMATION>~~	~~0-1~~		~~Generic entity for any additional information~~

# 2	**<DEVICE_ID>:** Device identification information.			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<ID>	0-1	string	A site-specific designation that uniquely identifies the device
	<MODEL>	1	string	Model designation used by the device vendor
	<SERIAL_NUMBER>	1	string	Serial number
	<MANUFACTURER>	1	string	Name of the manufacturer
	<DATE_MANUFACTURED>	0-1	date	Date the device was manufactured
	<DATE_RELEASED>	0-1	date	Date the device was installed and released to manufacturing

# 3	**<INFORMATION_STATUS>:** Classification of the listed information
Value	**Definition**
SPECIFICATION_CUSTOMER	Specification of the machine by the customer
SPECIFICATION_VENDOR	Specification of the machine by the vendor
ACCEPTANCE_VENDOR	Properties of the machine during acceptance testing at the vendor's site
ACCEPTANCE_USER	Properties of the machine during acceptance testing at the customer's site
COLLISION	Properties of the machine immediately after a machine collision
INTERIM	Properties of the machine at an arbitrary instance
MOVE	Properties of the machine immediately after moving the machine to a new location
REBUILD	Properties of the machine immediately after adding or changing major machine components affecting the nominal specifications of the machine (e.g., controller retrofit)
REPAIR	Properties of the machine after repairing the machine

# 4	**<LOCATOR>:** Location and ownership information of the machine within a company. Below are some suggested elements. The exact content of the <LOCATOR> element is company specific.			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<BUSINESS_UNIT>	0-1	string	Facility code of business unit within the company to which the machine belongs
	<PLANT_LOCATION>	0-1	string	Geographic location of the plant where the machine resides
	<BUILDING>	0-1	string	Designation of the building in which the machine is installed
	<CELL>	0-1	string	Description of the actual location of the cell

# 4	**<LOCATOR>:** Location and ownership information of the machine within a company. Below are some suggested elements. The exact content of the <LOCATOR> element is company specific.			
#	**Tag**	**Quantity**	**Type**	**Definition**
				within the plant

# 5	**<MACHINE_CLASS>:** Classification of machine based on its main function
Value	**Definition**
TURNING_MACHINE	Machine tool in which the principle movement is the rotation of the workpiece against the stationary cutting tool(s) and where cutting energy is provided by the workpiece rotation.
NC_TURNING_MACHINE	Numerically controlled turning machine
TURNING_CENTER	Numerically controlled turning machine equipped with power-driven tool(s) and the capacity to orient the work-holding spindle around its axis. This machine may include additional features such as programmable tool changing from a magazine.
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.
NC_MILLING_MACHINE	Numerically controlled milling machine
MACHINING CENTER	A numerically controlled milling machine with programmable tool-changing capabilities and the capacity of performing multiple operations, including milling, drilling, tapping, turning, and boring.

# 6	**<SPINDLE_ORIENTATION>:** Orientation of the work spindle
Value	**Definition**
VERTICAL	Spindle oriented in vertical direction.
HORIZONTAL	Spindle oriented in horizontal direction
UNIVERSAL	Spindle is mounted on a mechanism that allows it to be oriented in horizontal, vertical or other directions

# 7	**<CONFIGURATION>:** Machine configuration			
#	**Tag**	**Quantity**	**Type**	**Definition**
8	<STANDARD>	0-1	multi-element	Standard or guideline in which the configuration is defined
	<CONFIGURATION_STRING>	0-1	string	Machine configuration according to the specified standard or guideline

# 8	**<STANDARD>:** Identification of a standard or (internal) guideline			
#	**Tag**	**Quantity**	**Type**	**Definition**

# 8	**<STANDARD>:** Identification of a standard or (internal) guideline			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<ORGANIZATION>	1	string	Name of the organization or company that issued the standard or guideline
	<NUMBER>	1	string	Number of the standard or guideline
	<NAME>	0-1	string	Name of the standard or guideline
	<YEAR>	1	gyear	Year when the standard or guideline was published.

# 9	**<WORK_ZONE> :** Properties of the machine work zone available for cutting operations (excludes the volume necessary to accomplish auxiliary functions such as tool or pallet change)			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<X>	1	float	Range of motion in X direction
	<Y>	0-1	float	Range of motion in Y direction
	<Z>	1	float	Range of motion in Z direction
	<A_MIN>	0-1	float	Smallest value A-axis coordinate in the machine coordinate system[1]
	<A_MAX>	0-1	float	Largest value A-axis coordinate in the machine coordinate system [1]
	<B_MIN>	0-1	float	Smallest value B-axis coordinate in the machine coordinate system [1]
	<B_MAX>	0-1	float	Largest value B-axis coordinate in the machine coordinate system [1]
	<C_MIN>	0-1	float	Smallest value C-axis coordinate in the machine coordinate system [1]
	<C_MAX>	0-1	float	Largest value C-axis coordinate in the machine coordinate system [1]
	<SPINDLE_TO_PIVOT>	0-1	float	For a machine with a swiveling or gimballing spindle, the distance between the spindle face and the spindle pivot axis This distance equals zero for a machine without a tilt head
	<TABLE_TO_PIVOT>	0-1	float	For a machine with a tilt table, the distance between the table surface and the table pivot axis. Use a negative number if the pivot axis is above the table surface in the machine coordinate frame. This distance equals zero for a machine without a tilt table.
	<SPINDLE_TO_TABLE_PIVOT_X>	0-1	float	For a machine with a rotary or tilt table, the minimum position in X of the spindle axis

[1] Use +INF or –INF for a rotary axis with infinite travel.

# 9	**<WORK_ZONE> :** Properties of the machine work zone available for cutting operations (excludes the volume necessary to accomplish auxiliary functions such as tool or pallet change)			
#	**Tag**	**Quantity**	**Type**	**Definition**
				relative to the rotary axis of the table when all rotary axes are at zero in the machine coordinate frame.
	<SPINDLE_TO_TABLE_PIVOT_Y>	0-1	float	For a machine with a rotary or tilt table, the minimum position in Y of the spindle axis relative to the rotary axis of the table when all rotary axes are at zero in the machine coordinate frame.
	<SPINDLE_TO_TABLE_PIVOT_Z>	0-1	float	For a machine with a rotary or tilt table, the minimum position in Z of the spindle face relative to the rotary axis of the table when all rotary axes are at zero in the machine coordinate frame.
	<SPINDLE_TO_TABLE>	0-1	float	Minimum position of the spindle face or spindle axis relative to the table surface when all rotary axes are at zero in the machine coordinate frame. Use a negative number if the spindle face or spindle axis can reach below the table surface.
	<SWING>	0-1	float	Largest outer part diameter that can be accommodated on a turning machine for the complete programmable range of the Z-axis
	<SWING_BED>	0-1	float	Largest outer part diameter that can be accommodated on a turning machine. This diameter may require a restriction on the allowed Z-axis travel to avoid interference with the saddle.
	<LENGTH>	0-1	float	Maximum part length on a turning machine
	<LENGTH_CENTERS>	0-1	float	Maximum part length between centers on a turning machine
	<DIAGRAM>	0-?	anyURI	Reference to diagram(s) describing the properties of the work zone

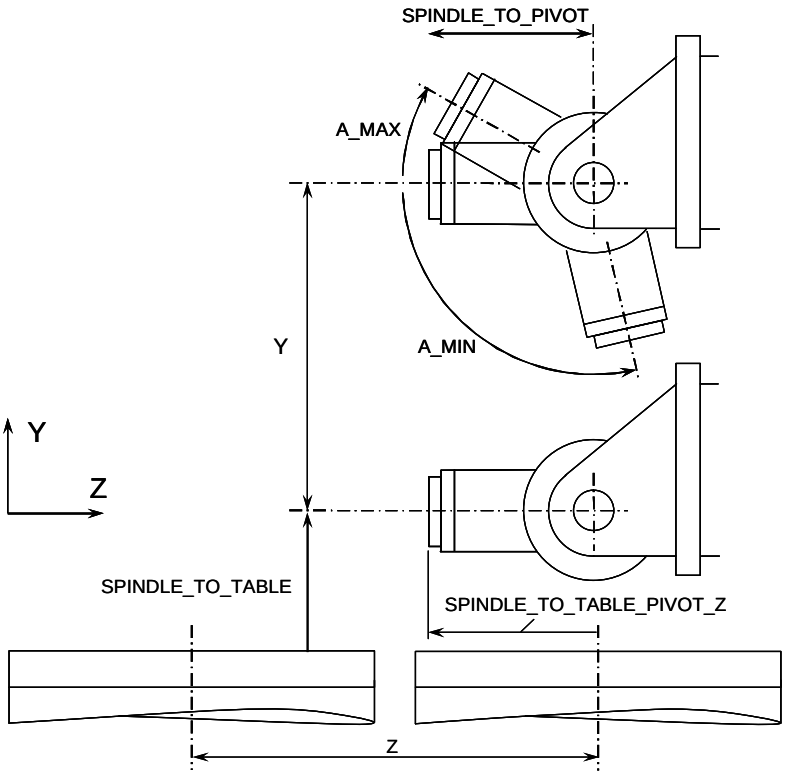

Figure 1. Work zone parameters for a horizontal machining center with A-axis tilt spindle and B-axis rotary table.

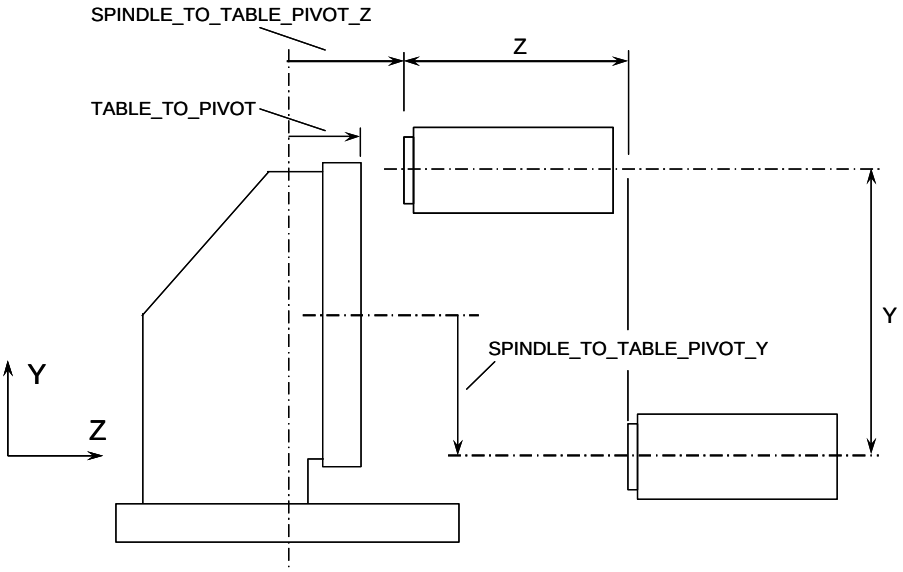

Figure 2. Work zone parameters for a horizontal machining center with a combination B- and C-axis rotary table.

2.3 Machining and Positioning Axes

# 10	**<AXES>**: Properties of the machine axes			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<NUMBER_MACHINING>	1	integer	Number of machining (contouring) axes
	<NUMBER_POSITIONING>	0-1	integer	Number of positioning (indexing) axes
	FEED_RATE	0-1	float	Maximum programmable feed rate (with all machining axes operating simultaneously)
	RAPID_TRAVERSE	0-1	float	Maximum rapid traverse speed
11	<AXIS>	0-?	multi-element	Properties of a machine axis

# 11	**<AXIS>:** Properties of a machine axis			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<AXIS_NAME>	1	string_axis	Character(s) used to designate the axis[2]
	<LINEAR>	1	boolean	Whether the axis generates a linear motion (as opposed to rotary motion)
	<MACHINING>	1	boolean	Whether the axis can be moved during machining (i.e., whether the axis is a contouring axis as opposed to a positioning or indexing axis)
	<TRAVEL>	1	float	Maximum programmable axis travel. INF is used to denote a rotary axis with infinite travel.
	<POSITION_MIN>	0-1	float	Minimum position within the machine coordinate system
	<PROGRAM_INCREMENT>	0-1	float	Smallest incremental motion that can be programmed
	<JOG_INCREMENT >	0-1	float	Smallest incremental motion input through a jog function
	<RESOLUTION>	0-1	float	Resolution of the motion feedback system
	<FEED_RATE>	0-1	float	Maximum programmable feed rate
	<RAPID_TRAVERSE>	0-1	float	Rapid traverse speed
	<ACCELERATION>	0-1	float	Acceleration or deceleration calculated by dividing 63.2% of the programmed feedrate by the time needed to reach this speed. (B5.54 section 7.10.5.3)
	<INDEX_TIME_90>	0-1	float	Time to index over a 90° angle
	<INDEX_TIME_180>	0-1	float	Time to index over a 180° angle

[2] The use of axis nomenclature defined in EIA 267 and ISO 841 is strongly encouraged.

# 11	**<AXIS>:** Properties of a machine axis			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<THRUST>	0-1	float	Maximum thrust of an axis
	<CTE>	0-1	float	Effective coefficient of thermal expansion of a linear axis
	<UCTE>	0-1	float	Estimated standard uncertainty in the effective coefficient of thermal expansion of a linear axis
12	<ACTUATOR_TYPE>	0-1	enumeration	Type of actuator device
	<CLAMP>	0-1	boolean	Ability of the axis to be clamped
	<THERMAL_STABILIZATION>	0-1	boolean	Whether a liquid or forced air is used to stabilize the temperature of the drive
13	<FEEDBACK_DEVICE>	0-1	enumeration	Type of position feedback device
14	<FEEDBACK_TYPE>	0-1	enumeration	Indicates whether the feedback device is absolute or incremental
15	<COUNTER_BALANCE>	0-1	multi-element	Type of counter balance, if any
16	<BEARING_TYPE>	0-1	enumeration	Type of bearings

# 12	**<ACTUATOR_TYPE>:** Type of actuator
Value	**Definition**
MANUAL	Manual actuation
LEADSCREW	Leadscrew (ballscrew) drive
FRICTION	Friction wheel or friction roller drive
LINEAR	Linear motor drive
RACK_PINION	Rack and pinion drive
DIRECT	Direct rotary drive (i.e., no transmission components)
INTEGRAL	Direct rotary drive with the drive located in between the axis bearings
WORM	Indirect rotary drive with worm wheel transmission
GEAR	Indirect rotary drive with gear transmission
BELT	Indirect rotary drive with belt transmission

# 13	**<FEEDBACK_DEVICE>:** Type of position feedback device
Value	**Definition**
SCALE	Linear scale (magnetic, optical, or inductive)
LASER	Laser-based displacement measurement
ROTARY_DIRECT	Encoder or resolver on the rotary axis or the element that translates rotary motion into linear motion (e.g., a leadscrew)

# 13 <FEEDBACK_DEVICE>: Type of position feedback device	
Value	**Definition**
ROTARY_INDIRECT	Encoder or resolver separated by transmission components from the rotating axis or the element that translates rotary motion into linear motion (e.g., a leadscrew)

# 14 <FEEDBACK_TYPE>: Indicates whether the feedback device is absolute or incremental	
Value	**Definition**
ABSOLUTE	Feedback device providing absolute position readings
INCREMENTAL	Feedback device providing incremental displacement readings that can be tracked to determine the position of an axis

# 15 <COUNTER_BALANCE>: Type of counter balance				
#	**Tag**	**Quantity**	**Value**	**Definition**
	<NONE>	0-1	boolean	No counterbalance
	<WEIGHT>	0-1	boolean	Dead weight counterbalance
	<HYDRAULIC>	0-1	boolean	Hydraulic counter balance
	<PNEUMATIC>	0-1	boolean	Pneumatic counter balance

# 16 <BEARING_TYPE>: Type of bearings	
Value	**Definition**
PLAIN	Plain bearing surfaces separated by a lubricant
ROLLING_ELEMENT	surfaces separated by ball or roller bearings
AEROSTATIC	surfaces fully separated by pressurized air
HYDROSTATIC	surfaces fully separated by a pressurized liquid
MAGNETIC	surfaces fully separated by a magnetic field

2.4 Work and Tool Spindles

# 17	**<SPINDLES>**: Properties of the machine spindles			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<NUMBER_WORKHOLDING>	0-1	integer	Number of workholding spindles
	<NUMBER_TOOLHOLDING>	0-1	integer	Number of tool spindles
18	<SPINDLE>	0-?	multi-element	Properties of a spindle

# 18	**<SPINDLE>:** Properties of a machine spindle			
#	**Tag**	**Quantity**	**Type**	**Definition**
2	<DEVICE_ID>	0-1	multi-element	Identification information
	<SPINDLE_NAME>	0-1	string_axis	Character(s) identifying the spindle. ~~Some spindles can also be used as a machining (contouring) or positioning (indexing) axis. In that case <SPINDLE_NAME> equals the respective axis designation~~[3]~~.~~
	<AXIS_FUNCTION>	0-1	boolean	Whether the spindle can be used as a machining (contouring) or positioning (indexing) axis (other than for rigid tapping). The properties of the machine axis can be found in the respective <AXIS> element
	<AXIS_NAME>	0-1	string_axis	Character(s) used to designate the axis if the spindle can be used as a machining (contouring) or positioning (indexing) axis[3]
	<TOOLHOLDING>	1	boolean	Whether the spindle holds the tool (as opposed to a spindle that holds the workpiece)
19	<ALIGNMENT>	0-1	enumeration	Orientation of the spindle axis in the machine coordinate system when all rotary axes are at zero
	<ORIENT>	0-1	boolean	Ability of the spindle to stop at a fixed angular position
	<CLAMP>	0-1	boolean	Ability of the spindle to be clamped at a fixed angular position
	<RIGID_TAPPING>	0-1	boolean	Whether axis control allows for rigid tapping
	<THREAD_MILLING>	0-1	boolean	Whether axis control allows for multiple-pass thread milling

[3] The use of axis nomenclature defined in EIA 267 and ISO 841 are strongly encouraged.

# 18	**<SPINDLE>:** Properties of a machine spindle			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<AUXILIARY_HEAD>	0-1	boolean	Capability to accommodate interchangeable head attachments
	<SPEED_MIN>	0-1	float	Minimum spindle speed
	<SPEED_MAX>	0-1	float	Maximum spindle speed
	<TORQUE_MIN>	0-1	float	Minimum spindle torque
	<TORQUE_MAX>	0-1	float	Maximum spindle torque
	<POWER_CONTINUOUS>	0-1	float	Maximum spindle power during continuous operation
	<POWER_INTERMITTENT>	0-1	float	Maximum spindle power during intermittent operation
	<POWER_CURVE>	0-1	anyURI	URI to a torque/power curve
	<THRUST_AXIAL>	0-1	float	Maximum allowed thrust in axial direction
	<THRUST_RADIAL>	0-1	float	Maximum allowed thrust in radial direction
	<RAMPUP_TIME>	0-1	float	Time required to reach maximum spindle speed
	<RAMPDOWN_TIME>	0-1	float	Time required to stop the spindle from the maximum spindle speed
	<THERMAL_STABILIZATION>	0-1	boolean	Whether a liquid or forced air is used to stabilize the temperature of the spindle
16	<BEARING_TYPE>	0-1	enumeration	Type of spindle bearings
12	<ACTUATOR_TYPE>	0-1	enumeration	Type of spindle drive
20	<COMPLIANCE>	0-1	multi-element	Static compliance of the spindle
21	<TOOLHOLDER_INTERFACE>	0-1	multi-element	Properties of the interface between a toolholding spindle and the toolholder
27	<CHUCK>	0-?	multi-element	Chuck properties of a workholding spindle
29	<COLLET>	0-?	multi-element	Collet properties of a workholding spindle
30	<BAR_FEEDER>	0-1	multi-element	Bar feeder properties of a workholding spindle
	<BORE_DIAMETER>	0-1	float	Diameter of the spindle bore
	<COOLANT_THRU>	0-1	boolean	Indicates the existence of through-spindle process coolant
	<COOLANT_PRESSURE>	0-1	float	Pressure of the process coolant provided through the spindle

# 19	**<ALIGNMENT>:** Orientation in the machine coordinate system when all rotary axes are at zero
Value	**Definition**
X	Aligned with the X-axis
Y	Aligned with the Y-axis
Z	Aligned with the Z-axis

# 20	**<SPINDLE_COMPLIANCE>**: Static compliance of the spindle			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<AXIAL>	0-1	float	Compliance in axial direction
	<RADIAL>	0-1	float	Compliance in radial direction defined at the spindle face
	<TILT>	0-1	float	Angular compliance around an axis orthogonal to the spindle axis

2.5 Tool Handling

# 21	**<TOOLHOLDER_INTERFACE>**: Properties of the interface between a toolholding spindle and the toolholder.			
#	**Tag**	**Quantity**	**Type**	**Definition**
22	<INTERFACE_TYPE>	1	enumeration	Toolholder interface designation
	<STYLE>	0-1	string	Toolholder style (e.g., A, B, C , etc.)
	<SIZE>	0-1	float	Toolholder size or taper
	<RETENTION_KNOB>	0-1	string	Retention knob type and/or model number

# 22	**<INTERFACE_TYPE>:** Toolholder interface designation
Value	**Definition**
HSK	See DIN 69893-1, -2, -3, -4, -5, -6
CAT	See ANSI/ASME B5.50 and ISO 7388-1, -2
BT	See JIS B6339
KM	See Kennametal standards
ISF	
SC	

# 23	**<TOOL_HANDLING>**: Properties of devices used to handle cutting tools.			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<NUMBER_TURRETS>	0-1	integer	Number of turrets
24	<TURRET>	0-?	multi-element	Properties of a turret
25	<TOOL_CHANGER>	0-?	multi-element	Properties of a tool changer

# 24	**<TURRET>**: Properties of a turret			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TURRET_NUMBER>	0-1	integer	Number of the turret
	<SPINDLE_NAME>	0-?	string_axis	Spindle(s) served by the turret
	<NUMBER_TOOLS_FIXED>	0-1	integer	Number of fixed tool positions
	<NUMBER_TOOLS_LIVE>	0-1	integer	Number of rotating tool positions
	<CTC_MIN>	0-1	float	Minimum cut-to-cut turret index time (typically for the nearest tool)
	<CTC_MAX>	0-1	float	Maximum cut-to-cut turret index time (typically for the furthest tool)

# 24	**<TURRET>**: Properties of a turret			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<SHANK_SQUARE>	0-1	float	Maximum shank size square tool block
	<SHANK_ROUND>	0-1	float	Maximum shank size round tool block

# 25	**<TOOL_CHANGER>**: Properties of a tool changer system			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<SPINDLE_NAME>	0-?	string_axis	Spindle(s) served by the tool changer
	<NUMBER_TOOLS>	0-1	integer	Number of tools that the tool changer can store
26	<STORAGE_CONFIGURATION>	0-1	enumeration	Type of tool store configuration
	<RANDOM_ACCESS>	0-1	boolean	Whether the tool can be stored in any of the empty slots after the next one has been loaded into the machine spindle
	<CTC_MIN>	0-1	float	Minimum cut-to-cut tool change time (typically for the nearest tool)
	<CTC_MAX>	0-1	float	Maximum cut-to-cut tool change time (typically for the furthest tool)
	<DIAMETER_FULL>	0-1	float	Maximum diameter tool if adjacent positions are occupied
	<DIAMETER_EMPTY>	0-1	float	Maximum diameter tool if adjacent positions are empty
	<TOOL_LENGTH>	0-1	float	Maximum tool length
	<TOOL_WEIGHT>	0-1	float	Maximum tool weight

# 26 **<STORAGE_CONFIGURATION>:** Type of tool store configuration (ISO 10791-9)	
Value	**Definition**
BI-DIRECTIONAL	Describes a tool changer system that can move in both directions to bring the tools to the loading position
UNI-DIRECTIONAL	Describes a tool changer system that can move only in one direction to bring the tools to the loading position
BOX-MATRIX	Describes a tool changer system 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

2.6 Workpiece Devices

# 27	**<CHUCK>**: Chuck properties			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<NUMBER_JAWS>	0-1	Integer	Number of jaws
	<INDEPENDENT_JAWS>	0-1	boolean	Whether the jaws can be moved independently
28	<CLAMPING_METHOD>	0-1	enumeration	Generation of clamping force
	<CLAMPING_FORCE_MIN>	0-1	float	Minimum clamping force (exerted by the draw bar)
	<CLAMPING_FORCE_MAX>	0-1	float	Maximum clamping force (exerted by the draw bar)
	<DIAMETER_MIN>	0-1	float	Minimum part diameter
	<DIAMETER_MAX>	0-1	float	Maximum part diameter
	<BORE_DIAMETER>	0-1	float	Diameter of the chuck bore
	<LENGTH>	0-1	float	Length of the chuck

# 28	**<CLAMPING_METHOD>:** Generation of clamping force
Value	**Definition**
MANUAL	Manual
HYDRAULIC	Hydraulic
PNEUMATIC	Pneumatic
MAGNETIC	Magnetic

# 29	**<COLLET>**: Collet properties			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<COLLET_TYPE>	0-1	string	Alphanumeric description collet clamp type
28	<CLAMPING_METHOD>	0-1	enumeration	Generation of clamping force
	<CLAMPING_FORCE_MIN>	0-1	float	Minimum clamping force (exerted by the draw bar)
	<CLAMPING_FORCE_MAX>	0-1	float	Maximum clamping force (exerted by the draw bar)
	<DIAMETER_MIN>	1	float	Minimum part diameter
	<DIAMETER_MAX>	1	float	Maximum part diameter
	<LENGTH>	0-1	float	Length of the collet

# 30	**<BAR_FEEDER>**: Bar feeder properties			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<LENGTH>	0-1	float	Maximum stock length
	<DIAMETER_MIN>	0-1	float	Minimum stock diameter
	<DIAMETER_MAX>	0-1	float	Maximum stock diameter

# 31	**<TAILSTOCK>**: Tailstock properties			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<SPINDLE_NAME>	0-1	string_axis	Spindle served by the tail stock
	<PROGRAM>	0-1	boolean	Whether the tailstock can be positioned under program control
	<TAPER>	0-1	string	Taper designation of the bore in the tailstock
	<TRAVEL>	0-1	float	Travel of the tailstock
	<THRUST>	0-1	float	Maximum clamping force which can be applied by the tailstock
32	<TAILSTOCK_QUILL>	0-1	multi-element	Properties of the tailstock quill

# 32	**<TAILSTOCK_QUILL>**: Properties of the tailstock quill			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<PROGRAM>	0-1	boolean	Whether the quill can be positioned under program control
	<TAPER>	0-1	string	Taper designation of the bore in the quill
	<TRAVEL>	0-1	float	Travel of the quill
	<WORKPIECE_WEIGHT>	0-1	float	Maximum workpiece mass that can be supported by the quill

# 33	**<TABLE> :** Properties of the work holding table			
#	**Tag**	**Quantity**	**Type**	**Definition**
19	<ALIGNMENT>	0-1	enumeration	Orientation of the axis perpendicular to the table surface when all rotary axes are at zero
	<LOAD_CAPACITY>	0-1	float	Maximum workpiece mass
34	<SHAPE>	0-1	enumeration	Shape of the table surface
35	<FIXTURE_STYLE>	0-1	enumeration	A designation of the fixture mechanism provided by the work holding table
	<WIDTH>	0-1	float	Size of a rectangular machine table in X-direction
	<LENGTH>	0-1	float	Size of a rectangular machine table in Y-direction

# 33 **<TABLE> :** Properties of the work holding table				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<DIAMETER>	0-1	float	Diameter of a round machine table
	<HEIGHT>	0-1	float	Minimum height of the machine table from the floor
27	<CHUCK>	0-1	multi-element	Properties of a work table which acts as a chuck

# 34 **<SHAPE>:** Shape of the table surface	
Value	**Definition**
RECTANGULAR	Rectangular table
CIRCULAR	Circular table

# 35 **<FIXTURE_STYLE>:** Designation of the fixture mechanism	
Value	**Definition**
T-SLOT	T-slots
HOLE	Threaded hole pattern
VACUUM	Vacuum
CHUCK	Chuck
~~OTHER~~	~~Other fixturing mechanism~~

# 36 **<PALLET>**: Properties pallet system				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<NUMBER_PALLETS>	0-1	integer	Number of pallets
37	<STORAGE_CONFIGURATION>	0-1	enumeration	Type of pallet store configuration
	<RANDOM_ACCESS>	0-1	boolean	Whether the pallet can be stored in any of the empty slots after the next one has been loaded into the machine
	<PCT_MIN>	0-1	float	Minimum pallet change time (typically for the nearest pallet)
	<PCT_MAX>	0-1	float	Maximum pallet change time (typically for the furthest pallet)
35	<FIXTURE_STYLE>	0-1	enumeration	A designation of the fixture mechanism provided by the pallet
	<PALLET_TYPE>	0-1	string	Designation pallet type
	<LOAD_CAPACITY>	0-1	float	Maximum workpiece mass
	<LENGTH>	0-1	float	Size of the pallet in Y-direction

# 36 **<PALLET>**: Properties pallet system				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<WIDTH>	0-1	float	Size of the pallet in X-direction
	<HEIGHT>	0-1	float	Minimum height of the pallet from the floor

# 37 **<STORAGE_CONFIGURATION>:** Type of pallet store configuration (ISO 10791-9)	
Value	**Definition**
CAROUSEL	Carousel type store
CHAIN	Chain type store
CAROUSEL_2_PLACE	Carousel two-place store
FIXED_2_PLACE	Fixed two-place store
MULTI_STOREY	Multi-story pallet store
STRAIGHT_LINE	Straight-line pallet store

2.7 Controller

# **38**	**<CONTROLLER>**: Properties of the machine controller			
#	**Tag**	**Quantity**	**Type**	**Definition**
2	<DEVICE_ID>	1	multi-element	Identification information
	<HANDWHEEL>	0-1	boolean	Whether the controller pendant is equipped with a handwheel
	<MBET>	0-1	float	Minimum block execution time
	<LOOKAHEAD >	0-1	integer	Number of blocks that the controller is able to look ahead
	<DRIP_FEED>	0-1	boolean	The existence of drip feed capability through communication port(s)
	<FEED_FORWARD>	0-1	boolean	The existence of feed forward capability
	<BUFFER_SIZE>	0-1	integer	The size of the memory buffer in the controller
	<TRANSFER_SPEED >	0-1	float	Maximum data transfer speed
	<INTERFACE_PROTOCOL>	0-?	string	Available interface protocol
	<CONTROL_PARAMETERS>	0-1	anyURI	URI to detailed information on available controller parameters
	<COMPENSATION_OPTIONS>	0-1	anyURI	URI to detailed information on available compensation options (includes probing data compensation)
	<NC_FUNCTIONS>	0-1	anyURI	URI to a detailed list of available NC functions
	<PLC_FUNCTIONS>	0-1	anyURI	URI to a detailed list of available PLC functions

2.8 Sensors

# 39	**<SENSORS>**: Properties of additional sensing devices			
#	**Tag**	**Quantity**	**Type**	**Definition**
40	<TOOL_SETTING>	0-?	multi-element	Properties of a tool setting station
44	<TOOL_BREAKAGE>	0-?	multi-element	Properties of a tool breakage sensor
42	<PART_PROBE>	0-?	multi-element	Properties of a part probe

# 40	**<TOOL_SETTING>**: Properties tool setting station			
#	**Tag**	**Quantity**	**Type**	**Definition**
2	<DEVICE_ID>	0-1	multi-element	Identification information
41	<PROBE_TYPE>	0-1	enumeration	Probe type
	<MEASURE_RADIUS>	1	boolean	Whether the tool setting station can measure tool radius
	<MEASURE_OFFSET>	1	boolean	Whether the tool setting station can measure tool offset/length
	<CONTACT>	0-1	boolean	Whether the tool setting station requires physical contact between probe and tool
	<MEASURE_ROTATING>	0-1	boolean	Whether the tool setting station can measure while rotating the spindle
	<MEASUREMENT_TIME>	0-1	float	Time required to measure tool parameters
	<MANUAL_SETUP>	0-1	boolean	Whether the tool setting station needs to be moved in position through a manual operation

# 41	**<PROBE_TYPE>:** Probe type
Value	**Definition**
SWITCHING	Switching probe (probe that gives a binary signal as a result of contact with or in proximity to an object)
NULLING	Nulling probe (probe that, in reference to a measured object, gives a signal that causes the machine to be driven to a position that will null the probe reading)
PROPORTIONAL	Proportional probe (probe that gives a signal proportional to a displacement of the probe from its free position)

# 42	**<PART_PROBE>**: Properties part probe			
#	**Tag**	**Quantity**	**Type**	**Definition**
2	<DEVICE_ID>	0-1	multi-element	Identification information

# 42	**<PART_PROBE>**: Properties part probe			
#	**Tag**	**Quantity**	**Type**	**Definition**
41	<PROBE_TYPE>	0-1	enumeration	Probe type
43	<DIMENSIONALITY>	0-1	enumeration	Maximum dimensionality of the measurement tasks that can be performed
	<APPROACH_RATE>	0-1	float	Approach rate
	<APPROACH_DISTANCE>	0-1	float	Approach distance
	<SETTLING_TIME>	0-1	float	Settling time of a proportional probe

# 43	**<DIMENSIONALITY>:** Maximum dimensionality of the measurement tasks that can be performed
Value	**Definition**
1D	Allows only 1-D measurements
2D	Allows only 2-D measurements
3D	Allows 3-D measurements

# 44	**<TOOL_BREAKAGE>**: Properties tool breakage sensor			
#	**Tag**	**Quantity**	**Type**	**Definition**
2	<DEVICE_ID>	0-1	multi-element	Identification information

2.9 Environment

# 45	**<ENVIRONMENT>**: Properties machine environment			
#	**Tag**	**Quantity**	**Type**	**Definition**
46	<AMBIENT_TEMPERATURE>	0-1	multi-element	Properties thermal environment.
	<AIR_SPEED>	0-1	float	Mean airspeed in the machine environment
	<HUMIDITY_MAX>	0-1	float	Maximum relative humidity
47	<SEISMIC_VIBRATION>	0-1	multi-element	Properties seismic vibration at the interface to the user-supplied foundation
	~~<ADDITIONAL_INFORMATION>~~	~~0-1~~		~~Generic entity for any additional information~~

# 46	**<AMBIENT_TEMPERATURE>**: Properties thermal environment			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<SAFE_MIN>	0-1	float	Minimum safe operating temperature, i.e., the minimum environmental temperature at which the machine can operate without damage to the machine.
	<SAFE_MAX>	0-1	float	Maximum safe operating temperature, i.e., the maximum ambient temperature at which the machine can operate without damage to the machine.
	<MEAN>	0-1	float	Mean ambient temperature
	<MEAN_CHANGE>	0-1	float	Significant mean temperature change, i.e., the change in mean ambient temperature that will result in a significant degradation of machine performance.
	<MEAN_CHANGE_RATE>	0-1	float	Maximum change in mean ambient temperature during an hour that will result in a significant degradation of machine performance.
	<DAILY_AMPLITUDE>	0-1	float	Maximum amplitude of the daily variation in ambient temperature (half the respective range)
	<CYCLE_AMPLITUDE>	0-?	float	Maximum amplitude of the superimposed cyclic variation in ambient temperature (half the respective range)
	<CYCLE_FREQUENCY>	0-?	float	Frequency of the superimposed cyclic variation in ambient temperature
	~~<CYCLE_FREQUENCY_MAX>~~	~~0-1~~	~~float~~	~~Maximum acceptable frequency of the superimposed cyclic variation in ambient temperature~~
	<GRADIENT_HORIZONTAL>	0-1	float	Maximum gradient of the ambient temperature in horizontal direction

# 46	**<AMBIENT_TEMPERATURE>**: Properties thermal environment			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<GRADIENT_ VERTICAL>	0-1	float	Maximum gradient of the ambient temperature in vertical direction

# 47	**<SEISMIC_VIBRATION>**: Properties seismic vibration at the interface to the user-supplied foundation			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<AMPLITUDE>	0-1	float	Maximum peak-to-peak amplitude of broad-band seismic vibration data at the interface to the user-supplied foundation
	<FREQUENCY_MIN>	0-1	float	Minimum frequency to which the specified vibration amplitude applies.
	<FREQUENCY_MAX>	0-1	float	Maximum frequency to which the specified vibration amplitude applies.
	<DETAILS>	0-1	anyURI	URI to detailed seismic vector vibration spectra at the interface to the user-supplied foundation

2.10 Installation

# 48	**<INSTALLATION>**: Installation and facility planning information			
#	**Tag**	**Quantity**	**Type**	**Definition**
49	<SIZE>	0-1	multi-element	Dimensions of the machine
	<WEIGHT>	0-1	float	Mass of the machine
50	<ELECTRICAL>	0-1	multi-element	Properties supplied electrical power.
51	<UTILITY_AIR>	0-1	multi-element	Properties air supply
52	<UTILITY_WATER>	0-1	multi-element	Properties water supply
53	<HYDRAULICS>	0-1	multi-element	Properties hydraulics system
	<CHILLER>	0-1	boolean	Whether the machine is equipped with a chiller system for temperature stabilization
	<THERMAL_STABILIZATION>	0-1	string	Requirements of the method used to stabilize the temperature of the machine (e.g., supply of a temperature controlled liquid)
54	<FOUNDATION>	0-1	multi-element	Foundation properties
	<INSTALLATION_DATA>	0-1	anyURI	URI to detailed information on machine installation data

# 49	**<SIZE> :** Overall dimensions of the machine			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<WIDTH>	1	float	Width of the machine footprint (horizontal dimension, usually in X, along the direction of material flow in between machines)
	<LENGTH>	1	float	Length of the machine footprint (horizontal dimension orthogonal to that of <WIDTH>)
	<HEIGHT>	1	float	Maximum height of the machine
	<DIAGRAM>	0-?	anyURI	Reference to diagram(s) describing the size of the machine

# 50	**<ELECTRICAL>**: Properties supplied electrical power			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<VOLTAGE>	1	float	Steady state line voltage required to operate the machine
	<PHASES>	1	integer	Number of phases
	<CYCLES>	1	integer	Number of cycles (frequency)
	<AMPERAGE>	0-1	float	Maximum required amperage
	<POWER_CONSUMPTION>	0-1	float	Maximum power consumption
	<VOLTAGE_TRANSIE	0-1	float	Allowed transient voltage change (%

# 50	**<ELECTRICAL>**: Properties supplied electrical power			
#	**Tag**	**Quantity**	**Type**	**Definition**
	NT>			nominal)
	<VOLTAGE_SAG>	0-1	float	Allowed short duration RMS voltage sag (% nominal)
	<VOLTAGE_SWELL>	0-1	float	Allowed short duration RMS voltage swell (% nominal)
	<VOLTAGE_UNDER>	0-1	float	Allowed long duration RMS voltage sag (% nominal)
	<VOLTAGE_OVER>	0-1	float	Allowed long duration RMS voltage swell (% nominal)

# 51	**<UTILITY_AIR>**: Properties of supplied air			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<PRESSURE>	1	float	Pressure of supplied air
	<FLOW_RATE>	0-1	float	Flow rate of supplied air
	<DEW_POINT>	0-1	float	Dew-point temperature of supplied air
	<PARTICLE_SIZE>	0-1	float	Maximum size of particles in the supplied air
	<PARTICLE_REMOVAL>	0-1	float	Percentage removal of maximum sized particles

# 52	**<UTILITY_WATER>**: Properties of supplied water			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<FLOW_RATE>	0-1	float	Maximum flow rate of supplied water
	<TEMPERATURE_MIN >	0-1	float	Minimum temperature of supplied water that will not result in a significant degradation of machine performance
	<TEMPERATURE_MAX>	0-1	float	Maximum temperature of supplied water that will not result in a significant degradation of machine performance

# 53	**<HYDRAULICS>**: Properties of the hydraulics system			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TYPE>	0-1	string	Type of hydraulic oil used by machine
	<PRESSURE>	0-1	float	Pump outlet pressure
	<CAPACITY>	0-1	float	Capacity of the hydraulics tank
	<TEMPERATURE_STABILIZED>	0-1	boolean	Indicates whether the temperature of the hydraulics is controlled by the machine

# 54	**<FOUNDATION>**: Properties machine foundation			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<SPECIAL>	0-1	boolean	Machine has special foundation requirements to achieve desired stiffness or to reduce effects seismic vibrations
	<THREE-POINT>	0-1	boolean	Whether the machine is supported at a total of three points
	<FOUNDATION_DATA>	0-1	anyURI	URI to detailed information on the machine foundation

2.11 Process coolant

# 55	**<COOLANT>**: Properties of the process coolant system			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TYPE>	0-1	string	Type of coolant used by the machine
56	<DELIVERY>	0-?	multi-element	Properties of a specific coolant delivery type
	<CAPACITY>	0-1	float	Capacity of the coolant tank
	<TEMPERATURE_STABILIZED>	0-1	boolean	Indicates whether the temperature of the coolant is controlled by the machine
	<TEMPERATURE_MIN >	0-1	float	Minimum temperature of supplied coolant that will not result in a significant degradation of machine performance
	<TEMPERATURE_MAX>	0-1	float	Maximum temperature of supplied coolant that will not result in a significant degradation of machine performance

# 56	**<DELIVERY>**: Properties of a specific coolant delivery type			
#	**Tag**	**Quantity**	**Type**	**Definition**
57	<DELIVERY_TYPE>	0-1	enumeration	Type of coolant delivery
58	<DELIVERY_MEANS>	0-1	enumeration	Means of coolant delivery
	<PRESSURE>	0-1	float	Maximum coolant pressure
	<FLOW_RATE>	0-1	tloat	Maximum coolant flow rate

# 57	**<DELIVERY_TYPE>:** Type of coolant delivery
Value	**Definition**
MIST	Low volume of liquid coolant delivered as a high-velocity aerosol
MICRO	Extremely low volume of lubricant delivered as a high-velocity aerosol.
FLOOD	Flood coolant, high volume of coolant at low velocity

# 58	**<DELIVERY_MEANS>:** Means of coolant delivery
Value	**Definition**
THRU_SPINDLE	Delivery of coolant through the spindle
THRU_TURRET	Delivery of coolant through the turret
EXTERNAL	Delivery of coolant neither through the spindle nor turret

2.12 Auxiliary

# **59**	**<AUXILIARY>**: Properties auxiliary equipment			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<CHIP_CONVEYOR>	0-1	multi-element	Properties chip conveyor

# **60**	**<CHIP_CONVEYOR>**: Properties chip conveyor system			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<CONVEYOR_TYPE >	0-1	anyURI	Type of chip conveyor
	<HEIGHT>	0-1	float	Height chip conveyor discharge
	<COMPACTOR>	0-1	boolean	Presence chip compactor

2.13 Performance

Specification of performance parameters listed in the performance forms of machine tool performance standards.

2.13.1 Generic Elements

# **61**	**<PERFORMANCE>**: Performance parameters according to a specified standard			
#	**Tag**	**Quantity**	**Type**	**Definition**
8	<STANDARD>	1	multi-element	Standard in which the listed performance parameters are defined
62	<POSITIONING >	0-?	multi-element	Performance parameters summarizing positioning errors
67	<GEOMETRIC>	0-?	multi-element	Performance parameters summarizing geometric errors (excluding positioning)
72	<SPINDLE_AXIS_ROTATION>	0-?	multi-element	Performance parameters summarizing spindle error motions
77	<DIAGONAL>	0-?	multi-element	Performance parameters summarizing diagonal displacement errors
81	<CIRCULAR>	0-?	multi-element	Performance parameters summarizing circular contouring errors
88	<THERMAL>	0-?	multi-element	Performance parameters summarizing thermal errors
96	<MACHINE_COMPLIANCE>	0-?	multi-element	Performance parameters summarizing static machine compliance and hysteresis
101	<MEASURING>	0-?	multi-element	Parameters summarizing machine performance as a measuring tool
106	<CNC>	0-?	multi-element	Parameters summarizing CNC performance
111	<SUBSYSTEMS_REPEATABILITY>	0-?	multi-element	Performance parameters summarizing subsystems repeatability
116	<SPINDLE_IDLE_RUN_LOSSES>	0-?	multi-element	Performance parameters summarizing spindle idle run losses
120	<CHATTER_LIMITS>	0-?	multi-element	Performance parameters summarizing chatter limits
127	<FULL_TORQUE>	0-?	multi-element	Performance parameters summarizing full torque capabilities
131	<MILLING_DEFLECTION>	0-?	multi-element	Performance parameters summarizing end milling or face milling deflection

2.13.2 Positioning accuracy and repeatability

# 62	**<POSITIONING>:** Performance parameters summarizing positioning errors			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-1	string	Identification of the test(s) from which the parameters have been extracted
63	<TEST_CLASS>	1	enumeration	Classification of the performance evaluation test
	<AXIS_NAME>	0-1	string_axis	Name of the machine axis
64	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 63	**<TEST_CLASS>:** Classification of the performance evaluation test
Value	**Definition**
AXIS_POSITIONING	Positioning error of a linear or rotary axis.
AXIS_POSITIONING_PERIODIC	Error in the linear or angular positioning of a machine axis that is periodic over an interval which normally coincides with the natural periodicity of the positioning feedback system.

# 64	**<PARAMETER>:** Performance parameter			
#	**Tag**	**Quantity**	**Type**	**Definition**
65	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
66	<APPROACH_DIRECTION>	0-1	enumeration	Direction of machine motion to which the specified performance parameter applies.

# 65	**<NAME>:** Preferred names for the performance parameters of an axis positioning tests
Value	**Definition**
SYSTEMATIC	Systematic deviation
ACCURACY	Accuracy
REPEATABILITY	Repeatability
PERIODIC	Periodic error
REVERSAL	Maximum of the absolute reversal deviations
MEAN_REVERSAL	Mean of the signed reversal deviations

# 66 **<APPROACH_DIRECTION>:** Direction of machine motion to which the specified performance parameter applies.	
Value	**Definition**
BIDIRECTIONAL	Parameter applies to bidirectional approach directions
UNIDIRECTIONAL	Parameter applies to unidirectional approach directions[4]
COUNTER_CLOCKWISE	Axis rotating in counter clockwise direction, designated by ↓
CLOCKWISE	Axis rotating in clockwise direction, designated by ↑
POSITIVE	Axis moving in positive direction, designated by ↑
NEGATIVE	Axis moving in negative direction, designated by ↓

[4] If only one unidirectional value is presented, it should be the maximum of the two unidirectional values (according to ASME B5.54: 2005)

2.13.3 Geometric Accuracy

# 67	**<GEOMETRIC>:** Performance parameters summarizing geometric errors (excluding positioning)			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the parameters have been extracted
68	<TEST_CLASS>	1	enumeration	Classification of the performance evaluation test
	<AXIS_NAME_REFERENCE>	0-1	string_axis	Name of the reference machine axis for parallelism and squareness
	<AXIS_NAME>	0-1	string_axis	Name of the machine axis
69	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 68	**<TEST_CLASS>:** Classification of the performance evaluation test
Value	**Definition**
AXIS_ALIGNMENT	Squareness or parallelism error between two axes
AXIS_ANGULAR	Angular error of an axis (roll, pitch, and yaw errors of a linear axis or the tilt motions of a rotary axis). This class does not include the positioning error of a rotary axis.
AXIS_TRANSLATION	Straightness error of a linear axis or the radial and axial errors of a rotary axis

# 69	**<PARAMETER>:** Performance parameter of a geometric accuracy test			
#	**Tag**	**Quantity**	**Type**	**Definition**
70	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
71	<MEASURAND>	0-1	enumeration	Definition of the measured or specified error
66	<APPROACH_DIRECTION>	0-1	enumeration	Direction of machine motion to which the specified performance parameter applies.

# 70	**<NAME>:** Preferred names for the performance parameters of a geometric accuracy test
Value	**Definition**
SYSTEMATIC_DEVIATION	Systematic deviation

# 70 **<NAME>:** Preferred names for the performance parameters of a geometric accuracy test	
Value	**Definition**
ACCURACY	Accuracy
REPEATABILITY	Repeatability
REVERSAL	Maximum of the absolute reversal deviations
SQUARENESS	Squareness error
PARALLELISM	Parallelism error
STRAIGHTNESS	Straightness error
ROLL	Roll error
PITCH	Pitch error
YAW	Yaw error
ERROR_MOTION	Error motion value

# 71 **<MEASURAND>:** Definition of the measured or specified error.	
Value	**Definition**
X	Translation error in X direction
Y	Translation error in Y direction
Z	Translation error in Z direction
A	Angular error around the X-axis
B	Angular error around the Y-axis
C	Angular error around the Z-axis

2.13.4 Spindle Axis of Rotation

# 72	**<SPINDLE_AXIS_ROTATION>:** Performance parameters summarizing spindle error motions			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-1	string	Identification of the test(s) from which the parameter set has been extracted
73	<TEST_CLASS>	1	enumeration	Classification of the performance evaluation test
	<SPINDLE_NAME>	0-1	string_axis	Name of the spindle
	<SPINDLE_SPEED>	0-1	float	Spindle speed
	<SPINDLE_SPEED_PERCENTAGE >	0-1	float	Spindle speed expressed as a percentage of the respective maximum speed
74	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 73	**<TEST_CLASS>:** Classification of the performance evaluation test
Value	**Definition**
SPINDLE_AXIS_ROTATION	Spindle axis of rotation
STRUCTURAL_MOTION	Structural error motion

# 74	**<PARAMETER>:** Performance parameter for a spindle axis of rotation test			
#	**Tag**	**Quantity**	**Type**	**Definition**
75	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
76	<MEASURAND>	1	enumeration	Definition of the measured or specified error motion

# 75	**<NAME>:** Preferred names for the performance parameters of spindle axis of rotation error
Value	**Definition**
AVERAGE_ERROR_MOTION	Average error motion value
ASYNCHRONOUS_ERROR_MOTION	Asynchronous error motion value
TOTAL_ERROR_MOTION	Total error motion value
STRUCTURAL_OFF	Range of the observed structural error motion (drives off)
STRUCTURAL_HOLD	Range of the observed structural error motion (drives in feed hold)

# 75 <NAME>: Preferred names for the performance parameters of spindle axis of rotation error	
Value	**Definition**
STRUCTURAL_PROG	Range of the observed structural error motion (drives program controlled)

# 76 <MEASURAND>: Definition of the measured or specified error motion for a spindle axis of rotation error.	
Value	**Definition**
X	Error motion in X direction (fixed sensitive direction)
Y	Error motion in Y direction (fixed sensitive direction)
Z	Error motion in Z direction (fixed sensitive direction)
A	Tilt error motion around X (fixed sensitive direction)
B	Tilt error motion around Y (fixed sensitive direction)
C	Tilt error motion around Z (fixed sensitive direction)
RADIAL	Radial error motion (rotating sensitive direction)
AXIAL	Axial error motion
TILT	Tilt error motion (rotating sensitive direction)

2.13.5 Diagonal Displacement

# 77	**<DIAGONAL>:** Performance parameters summarizing diagonal displacement errors			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-1	string	Identification of the test(s) from which the parameter set has been extracted
78	<TEST_CLASS>	1	enumeration	Classification of the performance evaluation test
	<NUMBER>	0-?	integer	Number of the diagonal
	<LENGTH>	0-1	float	Length of the diagonal
79	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 78	**<TEST_CLASS>:** Classification of the performance evaluation test
Value	**Definition**
DIAGONAL_POSITIONING	Diagonal displacement error

# 79	**<PARAMETER>:** Performance parameter of a diagonal displacement test			
#	**Tag**	**Quantity**	**Type**	**Definition**
80	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~

# 80	**<NAME>:** Preferred names for the performance parameters of diagonal tests
Value	**Definition**
SYSTEMATIC_DEVIATION	Bidirectional systematic deviation
REVERSAL	Maximum of the absolute reversal deviations

2.13.6 Circular Tests

# 81	**<CIRCULAR>:** Performance parameters summarizing circular contouring errors			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test from which the parameter set has been extracted
82	<TEST_CLASS>	1	enumeration	Classification of the performance evaluation test
83	<PLANE>	0-1	multi-element	Plane of the circle
	<RADIUS>	0-1	float	Nominal radius of the circular contour
	<FEED_RATE>	0-1	float	Nominal feed rate
	<INCLUDED_ANGLE>	0-1	float	Included angle of the contour along an arc
84	<INTERPOLATION>	0-1	enumeration	Interpolation mode of the machine tool motion
85	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 82	**<TEST_CLASS>:** Classification of the performance evaluation test
Value	**Definition**
CIRCULAR	Circular tests

# 83	**<PLANE>:** Specification of a plane in the machine workspace by defining the two linear axes that generate the tested machine motion.			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<AXIS_NAME_1>	1	string_axis	Machine axis that points in the local X direction of the plane
	<AXIS_NAME_2>	1	string_axis	Machine axis that points in the local Y direction of the plane

# 84	**<INTERPOLATION>: I**nterpolation mode of the machine tool motion
Value	**Definition**
CIRCULAR	Circular interpolation mode (usually G02 or G03)
LINEAR	Linear interpolation mode (usually G01)

# 85	**<PARAMETER>:** Performance parameter of a circular test			
#	**Tag**	**Quantity**	**Type**	**Definition**
86	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~

# 85 **<PARAMETER>:** Performance parameter of a circular test				
#	**Tag**	**Quantity**	**Type**	**Definition**
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
87	<APPROACH_DIRECTION>	0-1	enumeration	Direction of machine motion to which the specified performance parameter applies.

# 86 **<NAME>:** Preferred names for the performance parameters of circular tests	
Value	**Definition**
RADIAL_DEVIATION_MIN	Minimum radial deviation
RADIAL_DEVIATION_MAX	Maximum radial deviation
CIRCULAR_DEVIATION	Circular deviation
CIRCULAR_HYSTERESIS	Circular hysteresis deviation

# 87 **<APPROACH_DIRECTION>:** Direction of machine motion to which the specified performance parameter applies.	
Value	**Definition**
COUNTER_CLOCKWISE	Circular motion in counter clockwise direction, designated by ↓
CLOCKWISE	Circular motion in clockwise direction, designated by ↑
UNIDIRECTIONAL	Worst case of the clockwise or counter clockwise directions

2.13.7 Thermal

# 88	**<THERMAL>:** Performance parameters summarizing thermal errors			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-1	string	Identification of the test(s) from which the parameter set has been extracted
89	<TEST_CLASS>	1	enumeration	Type of thermal test
	<AXIS_NAME>	0-1	string-axis	Name of the tested axis or spindle for the warm-up or transient shut-off test of a spindle or axis.
	<SPINDLE_SPEED>	0-1	float	Spindle speed during a spindle warm-up, transient shut-down, or composite test
	<FEED_RATE>	0-1	float	Feed rate during an axis warm-up or composite test
	<COOLANT>	0-1	boolean	Whether the process-coolant is active during the test
	~~<TRAVEL>~~	~~0-1~~	~~float~~	~~Distance between the two target positions for a test for errors due to heat generated by a moving axis~~
	<SENSOR_OFFSET>	0-1	float	Distance between the two displacement sensors used to measure the thermal drift in the orientation of a spindle axis of rotation
90	<MACHINE_POSITION>	0-1	multi-element	Position of the machine axes at the test location
92	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 89	**<TEST_CLASS>:** Classification of the performance evaluation test
Value	**Definition**
THERMAL_AXIS	Thermal drift due to the heat generated by moving axes.
THERMAL_COMPOSITE	Thermal drift due to the combined effects of the heat generated by the spindle and machine axes.
THERMAL_ETVE	Environmental Temperature Variation Error
THERMAL_SPINDLE	Thermal drift to the heat generated by the spindle (Spindle warm-up and transient shut-off test)

# 90	**<MACHINE_POSITION>:** Position in the machine coordinate frame defined by listing the positions of relevant machine tool axes			
#	**Tag**	**Quantity**	**Type**	**Definition**
91	<AXIS_POSITION>	1-?	multi-element	Position of a machine tool axis

# 91	**<AXIS_POSITION>:** Position of a machine tool axis. No offset for tool, workpiece, fixture, or pallet is applied. The position is specified in the machine coordinate system.			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<AXIS_NAME>	1	string_axis	Name of the axis
	<POSITION>	1	float	Position of the axis

# 92	**<PARAMETER>:** Performance parameter of a thermal test			
#	**Tag**	**Quantity**	**Type**	**Definition**
93	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
94	<MEASURAND>	0-1	enumeration	Definition of the measured or specified error
	<DURATION>	0-1	float	Time over which the specified drift is measured
95	<APPROACH_DIRECTION>	0-1	enumeration	For an axis warm-up test, direction of machine motion to which the specified performance parameter applies
	<TARGET>	0-1	float	For an axis warm-up test, the target position of the tested machine axis where the specified drift is measured

# 93	**<NAME>:** Preferred names for the performance parameters of thermal tests
Value	**Definition**
ETVE	Range of the observed drift during an ETVE test
WARMUP	Range of the observed drift during a warm-up cycle
COOLDOWN	Range of the observed drift during a cool-down cycle
SPECTRUM	Range of the observed drift during a spindle warm-up cycle that contains a spectrum of various spindle speeds
COMPOSITE	Range of the observed drift during a composite thermal test

# 94	**<MEASURAND>:** Measured or specified drift for a thermal test
Value	**Definition**
X	Error in X direction
Y	Error in Y direction
Z	Error in Z direction
A	Angular error around X
B	Angular error around Y

# 94 **<MEASURAND>:** Measured or specified drift for a thermal test	
Value	**Definition**
C	Angular error around Z
XS	Error in X direction at the indicator closest to the spindle face
YS	Error in Y direction at the indicator closest to the spindle face
ZS	Error in Z direction at the indicator closest to the spindle face

# 95 **<APPROACH_DIRECTION>:** Direction of machine motion to which the specified performance parameter applies.	
Value	**Definition**
POSITIVE	Axis moving in positive direction, designated by ↑
NEGATIVE	Axis moving in negative direction, designated by ↓
COUNTER_CLOCKWISE	Axis rotating in counter clockwise direction, designated by ↓
CLOCKWISE	Axis rotating in clockwise direction, designated by ↑

2.13.8 Machine Compliance and Hysteresis

# 96	**<MACHINE_COMPLIANCE>:** Performance parameters summarizing static machine compliance and hysteresis			
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the parameter set has been extracted
97	<TEST_CLASS>	1	enumeration	Classification of the performance evaluation test
98	<DIRECTION>	0-1	enumeration	Direction of the measured compliance and hysteresis
	<AXIS_NAME_ROTARY>	0-1	string_axis	If applicable, name of the rotary axis being tested
	<RADIUS>	0-1	float	Effective arm of the applied force or measured displacement when testing a rotary axis.
	<CLAMPED>	0-1	boolean	Whether the tested rotary axis is clamped during the measurement
	<AXIS_NAME_LOAD>	0-1	string_axis	Name of the axis that generates the load. When an external load is applied this element is empty.
90	<MACHINE_POSITION>	0-1	multi-element	Position of the machine axes at the test location
99	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 97	**<TEST_CLASS>:** Classification of the performance evaluation test
Value	**Definition**
MACHINE_COMPLIANCE	Static machine compliance and hysteresis

# 98	**<DIRECTION:** Direction of the measured compliance and hysteresis
Value	**Definition**
X	X direction
Y	Y direction
Z	Z direction
A	Angle around X
B	Angle around Y
C	Angle around C

# 99	**<PARAMETER>:** Performance parameter for a compliance and hysteresis test			
#	**Tag**	**Quantity**	**Type**	**Definition**

# 99	**<PARAMETER>:** Performance parameter for a compliance and hysteresis test			
#	**Tag**	**Quantity**	**Type**	**Definition**
100	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~

# 100	**<NAME>:** Preferred names for the performance parameters of a compliance and hysteresis test
Value	**Definition**
HYSTERESIS	Hysteresis
COMPLIANCE	Static compliance

2.13.9 Machine performance as a measuring tool

# 101 **<MEASURING>:** Parameters summarizing machine performance as a measuring tool				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the parameter set has been extracted
102	<TEST_CLASS>	1	enumeration	Type of test for the machine performance as a measuring tool
43	<DIMENSIONALITY>	0-1	enumeration	Dimensionality of the measuring task
103	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 102 **<TEST_CLASS>:** Classification of the performance evaluation test	
Value	**Definition**
MEAS_FEATURE	Feature Location Repeatability (FLR), Feature Measurement Accuracy (FMA), Linear Measurement Accuracy (LMA), Vector Repeatability Error (VRE)
MEAS_LOBING	Probe lobing
MEAS_WORKPIECE	Workpiece location

# 103 **<PARAMETER>:** Performance parameter addressing the performance of a machine as a measuring tool				
#	**Tag**	**Quantity**	**Type**	**Definition**
104	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
105	<MEASURAND>	0-1	enumeration	Direction of the measured error

# 104 **<NAME>:** Preferred names for performance parameters addressing the performance of a machine as a measuring tool	
Value	**Definition**
FLR	Feature location repeatability
FMA	Feature measurement accuracy
LMA	Linear measurement accuracy
VRE	Vector repeatability error
VMP	Volumetric measurement performance
LOBING	Probe lobing
WLE	Workpiece location error

# 104	**<NAME>:** Preferred names for performance parameters addressing the performance of a machine as a measuring tool
Value	**Definition**

# 105	**<MEASURAND:** Direction of the feature location repeatability or linear measurement accuracy.
Value	**Definition**
X	X-direction
Y	Y-direction
Z	Z-direction

2.13.10 CNC Performance

# 106 **<CNC>:** Parameters summarizing CNC performance				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the parameter set has been extracted
107	<TEST_CLASS>	1	enumeration	Type of CNC Performance test
	<AXIS_NAME>	0-1	string-axis	Name of the tested axis
	<FEED_RATE>	0-1	float	Nominal feed rate
	<FEED_RATE_PERCENTAGE>	0-1	float	Feed rate as a percentage of the maximum feed rate
108	<INTERPOLATION>	0-1	enumeration	Interpolation mode of the machine tool motion
109	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 107 **<TEST_CLASS>:** Classification of the performance evaluation test	
Value	**Definition**
AXIS_MOTION	Velocity, acceleration, or deceleration of axis motion.
AXIS_LEAST_INCREMENT	Smallest increment at which a machine axis can position in a specified period of time
CNC_MBET	Minimum Block Execution Time
CNC_VSFR	Varying Segment Feed Rate

# 108 **<INTERPOLATION>:** Defines the interpolation mode during a feed rate and acceleration test	
Value	**Definition**
RAPID_TRAVERSE	Rapid traverse mode (usually G00)
LINEAR	Linear interpolation mode (usually G01)

# 109 **<PARAMETER>:** Performance parameter				
#	**Tag**	**Quantity**	**Type**	**Definition**
110	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
95	<APPROACH_DIRECTION>	0-1	enumeration	Direction of motion during the test

# 110 <NAME>: Preferred names for the CNC performance parameters	
Value	**Definition**
MBET_VMAX	Maximum steady feed rate during a test for Minimum Block Execution Time
MBET	Minimum Block Execution Time
LEAST_INCREMENT	Least increment step during a least increment test
REVERSAL	Reversal error during a least increment test
FEED_RATE	Mean actual feed rate
FEED_RATE_ERROR	Difference between the mean actual feed rate and the nominal feed rate
FEED_RATE_RANGE	Observed variation in actual feed rate
TIME_TO_REACH_FEED_RATE	Time to reach 63.2% of the programmed feed rate
ACCELERATION	Estimated mean acceleration during the time to reach 63.2% of programmed feed rate
DECELERATION	Estimated mean deceleration during the time to reduce the programmed feed rate by 63.2%
ACCELERATION_MEAN	Mean acceleration for all axes, feed rates, and approach directions
DECELERATION_MEAN	Mean deceleration for all axes, feed rates, and approach directions

2.13.11 Subsystems Repeatability

# 111 **<SUBSYSTEMS_REPEATABILITY>:** Performance parameters summarizing subsystems repeatability				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the parameter set has been extracted
112	<TEST_CLASS>	1	enumeration	Type of subsystems repeatability test
	<DEVICE_NAME>	0-1	string	Name of the device (e.g., turret, tool changer, pallet changer) whose repeatability is tested
	<TOOL_LENGTH>	0-1	float	Tool length for tool change and gauge line repeatability
	<TOOL_LENGTH_LONG>	0-1	float	Length of the long tool for tool change and turret repeatability
111	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 112 **<TEST_CLASS>:** Classification of the performance evaluation test	
Value	**Definition**
REPEATABILITY_GAGE_LINE	Subsystem repeatability of the gage line for all the pockets on a turret
REPEATABILITY_PALLET	Subsystem repeatability of the pallet changer
REPEATABILITY_TOOL	Subsystem repeatability of the tool changer
REPEATABILITY_TOOL_SETTING	Subsystem repeatability of the tool setting station
REPEATABILITY_TURRET	Subsystem repeatability of turret positioning

# 113 **<PARAMETER>:** Performance parameter				
#	**Tag**	**Quantity**	**Type**	**Definition**
114	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
115	<MEASURAND>	0-1	enumeration	Designation of the tested repeatability

# 114 **<NAME>:** Preferred names for the CNC performance parameters	
Value	**Definition**
REPEATABILITY	Repeatability
REPEATABILITY_LONG	Repeatability associated with a long tool length

# 114 <NAME>: Preferred names for the CNC performance parameters	
Value	**Definition**

# 115 <MEASURAND: Direction of the measured error	
Value	**Definition**
X	X direction
Y	Y direction
Z	Z direction
A	Angle around X
B	Angle around Y
C	Angle around Z
LENGTH	Tool length
DIAMETER	Tool diameter

2.13.12 Cutting Performance Tests

2.13.12.1 Spindle Idle Run Losses Test

# 116 <SPINDLE_IDLE_RUN_LOSSES>: Performance parameters summarizing spindle idle run losses				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the parameter set has been extracted
117	<TEST_CLASS>	1	enumeration	Classification of the test
	<SPINDLE_NAME>	0-1	string_axis	Character(s) identifying the spindle
118	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 117 <TEST_CLASS>: Classification of the performance evaluation test	
Value	**Definition**
SPINDLE_IDLE_RUN_LOSSES	Measurement of lost power due to idle running of the spindle

# 118 <PARAMETER>: Performance parameter				
#	**Tag**	**Quantity**	**Type**	**Definition**
119	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
	<SPINDLE_SPEED_PERCENTAGE >	1	float	Spindle speed expressed as a percentage of the respective maximum speed

# 119 <NAME>: Preferred name for the spindle idle run losses performance parameter	
Value	**Definition**
LOST_POWER	Lost power due to idle running of the spindle at a particular speed

2.13.12.2 Chatter Limits Test

# 120 <CHATTER_LIMITS>: Performance parameters summarizing chatter limits				
#	**Tag**	**Quantity**	**Type**	**Definition**

# 120 **<CHATTER_LIMITS>:** Performance parameters summarizing chatter limits				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the parameter set has been extracted
121	<TEST_CLASS>	1	enumeration	Classification of the test
	<SPINDLE_NAME>	0-1	string_axis	Character(s) identifying the spindle
122	<MACHINE_RANGE>	0-1	enumeration	Classification of the machine according to the maximum spindle torque available
	<TEST_MATERIAL>	0-1	string	Material of the workpiece used in the test
	<CUTTING_TOOL>	0-1	string	Description of cutting tool used in the test
	<SPINDLE_SPEED>	0-1	float	Spindle speed
	<FEED_RATE>	0-1	float	Feed rate
123	<MILLING_TYPE>	0-1	enumeration	Indication of face milling versus end milling
124	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 121 **<TEST_CLASS>:** Classification of the performance evaluation test	
Value	**Definition**
CHATTER_LIMITS	Chatter limits test

# 122 **<MACHINE_RANGE>:** Classification of the machine according to the maximum spindle torque available	
Value	**Definition**
VERY_LIGHT	Maximum spindle torque < 10 Nm
LIGHT	Maximum spindle torque between 10 and 25 Nm
MEDIUM_LIGHT	Maximum spindle torque between 25 and 65 Nm
MEDIUM	Maximum spindle torque between 65 and 150 Nm
MEDIUM_HEAVY	Maximum spindle torque between 150 and 375 Nm
HEAVY	Maximum spindle torque between 375 and 750 Nm

# 123 **<MILLING_TYPE>:** Classification of the milling process	
Value	**Definition**
FACE_MILLING	Milling process where the milled surface generated is flat and perpendicular to the cutter axis.
END_MILLING	Milling process used for profiling

# 124 **<PARAMETER>:** Performance parameter				
#	**Tag**	**Quantity**	**Type**	**Definition**

# 124 **<PARAMETER>:** Performance parameter				
#	**Tag**	**Quantity**	**Type**	**Definition**
125	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
	<CUTTING_DIRECTION>	0-1	axis_string	Machine axis generating feed motion
	<RADIAL_IMMERSION>	0-1	float	Ratio of radial depth of cut to diameter of the cutting tool
126	<MILLING_DIRECTION>	0-1	enumeration	Indication of up-, down-, or slot milling

# 125 **<NAME>:** Preferred names for the chatter limits performance parameters	
Value	**Definition**
B_MAX	Maximum axial depth of cut without chatter
AREA_MAX	Maximum cross-sectional area of cut without chatter

# 126 **<MILLING_DIRECTION>:** Indication of up, down, or slot milling	
Value	**Definition**
<UP>	Up milling
<DOWN>	Down milling
<SLOT>	Slot milling

2.13.12.3 Full Torque Test

# 127 **<FULL_TORQUE>:** Performance parameters summarizing full torque capabilities				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the parameter set has been extracted
128	<TEST_CLASS>	1	enumeration	Classification of the test
	<SPINDLE_NAME>	0-1	string_axis	Character(s) identifying the spindle
122	<MACHINE_RANGE>	0-1	enumeration	Classification of the machine according to the maximum spindle torque available
	<TEST_MATERIAL>	0-1	string	Material of the workpiece used in the test
	<CUTTING_TOOL>	0-1	string	Description of cutting tool used in the test

# 127 **<FULL_TORQUE>:** Performance parameters summarizing full torque capabilities				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<SPINDLE_SPEED>	0-1	float	Speed of the spindle used in the test
	<FEED_RATE>	0-1	float	Axis feedrate used in the test
	<CUTTING_DIRECTION>	0-1	axis_string	Machine axis generating feed motion
126	<MILLING_DIRECTION>	0-1	enumeration	Indication of up milling or down millling
	<RADIAL_DEPTH>	0-1	float	Radial depth of cut
	<AXIAL_DEPTH>	0-1	float	Axial depth of cut
129	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 128 **<TEST_CLASS>:** Classification of the performance evaluation test	
Value	**Definition**
FULL_TORQUE	Full torque test

# 129 **<PARAMETER>:** Performance parameter				
#	**Tag**	**Quantity**	**Type**	**Definition**
130	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
	<EXPECTED_VALUE>	0-1	float	Expected value of the parameter

# 130 **<NAME>:** Preferred names for the chatter limits performance parameters	
Value	**Definition**
POWER	Power
TORQUE	Torque

2.13.12.4 End Milling and Face Milling Deflection Test

# 131 **<MILLING_DEFLECTION>:** Performance parameters summarizing end milling or face milling deflection				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the test(s) from which the

# 131 **<MILLING_DEFLECTION>:** Performance parameters summarizing end milling or face milling deflection				
#	**Tag**	**Quantity**	**Type**	**Definition**
				parameter set has been extracted
132	<TEST_CLASS>	1	enumeration	Classification of the test
	<SPINDLE_NAME>	0-1	string_axis	Character(s) identifying the spindle
122	<MACHINE_RANGE>	0-1	enumeration	Classification of the machine according to the maximum spindle torque available
	<TEST_MATERIAL>	0-1	string	Material of the workpiece used in the test
	<CUTTING_TOOL>	0-1	string	Description of cutting tool used in the test
	<SPINDLE_SPEED>	0-1	float	Speed of the spindle used in the test
	<FEED_RATE>	0-1	float	Axis feedrate used in the test
133	<PARAMETER>	0-?	multi-element	Performance parameter(s)

# 132 **<TEST_CLASS>:** Classification of the performance evaluation test	
Value	**Definition**
END_MILLING_DEFLECTION	Measurement of end mill deflection due to cutting forces
FACE_MILLING_DEFLECTION	Measurement of face mill deflection due to cutting forces

# 133 **<PARAMETER>:** Performance parameter				
#	**Tag**	**Quantity**	**Type**	**Definition**
134	<NAME>	1	string	Name of a performance parameter
	<VALUE>	0-1	float	Estimated value of the parameter
	~~<TOLERANCE>~~	~~0-1~~	~~float~~	~~Tolerance value for the parameter~~
	~~<UNCERTAINTY>~~	~~0-1~~	~~float~~	~~Combined standard measurement uncertainty of the parameter value~~
	<CUTTING_DIRECTION>	0-1	axis_string	Machine axis generating feed motion
	<RADIAL_DEPTH>	0-1	float	Radial depth of cut in case of an end milling deflection test
	<AXIAL_DEPTH>	0-1	float	Axial depth of cut in case of a face milling deflection test
126	<MILLING_DIRECTION>	0-1	enumeration	Indication of up, down, or slot milling
	<RADIAL_IMMERSION>	0-1	float	Ratio of radial depth of cut to diameter of the cutting tool

# 134 **<NAME>:** Preferred names for the end milling and face milling deflection test performance parameters	
Value	**Definition**
ERROR_MAX	Maximum observed deviation from the ideal surface

# 134 <NAME>: Preferred names for the end milling and face milling deflection test performance parameters	
Value	**Definition**
ERROR_RANGE	Range of deviations from the ideal surface

2.14 Machine Errors

This Section contains elements summarizing the errors of a machine tool at a certain instance. The data is extracted from the results of various performance tests. The data can be used to build compensation tables or to simulate the machine errors.

The errors specified according to this standard conform to the following rules:

- Errors are defined as the actual (measured) response of a machine tool minus the nominal or anticipated (commanded) response.
- Errors are defined in the standard machine coordinate system designated by EIA 267 or ISO 841. This coordinate system considers the workpiece stationary and defines the motions of the tool relative to this workpiece:
- A translation error has a positive sign if it corresponds to a positive displacement of the tool relative to the workpiece in the standard machine coordinate system
- An angular error around an axis has a positive sign if it corresponds to a positive rotation of the tool relative to the workpiece around the respective axis of the standard machine coordinate system. Positive rotations are defined using the right-hand rule
- The squareness error between two axes is reported as positive if the angle between the respective positive coordinate axes in the standard machine coordinate system exceeds 90 degrees (Figure 3).
- The parallelism error between two axes is reported as positive if the distance between the actual axes increases when moving along the positive coordinate direction parallel to the axes. ~~of an axis Z to C, e.g., Z to C, is reported as positive if a positive rotation around an axis of the standard machine coordinate system moves axis C to an orientation parallel to Z (Figure 6).~~
- All reported errors correspond to measurement values obtained using the procedures outlined in the referenced machine tool performance standards. This implies that:
  - Error values have been compensated for known systematic errors in instrumentation, reference artifacts, and setup that are unrelated to the specified machine property. The respective compensations are to be performed according to the procedures and accuracy requirements outlined in the standards where the respective tests are described.
  - No corrections have been made for Abbe errors introduced by an offset in the position of the measurement target relative to the tool gage point. The respective Abbe offset is reported with the error values.
- ~~The error values reported for an angular or positioning error of an axis have an arbitrary average value~~
- ~~The straightness error of an axis at a target point is reported relative to the least-squares best-fit line through the respective measurement data.~~

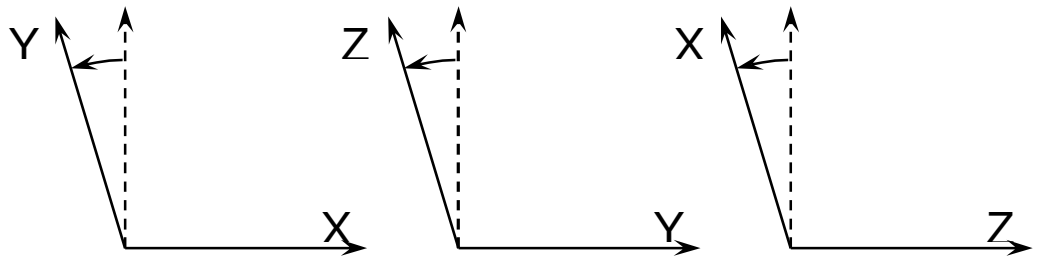

Figure 3: Positive squareness errors.

# 135 **<MACHINE_ERRORS>:** Summary of the machine errors at an instance				
#	**Tag**	**Quantity**	**Type**	**Definition**
136	<GEOMETRY>	0-?	multi-element	Errors in machine geometry at a reference state (positioning, geometric, and alignment errors)

2.14.1 Errors in machine geometry

# 136 **<GEOMETRY>:** Errors in machine geometry at a reference state (positioning, geometric, and alignment errors)				
#	**Tag**	**Quantity**	**Type**	**Definition**
137	<COMPENSATION_STATUS>	0-1	enumeration	Status of the machine tool error compensation
138	<AXIS_GEOMETRY>	0-?	multi-element	Positioning, straightness, and angular errors of a machine tool axis
143	<AXIS_ALIGNMENT>	0-?	multi-element	Alignment error between two machine axes
144	<AXIS_OFFSET>	0-?	multi-element	Offset in the position of the average axis of rotation of a rotary axis

# 137 **<COMPENSATION_STATUS>:** Status of the machine tool error compensation	
Value	**Definition**
BEFORE_COMPENSATION	Data applies to machine errors before compensation
AFTER_COMPENSATION	Data applies to a compensated machine
COMPENSATION	Data is used to generate the machine compensation

# 138 **<AXIS_GEOMETRY>:** Positioning, straightness, and angular errors of a machine tool axis				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-?	string	Identification of the tests on whose data this element is based
	<AXIS_NAME>	1	string_axis	Name of a machine tool axis
	<AXIS_DRIVE_ID>	0-1	string	Identification of the addressed drive for an axis with two drives, each with separate error data.
90	<MACHINE_POSITION>	0-1	multi-element	Position of the machine axes at the line where the errors are defined or measured
139	<MEASUREMENT_OFFSET>	0-1	multi-element	Effective tool offset at the functional point of the error measurement
140	<ERROR_TABLE>	1-?	multi-element	Error values for a particular error source

# 138 **<AXIS_GEOMETRY>:** Positioning, straightness, and angular errors of a machine tool axis				
#	**Tag**	**Quantity**	**Type**	**Definition**
				and approach direction

# 139 **<MEASUREMENT_OFFSET>:** Effective tool offset at the functional point of the measurement as defined in the machine coordinate system				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<X>	0-1	float	Offset in X-direction
	<Y>	0-1	float	Offset in Y-direction
	<Z>	0-1	float	Offset in Z-direction

# 140 **<ERROR_TABLE>:** Error values for a particular error source and approach direction				
#	**Tag**	**Quantity**	**Type**	**Definition**
141	<MEASURAND>	1	enumeration	Specified error
	<TARGETS>	1	list_of_float	Space delimited list of axis positions where the errors are measured
	<PERIODIC>	0-1	boolean	The error table describes a periodic error. The error data between the first and last target point should be repeated over the complete range of axis motion.
142	<APPROACH_DIRECTION>	1	enumeration	Approach direction(s) of the axis for which the error values were obtained
	<ERROR>	1	list_of_float	Space delimited list of the error values. The error values are listed in the same order as the respective target points.

# 141 **<MEASURAND>:** Indication of the listed error motion	
Value	**Definition**
X	Displacement error in X direction
Y	Displacement error in Y direction
Z	Displacement error in Z direction
A	Angular error around the X-axis
B	Angular error around the Y-axis
C	Angular error around the Z-axis

# 142 **<APPROACH_DIRECTION>:** Approach direction(s) of the axis for which the error values were obtained	
Value	**Definition**
BIDIRECTIONAL	Average of both approach directions

# 142 **<APPROACH_DIRECTION>:** Approach direction(s) of the axis for which the error values were obtained	
Value	**Definition**
COUNTER_CLOCKWISE	Axis rotating in counter clockwise direction, designated by ↓
CLOCKWISE	Axis rotating in clockwise direction, designated by ↑
POSITIVE	Axis moving in positive direction, designated by ↑
NEGATIVE	Axis moving in negative direction, designated by ↓

# 143 **<AXIS_ALIGNMENT>:** Alignment error between two axes				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-1	string	Identification designation of the test on whose data this element is based
	<AXIS_NAME_REFERENCE>	1	string_axis	Name of the reference axis
	<AXIS_NAME>	1	string_axis	Name of the second axis
141	<MEASURAND>	1	enumeration	For parallelism, the described alignment angle (A, B, or C)
90	<MACHINE_POSITION>	0-1	multi-element	Position of the machine axes at the point where the alignment error is obtained or defined
	<ERROR>	1	float	Value for the alignment error

# 144 **<AXIS_OFFSET>:** Offset of the average axis of rotation				
#	**Tag**	**Quantity**	**Type**	**Definition**
	<TEST_ID>	0-1	string	Identification designation of the test on whose data this element is based
	<AXIS_NAME_REFERENCE>	0-1	string_axis	Name of the reference axis
	<AXIS_NAME>	1	string_axis	Name of the axis
141	<MEASURAND>	1	enumeration	The described error (X, Y, or Z for the position of the axis of rotation~~, or A, B, or C for the offset in the angle at home position~~)
	<ERROR>	1	float	Value for the offset error

APPENDIX A XML Examples

A.1 Performance

```
<PERFORMANCE>
   <STANDARD>
      <ORGANIZATION>ASME</ORGANIZATION>
      <NUMBER>B5.54</NUMBER>
      <YEAR>2002</YEAR>
   </STANDARD>

   <POSITIONING>
      <TEST_CLASS>AXIS_POSITIONING</TEST_CLASS>
      <AXIS_NAME>X</AXIS_NAME>
      <PARAMETER>
         <NAME>SYSTEMATIC</NAME>
         <VALUE>0.012</VALUE>
         <APPROACH_DIRECTION>BIDIRECTIONAL</APPROACH_DIRECTION>
      </PARAMETER>
      <PARAMETER>
         <NAME>ACCURACY</NAME>
         <VALUE>0.016</VALUE>
         <APPROACH_DIRECTION>BIDIRECTIONAL</APPROACH_DIRECTION>
      </PARAMETER>
   </POSITIONING>

   <POSITIONING>
      <TEST_CLASS>AXIS_POSITIONING</TEST_CLASS>
      <AXIS_NAME>Y</AXIS_NAME>
      <PARAMETER>
         <NAME>SYSTEMATIC</NAME>
         <VALUE>0.008</VALUE>
         <APPROACH_DIRECTION>BIDIRECTIONAL</APPROACH_DIRECTION>
      </PARAMETER>
      <PARAMETER>
         <NAME>ACCURACY</NAME>
         <VALUE>0.010</VALUE>
         <APPROACH_DIRECTION>BIDIRECTIONAL</APPROACH_DIRECTION>
      </PARAMETER>
   </POSITIONING>

   <SPINDLE_AXIS_ROTATION>
      <TEST_CLASS>SPINDLE_AXIS_ROTATION</TEST_CLASS>
      <SPINDLE_NAME>1</SPINDLE_NAME>
      <SPINDLE_SPEED>10000</SPINDLE_SPEED>
      <PARAMETER>
         <NAME>AVERAGE_ERROR_MOTION</NAME>
         <VALUE>0.0004</VALUE>
         <MEASURAND>RADIAL</MEASURAND>
      </PARAMETER>
      <PARAMETER>
         <NAME>AVERAGE_ERROR_MOTION</NAME>
         <VALUE>0.0008</VALUE>
         <MEASURAND>AXIAL</MEASURAND>
      </PARAMETER>
      <PARAMETER>
         <NAME>ASYNCHRONOUS_ERROR_MOTION</NAME>
         <VALUE>0.0006</VALUE>
         <MEASURAND>RADIAL</MEASURAND>
      </PARAMETER>
```

```
   <PARAMETER>
      <NAME>ASYNCHRONOUS_ERROR_MOTION</NAME>
      <VALUE>0.001</VALUE>
      <MEASURAND>AXIAL</MEASURAND>
   </PARAMETER>
</SPINDLE_AXIS_ROTATION>

<CIRCULAR>
   <TEST_CLASS>CIRCULAR</TEST_CLASS>
   <PLANE>
      <AXIS_NAME_1>X</AXIS_NAME_1>
      <AXIS_NAME_2>Y</AXIS_NAME_2>
   </PLANE>
   <RADIUS>150</RADIUS>
   <FEED_RATE>2000</FEED_RATE>

   <PARAMETER>
      <NAME>CIRCULAR_DEVIATION</NAME>
      <VALUE>0.004</VALUE>
      <APPROACH_DIRECTION>CLOCKWISE</APPROACH_DIRECTION>
   </PARAMETER>
   <PARAMETER>
      <NAME>CIRCULAR_DEVIATION</NAME>
      <VALUE>0.006</VALUE>
      <APPROACH_DIRECTION>COUNTER_CLOCKWISE</APPROACH_DIRECTION>
   </PARAMETER>
</CIRCULAR>

<CIRCULAR>
   <TEST_CLASS>CIRCULAR</TEST_CLASS>
   <PLANE>
      <AXIS_NAME_1>X</AXIS_NAME_1>
      <AXIS_NAME_2>Z</AXIS_NAME_2>
   </PLANE>
   <RADIUS>150</RADIUS>
   <FEED_RATE>2000</FEED_RATE>

   <PARAMETER>
      <NAME>CIRCULAR_DEVIATION</NAME>
      <VALUE>0.008</VALUE>
      <APPROACH_DIRECTION>CLOCKWISE</APPROACH_DIRECTION>
   </PARAMETER>
   <PARAMETER>
      <NAME>CIRCULAR_DEVIATION</NAME>
      <VALUE>0.009</VALUE>
      <APPROACH_DIRECTION>COUNTER_CLOCKWISE</APPROACH_DIRECTION>
   </PARAMETER>
</CIRCULAR>

<MACHINE_COMPLIANCE>
   <TEST_CLASS>MACHINE_COMPLIANCE</TEST_CLASS>
   <DIRECTION>X</DIRECTION>
   <AXIS_NAME_LOAD>X</AXIS_NAME_LOAD>

   <MACHINE_POSITION>
      <AXIS_POSITION>
         <AXIS_NAME>X</AXIS_NAME><POSITION>0</POSITION>
      </AXIS_POSITION>
      <AXIS_POSITION>
         <AXIS_NAME>Y</AXIS_NAME><POSITION>200</POSITION>
      </AXIS_POSITION>
      <AXIS_POSITION>
         <AXIS_NAME>Z</AXIS_NAME><POSITION>200</POSITION>
```

```
         </AXIS_POSITION>
      </MACHINE_POSITION>

      <PARAMETER>
         <NAME>HYSTERESIS</NAME>
         <VALUE>0.004</VALUE>
      </PARAMETER>
      <PARAMETER>
         <NAME>COMPLIANCE</NAME>
         <VALUE>0.000020</VALUE>
      </PARAMETER>
   </MACHINE_COMPLIANCE>
</PERFORMANCE>
```

A.2 Errors in Machine Geometry

```
<MACHINE_ERRORS>
   <GEOMETRY>
      <COMPENSATION_STATUS>AFTER_COMPENSATION</COMPENSATION_STATUS>

      <AXIS_GEOMETRY>
         <TEST_ID>X_POS_123</TEST_ID>
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