MTConnect® Specification and Materials

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1 Overview

MTConnect® is a standard based on an open protocol for data integration. MTConnect® is not intended to replace the functionality of existing products, but it strives to enhance the data acquisition capabilities of devices and applications and move toward a plug-and-play environment to reduce the cost of integration.

MTConnect® is built upon the most prevalent standards in the manufacturing and software industry, maximizing the number of tools available for its implementation and providing the highest level of interoperability with other standards and tools in these industries.

To facilitate this level of interoperability, a number of objectives are being met. Foremost is the ability to transfer data via a standard protocol which includes:

• A device identity (i.e. model number, serial number, calibration data, etc.).
• The identity of all the independent components of the device.
• Possibly a device’s design characteristics (i.e. axis length, maximum speeds, device thresholds, etc.).
• Most importantly, data captured in real or near-real-time (i.e. current speed, position data, temperature data, program block, etc.) by a device that can be utilized by other devices or applications (e.g. utilized by maintenance diagnostic systems, management production information systems, CAM products, etc.).

The types of data that may need to be addressed in MTConnect® could include:

• Physical and actual device design data
• Measurement or calibration data
• Near-real-time data from the device

To accommodate the vast amount of different types of devices and information that may come into play, MTConnect® will provide a common high-level vocabulary and structure.

The first version of MTConnect® will focus on a limited set of the characteristics mentioned above that were selected based on the fact that they can have an immediate affect on the efficiency of operations.

1.1 MTConnect® Document Structure

The MTConnect® specification is subdivided using the following scheme:

| Part 1: Overview and Protocol |
| Part 2: Components and Data Items |
| Part 3: Streams, Events, Samples, and Condition |
| Part 4: Assets |

These four documents are considered the bases of the MTConnect standard. Information applicable to basic machine and device types will be included in these documents. Additional parts to the standard will be added to provide information and extensions to the standard focused on specific devices, components, or technologies considered requiring separate emphasis. All
information specific to the topic of each additional part **MUST** be included within that document even when it is a subject matter of one of the base parts of the standard.

Documents will be named (file name convention) as follows:

    MTC_Part_<Number>_<Description>.doc.

For example, the file name for Part 2 of the standard is MTC_Part_2_Components.doc.

All documents will be developed in Microsoft® Word format and released in Adobe® PDF format.
2 Purpose of This Document

The four base MTConnect® documents are intended to:

• define the MTConnect® standard;
• specify the requirements for compliance with the MTConnect® standard;
• provide engineers with sufficient information to implement Agents for their devices;
• provide developers with the necessary guidelines to use the standard to develop applications.

Part 1 of the MTConnect Standard provides an overview of the MTConnect Architecture and Protocol; including communication, fault tolerance, connectivity, and error handling requirements.

Part 2 of the MTConnect® standard focuses on the data model and description of the information that is available from the device. The descriptive data defines how a piece of equipment should be modeled, the structure of the component hierarchy, the names for each component (if restricted), and allowable data items for each of the components.

Part 3 of the MTConnect standard focuses on the data returned from a current or sample request (for more information on these requests, see Part 1). This section covers the data representing the state of the machine.

Part 4 of the MTConnect® standard provides a semantic model for entities that are used in the manufacturing process, but are not considered to be a device nor a component. These entities are defined as MTConnect® Assets. These assets may be removed from a device without detriment to the function of the device, and can be associated with other devices during their lifecycle. The data associated with these assets will be retrieved from multiple sources that are responsible for providing their knowledge of the asset. The first type of asset to be addressed is Tooling.

2.1 Terminology

Adapter An optional software component that connects the Agent to the Device.

Agent A process that implements the MTConnect® HTTP protocol, XML generation, and MTConnect protocol.

Alarm An alarm indicates an event that requires attention and indicates a deviation from normal operation. Alarms are reported in MTConnect as Condition.

Application A process or set of processes that access the MTConnect® Agent to perform some task.

Attribute A part of an XML element that provides additional information about that XML element. For example, the name XML element of the Device is given as <Device name="mill-1">...</Device>

CDATA The text in a simple content element. For example, This is some text, in <Message ...>This is some text</Message>.
Component  A part of a device that can have sub-components and data items. A
     component is a basic building block of a device.

Controlled Vocabulary  The value of an element or attribute is limited to a restricted set of
     possibilities. Examples of controlled vocabularies are country codes: US, JP,
     CA, FR, DE, etc…

Current  A snapshot request to the Agent to retrieve the current values of all the data
     items specified in the path parameter. If no path parameter is given, then the
     values for all components are provided.

Data Item  A data item provides the descriptive information regarding something that can
     be collected by the Agent.

Device  A piece of equipment capable of performing an operation. A device may be
     composed of a set of components that provide data to the application. The
     device is a separate entity with at least one component or data item providing
     information about the device.

Discovery  Discovery is a service that allows the application to locate Agents for devices
     in the manufacturing environment. The discovery service is also referred to as
     the Name Service.

Event  An event represents a change in state that occurs at a point in time. Note: An
     event does not occur at predefined frequencies.

HTTP  Hyper-Text Transport Protocol. The protocol used by all web browsers and
     web applications.

Instance  When used in software engineering, the word instance is used to define a
     single physical example of that type. In object-oriented models, there is the
     class that describes the thing and the instance that is an example of that thing.

LDAP  Lightweight Directory Access Protocol, better known as Active Directory in
     Microsoft Windows. This protocol provides resource location and contact
     information in a hierarchal structure.

MIME  Multipurpose Internet Mail Extensions. A format used for encoding multipart
     mail and http content with separate sections separated by a fixed boundary.

Probe  A request to determine the configuration and reporting capabilities of the
     device.

REST  REpresentational State Transfer. A software architecture where the client and
     server move through a series of state transitions based solely on the request
     from the client and the response from the server.

Results  A general term for the Samples, Events, and Condition contained in a
     ComponentStream as a response from a sample or current request.
Sample
A sample is a data point from within a continuous series of data points. An example of a Sample is the position of an axis.

Socket
When used concerning inter-process communication, it refers to a connection between two end-points (usually processes). Socket communication most often uses TCP/IP as the underlying protocol.

Stream
A collection of Events, Samples, and Condition organized by devices and components.

Service
An application that provides necessary functionality.

Tag
Used to reference an instance of an XML element.

TCP/IP
TCP/IP is the most prevalent stream-based protocol for inter-process communication. It is based on the IP stack (Internet Protocol) and provides the flow-control and reliable transmission layer on top of the IP routing infrastructure.

URI
Universal Resource Identifier. This is the official name for a web address as seen in the address bar of a browser.

UUID
Universally unique identifier.

XPath
XPath is a language for addressing parts of an XML Document. See the XPath specification for more information. http://www.w3.org/TR/xpath

XML

XML Schema
The definition of the XML structure and vocabularies used in the XML Document.

XML Document
An instance of an XML Schema which has a single root XML element and conforms to the XML specification and schema.

XML Element
An element is the central building block of any XML Document. For example, in MTConnect® the Device XML element is specified as <Device>...</Device>

XML NMTOKEN
The data type for XML identifiers. It MUST start with a letter, an underscore “_” or a colon “:” and then it MUST be followed by a letter, a number, or one of the following “.”, “-“,” “,” “:”. An NMTOKEN cannot have any spaces or special characters.

2.2 Terminology and Conventions
Please refer to Part 1 “Overview and Protocol” Section 2 for XML Terminology and Documentation conventions.
3 Cutting Tool and Cutting Tool Archetype

There are two models used to represent a cutting tool, a CuttingToolArchetype and a CuttingTool. The CuttingToolArchitype represent the static cutting tool geometries and nominal values as one would expect from a tool catalog and the CuttingTool represents the use or application of the tool on the shop floor with actual measured values and process data. In version 1.3 it was decided to separate out these two concerns since not all devices will have access to both pieces of information. In this way a generic definition of the cutting tool can coexist with a specific assembly information model with minimal redundancy of data.

Figure 1: Cutting Tool Schema
The following sections will contain the definition of the cutting tool and the cutting tool archetype and describe their unique components. Following that will be a the common entities for both elements.

### 3.1 CuttingTool and CuttingToolArchitype attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>timestamp</td>
<td>The time this asset was last modified. Always given in UTC. The timestamp <strong>MUST</strong> be provided in UTC (Universal Time Coordinate, also known as GMT). This is the time the asset data was last modified.</td>
<td>1</td>
</tr>
<tr>
<td>assetId</td>
<td>The unique identifier of the instance of this tool. This will be the same as the toolId and serialNumber in most cases. The assetId <strong>SHOULD</strong> be the combination of the toolId and serialNumber as in toolId.serialNumber or an equivalent implementation dependent identification scheme.</td>
<td>1</td>
</tr>
<tr>
<td>serialNumber</td>
<td>The unique identifier for this assembly. This is defined as an XML string type and is implementation dependent.</td>
<td>1</td>
</tr>
<tr>
<td>toolId</td>
<td>The identifier for the class of cutting tool. This is defined as an XML string type and is implementation dependent.</td>
<td>1</td>
</tr>
<tr>
<td>deviceUuid</td>
<td>The device’s UUID that supplied this data. This optional element references to the UUID attribute given in the device element. This can be any series of numbers and letters as defined by the XML type NMTOKEN.</td>
<td>1</td>
</tr>
<tr>
<td>manufacturers</td>
<td>The manufacturers of the cutting tool. An optional attribute referring to the manufacturers of this tool, this will reference the Tool Item and Adaptive Items specifically. The Cutting Items manufacturers’ will be an attribute of the CuttingItem elements. The representation will be a comma (,) delimited list of manufacturer names. This can be any series of numbers and letters as defined by the XML type string.</td>
<td>0..1</td>
</tr>
<tr>
<td>removed</td>
<td>This is an indicator that the cutting tool has been removed from the device. If the asset is marked as removed, it will not be visible to the client application unless the <strong>includeRemoved=true</strong> parameter is provided in the URL. If this attribute is not present it <strong>MUST</strong> be assumed to be false. The value is an xsi:boolean type and <strong>MUST</strong> be true or false.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

### 3.2 Description

The description **MAY** contain mixed content, meaning that an additional XML element or plain text may be provided as part of the content of the description tag. Currently the description contains no additional attributes.
4 CuttingToolArchetype

The cutting tool archetype will have the identical structure as the CuttingTool, except for a few entities. The CuttingTool will no longer carry the CuttingToolDefinition, this MUST only appear in the CuttingToolArchetype. The CuttingToolArchetype MUST NOT have measured values and MUST NOT have any of the following items: Status, ToolLife values, Location, or a ReconditionCount.

MTConnect will adopt the ISO 13399 structure when formulating the vocabulary for cutting tool geometries and structure to be represented in the CuttingToolArchetype. The nominal values provided in the CuttingToolLifeCycle section are only concerned with two aspects of the cutting tool, the Cutting Tool and the Cutting Item. The Tool Item, Adaptive Item, and Assembly Item will only be covered in the CuttingToolDefinition section of this document since this section contains the full ISO 13399 information about a Cutting Tool.

Figure 2: Cutting Tool Parts

The previous diagram illustrates the parts of a cutting tool. The cutting tool is the aggregate of all the components and the cutting item is the part of the tool that removes the material from the workpiece. These are the primary focus of MTConnect.
Figure 3: Cutting Tool Composition

Figure 3 provides another view of the cutting tool composition model. The adaptive items and tool items will be used for measurements, but will not be modeled as separate entities. When we are referencing the cutting tool we are referring to the entirety of the assembly and when we provide data regarding the cutting item we are referencing each individual item as illustrated on the left of the previous diagram.

Figures 4 and 5 further illustrates the components of the cutting tool. As we compose the Tool Item, Cutting Item, Adaptive Item, we get a Cutting Tool. The Tool Item, Adaptive Item, and Assembly Item will only be in the CuttingToolDefinition section that will contain the full ISO 13399 information.
Reference ISO13399

Figure 4: Cutting Tool, Tool Item and Cutting Item
The above diagrams use the ISO 13399 codes for each of the measurements. These codes will be translated into the MTConnect vocabulary as illustrated below. The measurements will have a maximum, minimum, and nominal value representing the tolerance of allowable values for this dimension. See below for a full discussion.

**Figure 6: Cutting Tool Measurements**
The MTConnect standard will not define the entire geometry of the cutting tool, but will provide the information necessary to use the tool in the manufacturing process. Additional information can be added to the definition of the cutting tool by means of schema extensions.

Additional diagrams will reference these dimensions by their codes that will be defined in the measurement tables. The codes are consistent with the codes used in ISO 13399 and have been standardized. MTConnect will use the full text name for clarity in the XML document.

The structure of the MTConnectAssets header is defined in Part 1: Overview and Protocol of the standard. A finite number of assets will be stored in the MTConnect agent. This finite number will be implementation specific and will depend on memory and storage constraints. The standard will not prescribe the number or capacity requirements for an implementation.

### 4.1 CuttingToolArchetype Elements

The elements associated with this cutting tool are given below. Each element will be described in more detail below and any possible values will be presented with full definitions. The elements **MUST** be provided in the following order as prescribed by XML. At least one of CuttingToolDefinition or CuttingToolLifeCycle **MUST** be supplied.
4.2 CuttingToolDefinition

The CuttingToolDefinition contains the detailed structure of the cutting tool. The information contained in this element will be static during its lifecycle. Currently we are referring to the external ISO 13399 standard to provide the complete definition and composition of the cutting tool as defined in Section 6.1 of this document.

4.3 CuttingToolDefinition attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>format</td>
<td>Format – EXPRESS, XML, TEXT, or UNDEFINED. Default: XML</td>
<td>0..1</td>
</tr>
</tbody>
</table>

4.3.1 format

The format attribute describes the expected representation of the enclosed data. If no value is given, the assumed format will be XML.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>XML</td>
<td>The default value for the definition. The content will be an XML document.</td>
</tr>
<tr>
<td>EXPRESS</td>
<td>The document will confirm to the ISO 10303 standard. STEP-NC part 21 file formats.</td>
</tr>
<tr>
<td>TEXT</td>
<td>The document will be a text representation of the tool data.</td>
</tr>
<tr>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>-------------</td>
<td>--------------------------------------------------</td>
</tr>
<tr>
<td>UNDEFINED</td>
<td>The document will be provided in an undefined format.</td>
</tr>
</tbody>
</table>

4.4 **CuttingToolDefinition Elements**

The only acceptable cutting tool definition at present is ISO 13399. Additional formats **MAY** be considered in the future.

4.5 **ISO 13399**

The ISO 13399 data **MUST** be presented in either XML (ISO 10303-28) or EXPRESS format (ISO 10303-21). An XML schema will be preferred as this will allow for easier integration with the MTConnect XML tools. EXPRESS will also be supported, but software tools will need to be provided or made available for handling this data representation.

There will be the root element of the ISO13399 document when XML is used. When EXPRESS is used the XML element will be replaced by the text representation.
## 5 CuttingTool

A Cutting Tool, also referred to as an assembly in this document, is an assembly of items for removing material from a work-piece through a shearing action at the defined cutting edge or edges of the Cutting Item. A Cutting Tool can be a single item or an assembly of one or more Adaptive Items, a Tool Item and several Cutting Items on a Tool Item.

### 5.1 CuttingTool Elements

The elements associated with this cutting tool are given below. Each element will be described in more detail below and any possible values will be presented with full definitions. The elements MUST be provided in the following order as prescribed by XML. At least one of CuttingToolDefinition or CuttingToolLifeCycle MUST be supplied.

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>An element that can contain any descriptive content. This can contain configuration information and manufacturer specific details. This element is defined to contain mixed content and XML elements can be added to extend the descriptive semantics of MTConnect.</td>
<td>0..1</td>
</tr>
<tr>
<td>CuttingToolDefinition</td>
<td>Reference to a ISO 13399, DEPRECATED for CuttingTool.</td>
<td>0..1</td>
</tr>
<tr>
<td>CuttingToolLifeCycle</td>
<td>MTConnect data regarding the use phase of this tool.</td>
<td>0..1</td>
</tr>
<tr>
<td>CuttingToolArchetypeReference</td>
<td>The content of this XML element is the Asset Id of the CuttingToolArchetype document. It MAY also contain a source attribute that gives the URL of the archetype data as well.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

### 5.2 CuttingToolArchetypeReference

This element references another asset document providing the static geometries and nominal values for all the measurements. This reduces the amount of data duplication as well as providing a mechanism for asset definitions to be provided before complete measurement has occurred.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source</td>
<td>The URL of the CuttingToolArchetype document. This MUST be a fully qualified URL as in <a href="http://example.com/asset/A213155">http://example.com/asset/A213155</a></td>
<td>0..1</td>
</tr>
</tbody>
</table>

Figure 2: Cutting Tool Archetype Reference

Generated by XMLSpy [www.altova.com](http://www.altova.com)
The elements of the CutterStatus element can be a combined set of Status elements. The standard allows any set of statuses to be combined, but only certain combinations make sense. A cutting tool SHOULD not be both NEW and USED at the same time. There are no rules in the schema to enforce this, but this is left to the implementer. The following combinations MUST NOT occur:

- **NEW** MUST NOT be used with USED, RECONDITIONED, or EXPIRED.
- **UNKNOWN** MUST NOT be used with any other status.
- **ALLOCATED** and **UNALLOCATED** MUST NOT be used together.
- **AVAILABLE** and **UNAVAILABLE** MUST NOT be used together.
- If the tool is **EXPIRED**, **BROKEN**, or **NOT_REGISTERED** it MUST NOT be **AVAILABLE**.
- All other combinations are allowed.

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Status</td>
<td>The status of the cutting tool. There can be multiple Status elements.</td>
<td>1..INF</td>
</tr>
</tbody>
</table>

### 5.3.1 Status

One of the values for the status of the cutting tool.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEW</td>
<td>A new tool that has not been used or first use. Marks the start of the tool history.</td>
</tr>
<tr>
<td>AVAILABLE</td>
<td>Indicates the tool is available for use. If this is not present, the tool is currently not ready to be used</td>
</tr>
<tr>
<td>UNAVAILABLE</td>
<td>Indicates the tool is unavailable for use in metal removal. If this is not present, the tool is currently not ready to be used</td>
</tr>
<tr>
<td>ALLOCATED</td>
<td>Indicates if this tool is has been committed to a device for use and is not available for use in any other device. If this is not present, this tool has not been allocated for this device and can be used by another device</td>
</tr>
<tr>
<td>UNALLOCATED</td>
<td>Indicates this Cutting Tool has not been committed to a process and can be allocated.</td>
</tr>
</tbody>
</table>
### Value

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MEASURED</td>
<td>The tool has been measured.</td>
</tr>
<tr>
<td>RECONDITIONED</td>
<td>The cutting tool has been reconditioned. See <code>ReconditionCount</code> for the number of times this cutter has been reconditioned.</td>
</tr>
<tr>
<td>USED</td>
<td>The tool is in process and has remaining tool life.</td>
</tr>
<tr>
<td>EXPIRED</td>
<td>The cutting tool has reached the end of its useful life.</td>
</tr>
<tr>
<td>BROKEN</td>
<td>Premature tool failure.</td>
</tr>
<tr>
<td>NOT_REGISTERED</td>
<td>This cutting tool cannot be used until it is entered into the system.</td>
</tr>
<tr>
<td>UNKNOWN</td>
<td>The cutting tool is an indeterminate state. This is the default value.</td>
</tr>
</tbody>
</table>

### 5.4 Location

This is the optional device specific pocket id providing the current pocket number this tool resides in. This can be any series of numbers and letters as defined by the XML type `NMTOKEN`. When a `POT` or `STATION` type is used, the value **MUST** be a numeric value. If a `negativeOverlap` or the `positiveOverlap` is provided, the tool reserves additional locations on either side, otherwise if they are not given, no additional locations are required for this tool. If the pot occupies the first or last location, a rollover to the beginning or the end of the index-able values may occur. For example, if there are 64 pots and the tool is in pot 64 with a `positiveOverlap` of 1, the first pot **MAY** be occupied as well.

#### 5.4.1 Location attributes:

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>The type of location being identified. Current <strong>MUST</strong> be one of <code>POT</code>, <code>STATION</code>, or <code>CRIB</code>.</td>
<td>1</td>
</tr>
<tr>
<td>positiveOverlap</td>
<td>The number of locations at higher index value from this location.</td>
<td>0..1</td>
</tr>
<tr>
<td>negativeOverlap</td>
<td>The number of location at lower index values from this location.</td>
<td>0..1</td>
</tr>
</tbody>
</table>
5.4.2 type

The type of location being identifier.

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>POT</td>
<td>The number of the pot in the tool handling system.</td>
</tr>
<tr>
<td>STATION</td>
<td>The tool location in a horizontal turning machine.</td>
</tr>
<tr>
<td>CRIB</td>
<td>The location with regard to a tool crib.</td>
</tr>
</tbody>
</table>

5.4.3 positiveOverlap

The number of locations at higher index values that the cutting tool occupies due to interference. The value MUST be an integer. If not provided it is assumed to be 0.

5.4.4 negativeOverlap

The number of locations at lower index values that the cutting tool occupies due to interference. The value MUST be an integer. If not provided it is not assumed to be 0.

The tool number assigned in the part program and is used for cross referencing this tool information with the process parameters. The value MUST be an integer.

5.5 ReconditionCount

This element MUST contain an integer value as the CDATA that represents the number of times the cutter has been reconditioned.

5.5.1 ReconditionCount attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximumCount</td>
<td>The maximum number of times this tool may be reconditioned</td>
<td>0..1</td>
</tr>
</tbody>
</table>
6 Common Entities

6.1 CuttingToolLifeCycle

The life cycle refers to the data pertaining the the application or the use of the tool. This data is provided by various devices, machine tool, presetters, and statistical process control applications. Life cycle data will not remain static, but will change periodically when a tool is used or measured. The life cycle has three conceptual parts; tool and cutting item identity, properties, and measurements. A measurement is defined as a constrained value that is reported in defined units and as a W3C floating point format.

The CuttingToolLifeCycle contains data for the entire tool assembly. The specific cutting items that are part of the CuttingToolLifeCycle are contained in the CuttingItems element. Each cutting item has similar properties as the assembly; identity, properties, and measurements.

The units for all measurements have been predefined in MTConnect and will be consistent with Part 2 and Part 3 of the standard. This means that all lengths and distances will be given in millimeters and all angular measures will be given in degrees. Quantities like ProcessSpindleSpeed will be given in RPM, the same as the RotaryVelocity in Part 3.
Figure 5: Cutting Tool Life Cycle
6.2 CuttingToolLifeCycle Elements

The elements associated with this cutting tool are given below. Each element will be described in more detail below and any possible values will be presented with full definitions. The elements MUST be provided in the following order as prescribed by XML.

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>CutterStatus</td>
<td>The status of the this assembly. Can be one more of the following values: NEW, AVAILABLE, UNAVAILABLE, ALLOCATED, UNALLOCATED, MEASURED, RECONDITIONED, NOT_REGISTERED, USED, EXPIRED, BROKEN, or UNKNOWN.</td>
<td>1</td>
</tr>
<tr>
<td>ReconditionCount</td>
<td>The number of times this cutter has been reconditioned.</td>
<td>0..1</td>
</tr>
<tr>
<td>ToolLife</td>
<td>The cutting tool life as related to this assembly</td>
<td>0..1</td>
</tr>
<tr>
<td>Location</td>
<td>The location this tool now resides in.</td>
<td>0..1</td>
</tr>
<tr>
<td>ProgramToolGroup</td>
<td>The tool group this tool is assigned in the part program.</td>
<td>0..1</td>
</tr>
<tr>
<td>ProgramToolNumber</td>
<td>The number of the tool as referenced in the part program.</td>
<td>0..1</td>
</tr>
<tr>
<td>ProcessSpindleSpeed</td>
<td>The constrained process spindle speed for this tool</td>
<td>0..1</td>
</tr>
<tr>
<td>ProcessFeedRate</td>
<td>The constrained process feed rate for this tool in mm/s.</td>
<td>0..1</td>
</tr>
<tr>
<td>ConnectionCodeMachineSide</td>
<td>Identifier for the capability to connect any component of the cutting tool together, except assembly items, on the machine side. Code: CCMS</td>
<td>0..1</td>
</tr>
<tr>
<td>Measurements</td>
<td>A collection of measurements for the tool assembly.</td>
<td>0..1</td>
</tr>
<tr>
<td>CuttingItems</td>
<td>An optional set of individual cutting items.</td>
<td>0..1</td>
</tr>
<tr>
<td>xs:any</td>
<td>Any additional properties not in the current document model. MUST be in separate XML namespace.</td>
<td>0..n</td>
</tr>
</tbody>
</table>

6.3 ProgramToolGroup

The optional identifier for the group of cutting tools when multiple tools can be used interchangeably. This is defined as an XML string type and is implementation dependent.

6.4 ProgramToolNumber

The tool number assigned in the part program and is used for cross referencing this tool information with the process parameters. The value MUST be an integer.
6.5 ToolLife:

![ToolLife Diagram]

The value is the current value for the tool life. The value **MUST** be a number. Tool life is an option element which can have three types, either minutes for time based, part count for parts based, or wear based using a distance measure. One tool life element can appear for each type, but there cannot be two entries of the same type. Additional types can be added in the future.

6.5.1 ToolLife attributes:

These is an optional attribute that can be used to further classify the operation type.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>The type of tool life being accumulated. MINUTES, PART_COUNT, or WEAR</td>
<td>1</td>
</tr>
<tr>
<td>countDirection</td>
<td>Indicates if the tool life counts from zero to maximum or maximum to zero, The values <strong>MUST</strong> be one of UP or DOWN.</td>
<td>1</td>
</tr>
<tr>
<td>warning</td>
<td>The point at which a tool life warning will be raised.</td>
<td>0..1</td>
</tr>
<tr>
<td>limit</td>
<td>The end of life limit for this tool. If the countDirection is DOWN, the point at which this tool should be expired, usually zero. If the countDirection is UP, this is the upper limit for which this tool should be expired.</td>
<td>0..1</td>
</tr>
<tr>
<td>initial</td>
<td>The initial life of the tool when it is new.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

6.5.1.1 ToolLife type attribute:

The value of type must be one of the following:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINUTES</td>
<td>The tool life measured in minutes. All units for minimum, maximum, and warningLevel <strong>MUST</strong> be provided in minutes.</td>
</tr>
<tr>
<td>Value</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>PART_COUNT</td>
<td>The tool life measured in parts. All units for minimum, maximum, and warningLevel MUST be provided supplied as the number of parts.</td>
</tr>
<tr>
<td>WEAR</td>
<td>The tool life measured in tool wear. Wear MUST be provided in millimeters as an offset to nominal. All units for minimum, maximum, and warningLevel MUST be given as millimeter offsets as well. The standard will only consider dimensional wear at this time.</td>
</tr>
</tbody>
</table>

### 6.5.1.2 ToolLife countDirection attribute:

The value of type must be one of the following:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOWN</td>
<td>The tool life counts down from the maximum to zero.</td>
</tr>
<tr>
<td>UP</td>
<td>The tool life counts up from zero to the maximum.</td>
</tr>
</tbody>
</table>

### 6.6 ProcessSpindleSpeed

The Process Spindle Speed MUST be specified in revolutions/minute (RPM). The CDATA MAY contain the process target spindle speed if available. The maximum and minimum speeds MAY be provided as attributes. At least one value MUST be provided.

#### 6.6.1 ProcessSpindleSpeed attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum</td>
<td>The upper bound for the tool’s target spindle speed</td>
<td>0..1</td>
</tr>
<tr>
<td>minimum</td>
<td>The lower bound for the tool’s spindle speed.</td>
<td>0..1</td>
</tr>
<tr>
<td>nominal</td>
<td>The nominal speed the tool is designed to operate at.</td>
<td>0..1</td>
</tr>
</tbody>
</table>
6.7 ProcessFeedRate

The Process Feed Rate **MUST** be specified in millimeters/second (mm/s). The CDATA **MAY** contain the process target feed rate if available. The maximum and minimum rates **MAY** be provided as attributes. At least one value **MUST** be provided.

6.7.1 ConnectionCodeMachineSide

This is an optional identifier for implementation specific connection component of the cutting tool on the machine side. Code: CCMS. The CDATA **MAY** be any valid string according to the referenced connection code standards.

6.7.2 ProcessSpindleSpeed attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>maximum</td>
<td>The upper bound for the tool's process target feed rate</td>
<td>0..1</td>
</tr>
<tr>
<td>minimum</td>
<td>The lower bound for the tool's feed rate.</td>
<td>0..1</td>
</tr>
<tr>
<td>nominal</td>
<td>The nominal feed rate the tool is designed to operate at.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

6.7.3 xs:any

Utilizing the new capability in XMLSchema 1.1, we are now able to add extension points where an additional element can be added to the document without being part of a substitution group. The new elements have the restriction that they **MUST NOT** be part of the MTConnect namespace and **MUST NOT** be one of the predefined elements mentioned above.

This will allow users to add additional properties to the Cutting Tool without having to change the definition of the Cutting Tool or modify the standard. We will be making use of this capability in version 1.3 of MTConnect which will necessitate upgrading to version 1.1 of XMLSchema.

6.8 Measurements

The Measurements element is a collection of one or more constrained scalar values associated with this cutting tool. The contents **MUST** be a subtype of CommonMeasurement or AssemblyMeasurement. The following section will define the abstract Measurement type used in both CuttingToolLifeCycle and CuttingItem. This section will then describe
the AssemblyMeasurement types. The CuttingItemMeasurement types will be
described at the end of the CuttingItem section.

A measurement is specific to a process and a machine tool at a particular shop. The tool zero
reference point or gauge line will be different depending on the particular implementation and
will be assumed to be consistent within the shop. MTConnect does not standardize the
manufacturing process or the definition of the zero point.

6.9 Measurement

Figure 9: Measurement

A measurement MUST be a scalar floating point value that MAY be constrained to a maximum
and minimum value. Since the CuttingToolLifeCycle’s main responsibility is to track
aspects of the tool that change over it’s use in the shop, MTConnect represents the current value
of the measurement MUST be in the CDATA (text between the start and end element) as the most
current valid value.

The minimum and maximum MAY be supplied if they are known or relevant to the
measurement. A nominal value MAY be provided to show the reference value for this
measurement.

There are three subtypes of Measurement: CommonMeasurement,
AssemblyMeasurement, and CuttingItemMeasurement. These abstract types MUST
NOT appear in an MTConnectAssets document, but are used in the schema as a way to
separate which measurements MAY appear in the different sections of the document. Only
subtypes that have extended these types MAY appear in the MTConnectAssets XML.

Measurements in the CuttingToolLifeCycle section MUST refer to the entire assembly and not
to an individual cutting item. Cutting item measurements MUST be located in the measurements
associated with the individual Cutting Item.
Measurements **MAY** provide an optional `units` attribute to reinforce the given units. The units **MUST** always be given in the predefined MTConnect units. If `units` are provided, they are only for documentation purposes. `nativeUnits` **MAY** optionally be provided to indicate the original units provided for the measurements.

### 6.9.1 Measurement attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>code</td>
<td>A shop specific code for this measurement. ISO 13399 codes <strong>MAY</strong> be used to for these codes as well.</td>
<td>0..1</td>
</tr>
<tr>
<td>maximum</td>
<td>The maximum value for this measurement. Exceeding this value would indicate the tool is not usable.</td>
<td>0..1</td>
</tr>
<tr>
<td>minimum</td>
<td>The minimum value for this measurement. Exceeding this value would indicate the tool is not usable.</td>
<td>0..1</td>
</tr>
<tr>
<td>nominal</td>
<td>The as advertised value for this measurement.</td>
<td>0..1</td>
</tr>
<tr>
<td>significantDigits</td>
<td>The number of significant digits in the reported value. This is used by applications to determine accuracy of values. This <strong>MAY</strong> be specified for all numeric values.</td>
<td>0..1</td>
</tr>
<tr>
<td>units</td>
<td>The units for the measurements. MTConnect defines all the units for each measurement, so this is mainly for documentation sake. See <em>MTConnect Part 2 – Components and Data Items</em> section 4.1.5: <code>units</code> for the full list.</td>
<td>0..1</td>
</tr>
<tr>
<td>nativeUnits</td>
<td>The units the measurement was originally recorded in. This is only necessary if they differ from units. See <em>MTConnect Part 2 – Components and Data Items</em> section 4.1.8: <code>nativeUnits</code> for the full list.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

### 6.10 CuttingToolMeasurement subtypes

These measurements are specific to the entire assembly and **MUST NOT** be used for the measurement pertaining to a `CuttingItem`. The following diagram will be used to for reference for the assembly specific measurements.

The Code in the following table will refer to the acronyms in the diagrams. We will be referring to many diagrams to disambiguate all measurements of the `CuttingTool` and `CuttingItem`. 
Figure 10: Cutting Tool Measurement Diagram 1
(Cutting Item, Tool Item, and Adaptive Item – ISO 13399)

Figure 11: Cutting Tool Measurement Diagram 2
(Cutting Item, Tool Item, and Adaptive Item – ISO 13399)

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Code</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>BodyDiameterMax</td>
<td>BDX</td>
<td>The largest diameter of the body of a tool item.</td>
<td>mm</td>
</tr>
<tr>
<td>Measurement</td>
<td>Code</td>
<td>Description</td>
<td>Units</td>
</tr>
<tr>
<td>------------------------------</td>
<td>-------</td>
<td>------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>BodyLengthMax</td>
<td>LBX</td>
<td>The distance measured along the X axis from that point of the item closest to the workpiece, including the cutting item for a tool item but excluding a protruding locking mechanism for an adaptive item, to either the front of the flange on a flanged body or the beginning of the connection interface feature on the machine side for cylindrical or prismatic shanks.</td>
<td>mm</td>
</tr>
<tr>
<td>DepthOfCutMax</td>
<td>APMX</td>
<td>The maximum engagement of the cutting edge or edges with the workpiece measured perpendicular to the feed motion.</td>
<td>mm</td>
</tr>
<tr>
<td>CuttingDiameterMax</td>
<td>DC</td>
<td>The maximum diameter of a circle on which the defined point Pk of each of the master inserts is located on a tool item. The normal of the machined peripheral surface points towards the axis of the cutting tool.</td>
<td>mm</td>
</tr>
<tr>
<td>FlangeDiameterMax</td>
<td>DF</td>
<td>The dimension between two parallel tangents on the outside edge of a flange.</td>
<td>mm</td>
</tr>
<tr>
<td>OverallToolLength</td>
<td>OAL</td>
<td>The largest length dimension of the cutting tool including the master insert where applicable.</td>
<td>mm</td>
</tr>
<tr>
<td>ShankDiameter</td>
<td>DMM</td>
<td>The dimension of the diameter of a cylindrical portion of a tool item or an adaptive item that can participate in a connection.</td>
<td>mm</td>
</tr>
<tr>
<td>ShankHeight</td>
<td>H</td>
<td>The dimension of the height of the shank.</td>
<td>mm</td>
</tr>
<tr>
<td>ShankLength</td>
<td>LS</td>
<td>The dimension of the length of the shank.</td>
<td>mm</td>
</tr>
<tr>
<td>UsableLengthMax</td>
<td>LUX</td>
<td>Maximum length of a cutting tool that can be used in a particular cutting operation including the non-cutting portions of the tool.</td>
<td>mm</td>
</tr>
<tr>
<td>ProtrudingLength</td>
<td>LPR</td>
<td>The dimension from the yz-plane to the furthest point of the tool item or adaptive item measured in the -X direction.</td>
<td>mm</td>
</tr>
<tr>
<td>Weight</td>
<td>WT</td>
<td>The total weight of the cutting tool in grams. The force exerted by the mass of the cutting tool.</td>
<td>grams</td>
</tr>
<tr>
<td>FunctionalLength</td>
<td>LF</td>
<td>The distance from the gauge plane or from the end of the shank to the furthest point on the tool, if a gauge plane does not exist, to the cutting reference point determined by the main function of the tool. The CuttingTool functional length will be the length of the entire tool, not a single cutting item. Each CuttingItem can have an independent FunctionalLength represented in its measurements.</td>
<td>mm</td>
</tr>
</tbody>
</table>
6.11 CuttingItems

An optional collection of cutting items that SHOULD be provided for each independent edge or insert. If the CuttingItems are not present; it indicates there is no specific information with respect to each of the cutting items. This does not imply there are no cutting items – there MUST be at least one cutting item – but there is no specific information.

### 6.11.1 CuttingItems attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>count</td>
<td>The number of cutting items.</td>
<td>1</td>
</tr>
</tbody>
</table>

6.12 CuttingItem

A cutting item is the portion of the tool that physically removes the material from the workpiece by shear deformation. The cutting item can be either a single piece of material attached to the tool item or it can be one or more separate pieces of material attached to the tool item using a permanent or removable attachment. A cutting item can be comprised of one or more cutting edges. Cutting items include: replaceable inserts, brazed tips and the cutting portions of solid cutting tools.

MTConnect considers Cutting Items as part of the Cutting Tool. A Cutting Item MUST NOT exist in MTConnect unless it is attached to a cutting tool. Some of the measurements, such as FunctionalLength, MUST be made with reference to the entire cutting tool to be meaningful.
6.12.1 CuttingItem attributes

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>indices</td>
<td>The number or numbers representing the individual cutting item or items on the tool.</td>
<td>1</td>
</tr>
<tr>
<td>itemId</td>
<td>The manufacturer identifier of this cutting item</td>
<td>0..1</td>
</tr>
<tr>
<td>manufacturers</td>
<td>The manufacturers of the cutting item</td>
<td>0..1</td>
</tr>
<tr>
<td>grade</td>
<td>The material composition for this cutting item</td>
<td>0..1</td>
</tr>
</tbody>
</table>

6.12.2 indices

An identifier that indicates the cutting item or items these data are associated with. The value MUST a single numbers ("1") or a comma separated set of individual elements ("1,2,3,4"), or as
a inclusive range of values as in ("1-10") or any combination of ranges and numbers as in "1-4,6-10,22". There MUST NOT be spaces or non-integer values in the text representation.

Indices SHOULD start numbering with the inserts or cutting items furthest from the gauge line and increasing in value as the items get closer to the gauge line. Items at the same distance MAY be arbitrarily numbered.

### 6.12.3 itemId
The manufactures’ identifier for this cutting item that MAY be the its catalog or reference number. The value MUST be an XML NMTOKEN value of numbers and letters.

### 6.12.4 manufacturers
This optional element references the manufacturers of this tool. At this level the manufacturers will reference the Cutting Item specifically. The representation will be a comma (,) delimited list of manufacturer names. This can be any series of numbers and letters as defined by the XML type string.

### 6.12.5 grade
This provides an implementation specific designation for the material composition of this cutting item.

### 6.13 A CuttingItem contains the following elements.

<table>
<thead>
<tr>
<th>Element</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>A free-form description of the cutting item.</td>
<td>0..1</td>
</tr>
<tr>
<td>Locus</td>
<td>A free form description of the location on the cutting tool.</td>
<td>0..1</td>
</tr>
<tr>
<td>ItemLife</td>
<td>The life of this cutting item.</td>
<td>0..3</td>
</tr>
<tr>
<td>Measurements</td>
<td>A collection of measurements relating to this cutting item.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

### 6.14 Description
An optional free form text description of this cutting item.

### 6.15 Locus
Locus represents the location of the cutting item with respect to the cutting tool. For clarity, the words FLUTE, INSERT, and CARTRIDGE SHOULD be used to assist in noting the location of a cutting item. The Locus MAY be any free form text, but SHOULD adhere to the following rules:

1. The location numbering SHOULD start at the furthest cutting item (#1) and work it’s way back to the cutting item closest to the gauge line.

2. Flutes SHOULD be identified as such using the word FLUTE:. For example: FLUTE: 1, INSERT: 2 - would indicate the first flute and the second furthest insert from the end of the tool on that flute.
3. Other designations such as CARTRIDGE MAY be included, but should be identified using upper case and followed by a colon (:).

6.16 ItemLife

The value is the current value for the tool life. The value MUST be a number. Tool life is an option element which can have three types, either minutes for time based, part count for parts based, or wear based using a distance measure. One tool life can appear for each type, but there cannot be two entries of the same type. Additional types can be added in the future.

6.16.1 ItemLife attributes:

These is an optional attribute that can be used to further classify the operation type.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
<th>Occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>The type of tool life being accumulated. MINUTES, PART_COUNT, or WEAR</td>
<td>1</td>
</tr>
<tr>
<td>countDirection</td>
<td>Indicates if the tool life counts from zero to maximum or maximum to zero. The values MUST be one of UP or DOWN.</td>
<td>1</td>
</tr>
<tr>
<td>warning</td>
<td>The point at which a tool life warning will be raised.</td>
<td>0..1</td>
</tr>
<tr>
<td>limit</td>
<td>The end of life limit for this tool. If the countDirection is DOWN, the point at which this tool should be expired, usually zero. If the countDirection is UP, this is the upper limit for which this tool should be expired.</td>
<td>0..1</td>
</tr>
<tr>
<td>initial</td>
<td>The initial life of the tool when it is new.</td>
<td>0..1</td>
</tr>
</tbody>
</table>

6.16.1.1 ItemLife type attribute:

The value of type must be one of the following:
<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MINUTES</td>
<td>The tool life measured in minutes. All units for minimum, maximum, and warningLevel MUST be provided in minutes.</td>
</tr>
<tr>
<td>PART_COUNT</td>
<td>The tool life measured in parts. All units for minimum, maximum, and warningLevel MUST be provided supplied as the number of parts.</td>
</tr>
<tr>
<td>WEAR</td>
<td>The tool life measured in tool wear. Wear MUST be provided in millimeters as an offset to nominal. All units for minimum, maximum, and warningLevel MUST be given as millimeter offsets as well.</td>
</tr>
</tbody>
</table>

### 6.16.1.2 ItemLife direction attribute:

The value of type must be one of the following:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DOWN</td>
<td>The tool life counts down from the maximum to zero.</td>
</tr>
<tr>
<td>UP</td>
<td>The tool life counts up from zero to the maximum.</td>
</tr>
</tbody>
</table>

### 6.17 CuttingItemMeasurement subtypes

These measurements are specific to an individual cutting item and MUST NOT be used for the measurement pertaining to an assembly. The following diagram will be used to for reference for the cutting item specific measurements.

The Code in the following table will refer to the acronym in the diagram. We will be referring to many diagrams to disambiguate all measurements of the cutting tools and items. We will present a few here; please refer to Appendix B for additional reference material.
Figure 15: Cutting Tool

Figure 16: Cutting Item
The following CuttingItem Measurements will refer the diagram above.

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Code</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuttingReferencePoint</td>
<td>CRP</td>
<td>The theoretical sharp point of the cutting tool from which the major functional dimensions are taken.</td>
<td>mm</td>
</tr>
<tr>
<td>CuttingEdgeLength</td>
<td>L</td>
<td>The theoretical length of the cutting edge of a cutting item over sharp corners.</td>
<td>mm</td>
</tr>
<tr>
<td>DriveAngle</td>
<td>DRVA</td>
<td>Angle between the driving mechanism locator on a tool item and the main cutting edge</td>
<td>degree</td>
</tr>
<tr>
<td>Measurement</td>
<td>Code</td>
<td>Description</td>
<td>Units</td>
</tr>
<tr>
<td>--------------------------</td>
<td>------</td>
<td>------------------------------------------------------------------------------</td>
<td>-------</td>
</tr>
<tr>
<td>Flange Diameter</td>
<td>DF</td>
<td>The dimension between two parallel tangents on the outside edge of a flange.</td>
<td>mm</td>
</tr>
<tr>
<td>Functional Width</td>
<td>WF</td>
<td>The distance between the cutting reference point and the rear backing surface of a turning tool or the axis of a boring bar.</td>
<td>mm</td>
</tr>
<tr>
<td>Inscribed Circle Diameter</td>
<td>IC</td>
<td>The diameter of a circle to which all edges of an equilateral and round regular insert are tangential.</td>
<td>mm</td>
</tr>
<tr>
<td>Point Angle</td>
<td>SIG</td>
<td>The angle between the major cutting edge and the same cutting edge rotated by 180 degrees about the tool axis.</td>
<td>degree</td>
</tr>
<tr>
<td>Tool Cutting Edge Angle</td>
<td>KAPR</td>
<td>The angle between the tool cutting edge plane and the tool feed plane measured in a plane parallel the xy-plane.</td>
<td>degree</td>
</tr>
<tr>
<td>Tool Lead Angle</td>
<td>PSIR</td>
<td>The angle between the tool cutting edge plane and a plane perpendicular to the tool feed plane measured in a plane parallel the xy-plane.</td>
<td>degree</td>
</tr>
<tr>
<td>Tool Orientation</td>
<td>N/A</td>
<td>The angle of the tool with respect to the workpiece for a given process. The value is application specific.</td>
<td>degree</td>
</tr>
<tr>
<td>Wiper Edge Length</td>
<td>BS</td>
<td>The measure of the length of a wiper edge of a cutting item.</td>
<td>mm</td>
</tr>
<tr>
<td>Step Diameter Length</td>
<td>SDLx</td>
<td>The length of a portion of a stepped tool that is related to a corresponding cutting diameter measured from the cutting reference point of that cutting diameter to the point on the next cutting edge at which the diameter starts to change.</td>
<td>mm</td>
</tr>
<tr>
<td>Step Included Angle</td>
<td>STAx</td>
<td>The angle between a major edge on a step of a stepped tool and the same cutting edge rotated 180 degrees about its tool axis.</td>
<td>degree</td>
</tr>
<tr>
<td>Cutting Diameter</td>
<td>DCx</td>
<td>The diameter of a circle on which the defined point Pk located on this cutting tool item. The normal of the machined peripheral surface points towards the axis of the cutting tool.</td>
<td>mm</td>
</tr>
<tr>
<td>Cutting Height</td>
<td>HF</td>
<td>The distance from the basal plane of the tool item to the cutting point.</td>
<td>mm</td>
</tr>
<tr>
<td>Corner Radius</td>
<td>RE</td>
<td>The nominal radius of a rounded corner measured in the X Y-plane.</td>
<td>mm</td>
</tr>
<tr>
<td>Weight</td>
<td>WT</td>
<td>The total weight of the cutting tool in grams. The force exerted by the mass of the cutting tool.</td>
<td>grams</td>
</tr>
<tr>
<td>Functional Length</td>
<td>LFx</td>
<td>The distance from the gauge plane or from the end of the shank of the cutting tool, if a gauge plane does not exist, to the cutting reference point determined by the main function of the tool. This measurement will be with reference to the Cutting Tool and MUST NOT exist without a cutting tool.</td>
<td>mm</td>
</tr>
<tr>
<td>Chamfer Flat Length</td>
<td>BCH</td>
<td>The flat length of a chamfer.</td>
<td>mm</td>
</tr>
<tr>
<td>Chamfer Width</td>
<td>CHW</td>
<td>The width of the chamfer</td>
<td>mm</td>
</tr>
<tr>
<td>Insert Width</td>
<td>W1</td>
<td>W1 is used for the insert width when an inscribed circle diameter is not practical.</td>
<td>mm</td>
</tr>
</tbody>
</table>
Appendices

A. Bibliography


B. Additional Illustrations

Figure 19: Cutting Tool Measurement Diagram 1
(Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)

Figure 20: Cutting Tool Measurement Diagram 2
(Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)
Figure 21: Cutting Item Measurement Diagram 3
(Cutting Item – ISO 13399)

SIDE CUTTING TOOLS KAPR ≤ 90°

Figure 22: Cutting Item Measurement Diagram 4
(Cutting Item – ISO 13399)
Figure 23: Cutting Item Measurement Diagram 5
(Cutting Item – ISO 13399)

Figure 24: Cutting Item Measurement Diagram 6
(Cutting Item – ISO 13399)
C. Cutting Tool Example

C.1 Shell Mill

Shellmill – KMT, KSSP300R4SD43L240
Adapter – Parlec, C50-12SM1
Insert – KMT, SDET43PDER8GB Grade KC725M

Steel Cutting Parameters:
Cutter Max RPM=13,300, 4 Flutes ,
76.2mm Dia (3"Dia)

Nominal Starting Parameters:
605 RPM
0.23mm/tooth (0.009"")
M/min 144.8 (475 SFM)
Feed Rate 553.2mm/min (21.78 in/min)

Figure 25: Shell Mill Side View
Figure 26: Indexable Insert Measurements

<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
    xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2 http://mtconnect.org/schemas/MTConnectAssets_1.2.xsd">
    <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024" sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
    <Assets>
        <CuttingTool serialNumber="1" toolId="KSSP300R4SD43L240" timestamp="2011-05-11T13:55:22" assetId="KSSP300R4SD43L240.1" manufacturers="KMT,Parlec">
            <CuttingToolLifeCycle>
                <CutterStatus><Status>NEW</Status></CutterStatus>
                <ProcessSpindleSpeed maximum="13300" nominal="10000"/>
            </CuttingToolLifeCycle>
            <ProcessFeedRate nominal="9.22">9.22</ProcessFeedRate>
            <ConnectionCodeMachineSide>CV50</ConnectionCodeMachineSide>
            <Measurements>
                <BodyDiameterMax code="BDX">73.25</BodyDiameterMax>
                <OverallToolLength nominal="222.25" minimum="221.996" maximum="222.504" code="OAL">222.25</OverallToolLength>
            </Measurements>
        </CuttingTool>
    </Assets>
</MTConnectAssets>
<UsableLengthMax code="LUX" nominal="82.55">82.55</UsableLengthMax>
<CuttingDiameterMax code="DC" nominal="76.2" maximum="76.213"
minimum="76.187">76.2</CuttingDiameterMax>

<BodyLengthMax code="LF" nominal="120.65" maximum="120.904"
minimum="120.404">120.65</BodyLengthMax>

<DepthOfCutMax code="APMX" nominal="60.96" maximum="60.95">
60.95</DepthOfCutMax>
<FlangeDiameterMax code="DF"
nominal="98.425">98.425</FlangeDiameterMax>

</Measurements>
<CuttingItems count="24">
<CuttingItem indices="1-24" itemId="SDET43PDER8GB" manufacturers="KMT"
grade="KC725M">
<Measurements>

<CuttingEdgeLength code="L" nominal="12.7" minimum="12.675"
maximum="12.725">12.7</CuttingEdgeLength>

<WiperEdgeLength code="BS" nominal="2.56">2.56</WiperEdgeLength>

<IncribedCircleDiameter code="IC"
nominal="12.7">12.7</IncribedCircleDiameter>

<CornerRadius code="RE" nominal="0.8">0.8</CornerRadius>

</Measurements>
</CuttingItem>
</CuttingItems>
</CuttingToolLifeCycle>
</CuttingTool>
</Assets>
</MTConnectAssets>
C.2 Step Drill

Step Drill – KMT, B732A08500HP Grade KC7315
Adapter – Parlec, C50-M12SF300-6

Note: Adapter Dimensions Shown are for KMT holder which has adjustable length of +/-5mm (Drill length tolerance = +/-0).

Figure 27: Step Drill Side View
<CutterStatus>Status>NEW</Status></CutterStatus>
<ProcessSpindleSpeed nominal="5893">5893</ProcessSpindleSpeed>
<ProcessFeedRate nominal="2.5">2.5</ProcessFeedRate>
<ConnectionCodeMachineSide>CV50 Taper</ConnectionCodeMachineSide>
<Measurements>
  <BodyDiameterMax code="BDX">31.8</BodyDiameterMax>
  <BodyLengthMax code="LBX" nominal="120.825" minimum="115.325" maximum="126.325">
    120.825
  </BodyLengthMax>
  <ProtrudingLength code="LPR" nominal="150.26">155.75</ProtrudingLength>
  <FlangeDiameterMax code="DF" nominal="98.425">98.425</FlangeDiameterMax>
  <OverallToolLength nominal="257.35" minimum="251.85" maximum="262.85">257.35</OverallToolLength>
</Measurements>

<CuttingItems count="2">
  <CuttingItem indices="1" manufacturers="KMT" grade="KC7315">
    <Measurements>
      <CuttingDiameter code="DC1" nominal="8.5135" minimum="8.506" maximum="8.521">8.5135</CuttingDiameter>
      <StepIncludedAngle code="STA1" nominal="90" minimum="89" maximum="91">90</StepIncludedAngle>
      <FunctionalLength code="LF1" nominal="154.286" minimum="148.786" maximum="159.786">154.286</FunctionalLength>
      <StepDiameterLength code="SDL1" nominal="9">9</StepDiameterLength>
      <PointAngle code="SIG" nominal="135" minimum="133" maximum="137">135</PointAngle>
    </Measurements>
  </CuttingItem>
  <CuttingItem indices="2" manufacturers="KMT" grade="KC7315">
    <Measurements>
      <CuttingDiameter code="DC2" nominal="12" minimum="12" maximum="12.011">12</CuttingDiameter>
      <FunctionalLength code="LF2" nominal="122.493" minimum="116.993" maximum="127.993">122.493</FunctionalLength>
      <StepDiameterLength code="SDL2" nominal="9">9</StepDiameterLength>
    </Measurements>
  </CuttingItem>
</CuttingItems>
</CuttingToolLifeCycle>
</CuttingTool>
</Assets>
</MTConnectAssets>
C.3 Shell Mill with Individual Loci

Figure 28: Shell Mill with Explicate Loci

<?xml version="1.0" encoding="UTF-8"?>
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024" sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
  <Assets>
    <CuttingTool serialNumber="1" toolId="KSSP300R4SD43L240" timestamp="2011-05-11T13:55:22" assetId="KSSP300R4SD43L240.1" manufacturers="KMT,Parlec">
      <Description>Keyway: 55 degrees</Description>
      <CuttingToolLifeCycle>
        <CutterStatus><Status>NEW</Status></CutterStatus>
      </CuttingToolLifeCycle>
      <Measurements>
        <UsableLengthMax code="LUX" nominal="82.55">82.55</UsableLengthMax>
      </Measurements>
    </CuttingTool>
  </Assets>
</MTConnectAssets>
<CuttingDiameterMax code="DC" nominal="76.2" maximum="76.213" minimum="76.187">76.2</CuttingDiameterMax>
<DepthOfCutMax code="APMX" nominal="60.96">60.95</DepthOfCutMax>
</Measurements>
<CuttingItems count="24">
  <CuttingItem indices="1" itemId="SDET43PDER8GB" manufacturers="KMT">
    <Locus>FLUTE: 1, ROW: 1</Locus>
    <Measurements>
      <DriveAngle code="DRVA" nominal="55">55</DriveAngle>
    </Measurements>
  </CuttingItem>
  <CuttingItem indices="2-24" itemId="SDET43PDER8GB" manufacturers="KMT">
    <Locus>FLUTE: 2-4, ROW: 1; FLUTE: 1-4, ROW 2-6</Locus>
  </CuttingItem>
</CuttingItems>
</CuttingToolLifeCycle>
</CuttingTool>
</Assets>
</MTConnectAssets>
C.4 Drill with Individual Loci

**Figure 29: Step Drill with Explicate Loci**

```xml
<?xml version="1.0" encoding="UTF-8"?>
<MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
 xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
 xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2 http://mtconnect.org/schemas/MTConnectAssets_1.2.xsd">
  <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024" senders="localhost" assetCount="2" version="1.2" instanceId="1234"/>
  <Assets>
    <CuttingTool serialNumber="1" toolId="KSEM0781LD" timestamp="2011-05-11T13:55:22" assetId="KSEM0781LD.1" manufacturers="KMT">
```

Table:

<table>
<thead>
<tr>
<th>FLUTE 1</th>
<th>FLUTE 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROW 1</td>
<td>1</td>
</tr>
<tr>
<td>~</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TPMT-2152-1P, GRADE=KCM15</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROW 2</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
</tbody>
</table>

```
<CuttingToolLifeCycle>
  <CutterStatus>
    <Status>NEW</Status>
  </CutterStatus>
  <ConnectionCodeMachineSide>HSK63A</ConnectionCodeMachineSide>
  <Measurements>
    <BodyDiameterMax code="BDX">52.75</BodyDiameterMax>
    <OverallToolLength nominal="172.29" code="OAL">172.29</OverallToolLength>
    <UsableLengthMax code="LUX" nominal="49">49</UsableLengthMax>
    <FlangeDiameterMax code="DF" nominal="62.94">62.94</FlangeDiameterMax>
  </Measurements>
  <CuttingItems count="3">
    <CuttingItem indices="1" itemId="KSEM0781LD" manufacturers="KMT" grade="KC7015">
      <Locus>FLUTE: 1, ROW: 1</Locus>
      <Measurements>
        <FunctionalLength code="LF1" nominal="154.42">154.42</FunctionalLength>
        <CuttingDiameter code="DC1" nominal="19.844">19.844</CuttingDiameter>
        <PointAngle code="SIG" nominal="140">140</PointAngle>
        <ToolCuttingEdgeAngle code="KAPR1" nominal="45">45</ToolCuttingEdgeAngle>
        <StepDiameterLength code="SLD1" nominal="39.8">39.8</StepDiameterLength>
      </Measurements>
    </CuttingItem>
    <CuttingItem indices="2-3" itemId="TPMT-21.52-FP" manufacturers="KMT" grade="KCM15">
      <Locus>FLUTE: 1-2, ROW: 2</Locus>
      <Measurements>
        <FunctionalLength code="LF2" nominal="112.9">112.9</FunctionalLength>
        <CuttingDiameter code="DC2" nominal="31">31</CuttingDiameter>
      </Measurements>
    </CuttingItem>
  </CuttingItems>
</CuttingToolLifeCycle>
</Assets>
</MTConnectAssets>
Figure 30: Shell Mill with Different Inserts on First Row
<CuttingItems count="9">
  <CuttingItem indices="1-3" itemId="EDPT180564PDER-LD" manufacturers="KMT">
    <Locus>FLUTE: 1-3, ROW: 1</Locus>
    <Measurements>
      <CornerRadius code="RE" nominal="6.25">6.35</CornerRadius>
    </Measurements>
  </CuttingItem>
  <CuttingItem indices="4-9" itemId="EDPT180508PDER-LD" manufacturers="KMT">
    <Locus>FLANGE: 1-4, ROW: 2-3</Locus>
  </CuttingItem>
</CuttingItems>