



**MTConnect® Standard**  
**Part 4.1 – Cutting Tools**  
**Version 1.8.0**

Prepared for: MTConnect Institute  
Prepared on: September 6, 2021

MTConnect® is a registered trademark of AMT - The Association for Manufacturing Technology. Use of *MTConnect* is limited to use as specified on <http://www.mtconnect.org/>.

## MTConnect Specification and Materials

The Association for Manufacturing Technology (AMT) owns the copyright in this *MTConnect* Specification or Material. AMT grants to you a non-exclusive, non-transferable, revocable, non-sublicensable, fully-paid-up copyright license to reproduce, copy and redistribute this *MTConnect* Specification or Material, provided that you may only copy or redistribute the *MTConnect* Specification or Material in the form in which you received it, without modifications, and with all copyright notices and other notices and disclaimers contained in the *MTConnect* Specification or Material.

If you intend to adopt or implement an *MTConnect* Specification or Material in a product, whether hardware, software or firmware, which complies with an *MTConnect* Specification, you shall agree to the *MTConnect* Specification Implementer License Agreement (“Implementer License”) or to the *MTConnect* Intellectual Property Policy and Agreement (“IP Policy”). The Implementer License and IP Policy each sets forth the license terms and other terms of use for *MTConnect* Implementers to adopt or implement the *MTConnect* Specifications, including certain license rights covering necessary patent claims for that purpose. These materials can be found at [www.MTConnect.org](http://www.MTConnect.org), or by contacting <mailto:info@MTConnect.org>.

*MTConnect* Institute and AMT have no responsibility to identify patents, patent claims or patent applications which may relate to or be required to implement a Specification, or to determine the legal validity or scope of any such patent claims brought to their attention. Each *MTConnect* Implementer is responsible for securing its own licenses or rights to any patent or other intellectual property rights that may be necessary for such use, and neither AMT nor *MTConnect* Institute have any obligation to secure any such rights.

This Material and all *MTConnect* Specifications and Materials are provided “as is” and *MTConnect* Institute and AMT, and each of their respective members, officers, affiliates, sponsors and agents, make no representation or warranty of any kind relating to these materials or to any implementation of the *MTConnect* Specifications or Materials in any product, including, without limitation, any expressed or implied warranty of noninfringement, merchantability, or fitness for particular purpose, or of the accuracy, reliability, or completeness of information contained herein. In no event shall *MTConnect* Institute or AMT be liable to any user or implementer of *MTConnect* Specifications or Materials for the cost of procuring substitute goods or services, lost profits, loss of use, loss of data or any incidental, consequential, indirect, special or punitive damages or other direct damages, whether under contract, tort, warranty or otherwise, arising in any way out of access, use or inability to use the *MTConnect* Specification or other *MTConnect* Materials, whether or not they had advance notice of the possibility of such damage.

# Table of Contents

|   |           |
|---|-----------|
| <b>1 Purpose of This Document</b>   | <b>2</b>  |
| <b>2 Terminology and Conventions</b>  | <b>3</b>  |
| 2.1 Glossary . . . . .  | 3         |
| 2.2 Acronyms . . . . .  | 9         |
| 2.3 MTConnect References . . . . .  | 9         |
| <b>3 Cutting Tool and Cutting Tool Archetype</b>                            | <b>10</b> |
| 3.1 XML Schema Structure for CuttingTool and CuttingToolArchetype . . . . . | 10        |
| 3.2 Common Attributes for CuttingTool and CuttingToolArchetype . . . . .    | 12        |
| 3.3 Common Elements for CuttingTool and CuttingToolArchetype . . . . .      | 14        |
| 3.3.1 Description Element for CuttingTool and CuttingToolArchetype . .      | 14        |
| <b>4 CuttingToolArchetype Information Model</b>                             | <b>15</b> |
| 4.1 Attributes for CuttingToolArchetype . . . . .                           | 19        |
| 4.2 Elements for CuttingToolArchetype . . . . .                             | 19        |
| 4.2.1 CuttingToolDefinition Element for CuttingToolArchetype . . . . .      | 20        |
| 4.2.1.1 Attributes for CuttingToolDefinition . . . . .                      | 20        |
| 4.2.1.1.1 format Attribute for CuttingToolDefinition . . . . .              | 20        |
| 4.2.1.2 Elements for CuttingToolDefinition . . . . .                        | 21        |
| 4.2.1.3 ISO13399 Standard . . . . .   | 21        |
| 4.2.2 CuttingToolLifeCycle Element for CuttingToolArchetype . . . . .       | 21        |
| <b>5 CuttingTool Information model</b>                                      | <b>22</b> |
| 5.1 Attributes for CuttingTool . . . . .                                    | 22        |
| 5.2 Elements for CuttingTool . . . . .                                      | 22        |
| 5.2.1 CuttingToolLifeCycle Elements for CuttingTool Only . . . . .          | 23        |
| 5.2.1.1 CutterStatus Element for CuttingToolLifeCycle . . . . .             | 23        |
| 5.2.1.1.1 Status Element for CutterStatus . . . . .                         | 24        |
| 5.2.1.2 ToolLife Element for CuttingToolLifeCycle . . . . .                 | 26        |
| 5.2.1.2.1 Attributes for ToolLife . . . . .                                 | 27        |
| 5.2.1.2.2 type Attribute for ToolLife . . . . .                             | 27        |
| 5.2.1.2.3 countDirection Attribute for ToolLife . . . . .                   | 28        |
| 5.2.1.3 Location Element for CuttingToolLifeCycle . . . . .                 | 28        |
| 5.2.1.3.1 Attributes for Location . . . . .                                 | 29        |
| 5.2.1.3.2 type Attribute for Location . . . . .                             | 31        |
| 5.2.1.3.3 positiveOverlap Attribute for Location . . . . .                  | 31        |
| 5.2.1.3.4 negativeOverlap Attribute for Location . . . . .                  | 31        |
| 5.2.1.4 ReconditionCount Element for CuttingToolLifeCycle . .               | 32        |
| 5.2.1.4.1 Attributes for ReconditionCount . . . . .                         | 32        |
| 5.2.2 CuttingToolArchetypeReference Element for Cutting Tool . . . . .      | 33        |

|   |           |
|---|-----------|
| 5.2.2.1    source Attribute for CuttingToolArcheTypeReference . . . . . | 33        |
| <b>6    Common Entity CuttingToolLifeCycle</b>                          | <b>34</b> |
| 6.1    CuttingToolLifeCycle . . . . .                                   | 34        |
| 6.1.1    XML Schema Structure for CuttingToolLifeCycle . . . . .        | 34        |
| 6.2    Elements for CuttingToolLifeCycle . . . . .                      | 36        |
| 6.2.1    ProgramToolGroup Element for CuttingToolLifeCycle . . . . .    | 37        |
| 6.2.2    ProgramToolNumber Element for CuttingToolLifeCycle . . . . .   | 37        |
| 6.2.3    ProcessSpindleSpeed Element for CuttingToolLifeCycle . . . . . | 38        |
| 6.2.3.1    Attributes for ProcessSpindleSpeed . . . . .                 | 38        |
| 6.2.4    ProcessFeedRate Element for CuttingToolLifeCycle . . . . .     | 39        |
| 6.2.4.1    Attributes for ProcessFeedRate . . . . .                     | 39        |
| 6.2.5    ConnectionCodeMachineSide Element for CuttingToolLifeCycle .   | 40        |
| 6.2.6    xs:any Element for CuttingToolLifeCycle . . . . .              | 40        |
| 6.2.7    Measurements Element for CuttingToolLifeCycle . . . . .        | 40        |
| 6.2.8    Measurement . . . . .  | 41        |
| 6.2.8.1    Attributes for Measurement . . . . .                         | 42        |
| 6.2.8.2    Measurement Subtypes for CuttingToolLifeCycle . . .          | 43        |
| 6.2.9    CuttingItems Element for CuttingToolLifeCycle . . . . .        | 47        |
| 6.2.9.1    Attributes for CuttingItems . . . . .                        | 48        |
| 6.2.10    CuttingItem . . . . .   | 48        |
| 6.2.10.1    Attributes for CuttingItem . . . . .                        | 50        |
| 6.2.10.1.1    indices Attribute for CuttingItem . . . . .               | 50        |
| 6.2.10.1.2    itemId Attribute for CuttingItem . . . . .                | 50        |
| 6.2.10.1.3    manufacturers Attribute for CuttingItem . . .             | 50        |
| 6.2.10.1.4    grade Attribute for CuttingItem . . . . .                 | 51        |
| 6.2.10.2    Elements for CuttingItem . . . . .                          | 51        |
| 6.2.10.2.1    Description Element for CuttingItem . . . . .             | 51        |
| 6.2.10.2.2    Locus Element for CuttingItem . . . . .                   | 52        |
| 6.2.10.2.3    ItemLife Element for CuttingItem . . . . .                | 53        |
| 6.2.10.2.4    Attributes for ItemLife . . . . .                         | 54        |
| 6.2.10.2.5    type Attribute for ItemLife . . . . .                     | 54        |
| 6.2.10.2.6    countDirection Attribute for ItemLife . . . . .           | 55        |
| 6.2.10.3    Measurement Subtypes for CuttingItem . . . . .              | 55        |
| <b>Appendices</b>   | <b>62</b> |
| A    Bibliography . . . . .   | 62        |
| B    Additional Illustrations . . . . .                                 | 64        |
| C    Cutting Tool Example . . . . .                                     | 68        |
| C.1    Shell Mill . . . . .   | 68        |
| C.2    Step Drill . . . . .   | 71        |
| C.3    Shell Mill with Individual Loci . . . . .                        | 73        |

September 6, 2021

|     |  |    |
|-----|--|----|
| C.4 | Drill with Individual Loci . . . . .                     | 75 |
| C.5 | Shell Mill with Different Inserts on First Row . . . . . | 77 |

## Table of Figures

|   |    |
|---|----|
| <b>Figure 1: Cutting Tool Schema</b>  | 11 |
| <b>Figure 2: Cutting Tool Parts</b>   | 15 |
| <b>Figure 3: Cutting Tool Composition</b>   | 16 |
| <b>Figure 4: Cutting Tool, Tool Item, and Cutting Item</b>  | 17 |
| <b>Figure 5: Cutting Tool, Tool Item, and Cutting Item 2</b>  | 17 |
| <b>Figure 6: Cutting Tool Measurements</b>  | 18 |
| <b>Figure 7: Cutting Tool Asset Structure</b>   | 18 |
| <b>Figure 8: CuttingToolDefinition Schema</b>   | 20 |
| <b>Figure 9: CutterStatus Schema</b>  | 23 |
| <b>Figure 10:ToolLife Schema</b>  | 26 |
| <b>Figure 11:Location Schema</b>  | 29 |
| <b>Figure 12:ReconditionCount Schema</b>  | 32 |
| <b>Figure 13:CuttingToolArcheTypeReference Schema</b>   | 33 |
| <b>Figure 14:CuttingToolLifeCycle Schema</b>  | 35 |
| <b>Figure 15:ProcessSpindleSpeed Schema</b>   | 38 |
| <b>Figure 16:ProcessFeedRate Schema</b>   | 39 |
| <b>Figure 17:Measurement Schema</b>   | 41 |
| <b>Figure 18:Cutting Tool Measurement Diagram 1</b>   | 43 |
| <b>Figure 19:Cutting Tool Measurement Diagram 2</b>   | 44 |
| <b>Figure 20:CuttingItems Schema</b>  | 47 |
| <b>Figure 21:CuttingItem Schema</b>   | 49 |
| <b>Figure 22:ItemLife Schema</b>  | 53 |
| <b>Figure 23:Cutting Tool</b>   | 56 |
| <b>Figure 24:Cutting Item</b>   | 56 |
| <b>Figure 25:Cutting Item Measurement Diagram 3</b>   | 57 |
| <b>Figure 26:Cutting Item Drive Angle</b>   | 57 |
| <b>Figure 27:Cutting Tool Measurement Diagram 1 (Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)</b> | 64 |
| <b>Figure 28:Cutting Tool Measurement Diagram 2 (Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)</b> | 65 |
| <b>Figure 29:Cutting Tool Measurement Diagram 3 (Cutting Item – ISO 13399)</b>                                  | 65 |
| <b>Figure 30:Cutting Tool Measurement Diagram 4 (Cutting Item – ISO 13399)</b>                                  | 66 |
| <b>Figure 31:Cutting Tool Measurement Diagram 5 (Cutting Item – ISO 13399)</b>                                  | 66 |
| <b>Figure 32:Cutting Tool Measurement Diagram 6 (Cutting Item – ISO 13399)</b>                                  | 67 |
| <b>Figure 33:Shell Mill Side View</b>   | 68 |
| <b>Figure 34:Indexable Insert Measurements</b>  | 68 |
| <b>Figure 35:Step Mill Side View</b>  | 71 |
| <b>Figure 36:Shell Mill with Explicate Loci</b>   | 73 |
| <b>Figure 37:Step Drill with Explicate Loci</b>   | 75 |
| <b>Figure 38:Shell Mill with Different Inserts on First Row</b>   | 77 |

## List of Tables

|  |    |
|--|----|
| <b>Table 1:</b> Attributes for CuttingTool and CuttingToolArchetype . . . . .      | 12 |
| <b>Table 2:</b> Common Elements for CuttingTool and CuttingToolArchetype . . . . . | 14 |
| <b>Table 3:</b> Elements for CuttingToolArchetype . . . . .                        | 19 |
| <b>Table 4:</b> Attributes for CuttingToolDefinition . . . . .                     | 20 |
| <b>Table 5:</b> Values for format attribute of CuttingToolDefinition . . . . .     | 21 |
| <b>Table 6:</b> Elements for CuttingTool . . . . .                                 | 22 |
| <b>Table 7:</b> Elements for CutterStatus . . . . .                                | 24 |
| <b>Table 8:</b> Values for Status Element of CutterStatus . . . . .                | 24 |
| <b>Table 9:</b> Attributes for ToolLife . . . . .                                  | 27 |
| <b>Table 10:</b> Values for type of ToolLife . . . . .                             | 28 |
| <b>Table 11:</b> Values for countDirection . . . . .                               | 28 |
| <b>Table 12:</b> Attributes for Location . . . . .                                 | 30 |
| <b>Table 13:</b> Values for type of Location . . . . .                             | 31 |
| <b>Table 14:</b> Attributes for ReconditionCount . . . . .                         | 32 |
| <b>Table 15:</b> Attributes for CuttingToolArchetypeReference . . . . .            | 33 |
| <b>Table 16:</b> Elements for CuttingToolLifeCycle . . . . .                       | 36 |
| <b>Table 17:</b> Attributes for ProcessSpindleSpeed . . . . .                      | 38 |
| <b>Table 18:</b> Attributes for ProcessFeedRate . . . . .                          | 39 |
| <b>Table 19:</b> Attributes for Measurement . . . . .                              | 42 |
| <b>Table 20:</b> Measurement Subtypes for CuttingTool . . . . .                    | 44 |
| <b>Table 21:</b> Attributes for CuttingItems . . . . .                             | 48 |
| <b>Table 22:</b> Attributes for CuttingItem . . . . .                              | 50 |
| <b>Table 23:</b> Elements for CuttingItem . . . . .                                | 51 |
| <b>Table 24:</b> Attributes for ItemLife . . . . .                                 | 54 |
| <b>Table 25:</b> Values for type of ItemLife . . . . .                             | 55 |
| <b>Table 26:</b> Values for countDirection . . . . .                               | 55 |
| <b>Table 27:</b> Measurement Subtypes for CuttingItem . . . . .                    | 57 |

## **1 Purpose of This Document**

- 2 This document, *MTConnect Standard: Part 4.1 - Cutting Tools* of the MTConnect Standard,  
3 establishes the rules and terminology to be used by designers to describe the function  
4 and operation of cutting tools used within manufacturing and to define the data that is pro-  
5 vided by an *Agent* from a piece of equipment. This part of the Standard also defines the  
6 structure for the XML document that is returned from an *Agent* in response to a probe  
7 request.
- 8 The data associated with these cutting tools will be retrieved from multiple sources that  
9 are responsible for providing their knowledge of an *MTConnect Asset*.

## **10 2 Terminology and Conventions**

11 Refer to Section 2 of *MTConnect Standard Part 1.0 - Overview and Fundamentals* for a  
12 dictionary of terms, reserved language, and document conventions used in the MTConnect  
13 Standard.

### **14 2.1 Glossary**

15 CDATA

16 General meaning:

17 An abbreviation for Character Data.

18 CDATA is used to describe a value (text or data) published as part of an XML ele-  
19 ment.

20 For example, "This is some text" is the CDATA in the XML element:

21 <Message ...>This is some text</Message>

22 Appears in the documents in the following form: CDATA

23 NMOKEN

24 The data type for XML identifiers.

25 Note: The identifier must start with a letter, an underscore "\_" or a colon. The next  
26 character must be a letter, a number, or one of the following ".", "-", "\_", ":". The  
27 identifier must not have any spaces or special characters.

28 Appears in the documents in the following form: NMOKEN.

29 XML

30 Stands for eXtensible Markup Language.

31 XML defines a set of rules for encoding documents that both a human-readable and  
32 machine-readable.

33 XML is the language used for all code examples in the MTConnect Standard.

34 Refer to <http://www.w3.org/XML> for more information about XML.

35 **Agent**

36 Refers to an MTConnect Agent.

37 Software that collects data published from one or more piece(s) of equipment, orga-  
38 nizes that data in a structured manner, and responds to requests for data from client

39 software systems by providing a structured response in the form of a *Response Document*  
40 that is constructed using the *semantic data models* defined in the Standard.

41 Appears in the documents in the following form: *Agent*.

42 **Asset**

43 item, thing or entity that has potential or actual value to an organization Ref:ISO  
44 55000:2014(en)

45 Note 1 to entry: Value can be tangible or intangible, financial or non-financial,  
46 and includes consideration of risks and liabilities. It can be positive or negative  
47 at different stages of the asset life.

48 Note 2 to entry: Physical assets usually refer to equipment, inventory and prop-  
49 erties owned by the organization. Physical assets are the opposite of intangible  
50 assets, which are non-physical assets such as leases, brands, digital assets, use  
51 rights, licences, intellectual property rights, reputation or agreements.

52 Note 3 to entry: A grouping of assets referred to as an asset system could also  
53 be considered as an asset.

54

55 **Attribute**

56 A term that is used to provide additional information or properties for an element.

57 Appears in the documents in the following form: attribute.

58 **Child Element**

59 A portion of a data modeling structure that illustrates the relationship between an  
60 element and the higher-level *Parent Element* within which it is contained.

61 Appears in the documents in the following form: *Child Element*.

62 **Component**

63 General meaning:

64 A *Structural Element* that represents a physical or logical part or subpart of a piece  
65 of equipment.

66 Appears in the documents in the following form: *Component*.

67 Used in Information Models:

68 A data modeling element used to organize the data being retrieved from a piece of  
69 equipment.

- 70           ● When used as an XML container to organize *Lower Level* Component elements.  
71  
72           Appears in the documents in the following form: Components.  
73           ● When used as an abstract XML element. Component is replaced in a data  
74           model by a type of *Component* element. Component is also an XML con-  
75           tainer used to organize *Lower Level* Component elements, *Data Entities*, or  
76           both.  
77           Appears in the documents in the following form: Component.

78       ***Current Request***

79       A *Current Request* is a *Request* to an *Agent* to produce an *MTConnectStreams Re-*  
80       *sponse Document* containing the *Observations Information Model* for a snapshot of  
81       the latest *observations* at the moment of the *Request* or at a given *sequence number*.

82       ***Data Entity***

83       A primary data modeling element that represents all elements that either describe  
84       data items that may be reported by an *Agent* or the data items that contain the actual  
85       data published by an *Agent*.

86       Appears in the documents in the following form: *Data Entity*.

87       ***Devices Information Model***

88       A set of rules and terms that describes the physical and logical configuration for a  
89       piece of equipment and the data that may be reported by that equipment.

90       Appears in the documents in the following form: *Devices Information Model*.

91       ***Equipment Metadata***

92       See *Metadata*

93       ***Information Model***

94       The rules, relationships, and terminology that are used to define how information is  
95       structured.

96       For example, an information model is used to define the structure for each *MTCon-*  
97       *nnect Response Document*; the definition of each piece of information within those  
98       documents and the relationship between pieces of information.

99       Appears in the documents in the following form: *Information Model*.

100       ***Lower Level***

101       A nested element that is below a higher level element.

102 **Metadata**

103 Data that provides information about other data.

104 For example, *Equipment Metadata* defines both the *Structural Elements* that rep-  
105 resent the physical and logical parts and sub-parts of each piece of equipment, the  
106 relationships between those parts and sub-parts, and the definitions of the *Data En-*  
107 *tities* associated with that piece of equipment.

108 Appears in the documents in the following form: *Metadata* or *Equipment Metadata*.

109 **MTConnect Agent**

110 See definition for *Agent*.

111 **MTConnect Asset**

112 An *MTConnect Asset* is an *Asset* used by the manufacturing process to perform  
113 tasks.

114 Note 1 to entry: An *MTConnect Asset* relies upon an *MTConnect Device* to  
115 provide *observations* and information about itself and the *MTConnect Device*  
116 revises the information to reflect changes to the *MTConnect Asset* during their  
117 interaction. Examples of *MTConnect Assets* are Cutting Tools, Part Information,  
118 Manufacturing Processes, Fixtures, and Files.

119 Note 2 to entry: A singular `assetId` uniquely identifies an *MTConnect Asset*  
120 throughout its lifecycle and is used to track and relate the *MTConnect Asset* to  
121 other *MTConnect Devices* and entities.

122 Note 3 to entry: *MTConnect Assets* are temporally associated with a device and  
123 can be removed from the device without damage or alteration to its primary  
124 functions.

125

126 **MTConnect Device**

127 An *MTConnect Device* is a piece of equipment or a manufacturing system that pro-  
128 duces *observations* about itself and/or publishes data using the *MTConnect Infor-*  
129 *mation Model*.

130 **MTConnect Information Model**

131 See *Information Model*

132 **MTConnectDevices Response Document**

133 A *Response Document* published by an *MTConnect Agent* in response to a *Probe*  
134 *Request*.

135 ***MTConnectStreams Response Document***

136     A *Response Document* published by an *MTConnect Agent* in response to a *Current*  
137     *Request* or a *Sample Request*.

138 ***observation***

139     The observed value of a property at a point in time.

140 ***Observations Information Model***

141     An *Information Model* that describes the *Streaming Data* reported by a piece of  
142     equipment.

143 ***Parent Element***

144     An XML element used to organize *Lower Level* child elements that share a common  
145     relationship to the *Parent Element*.

146     Appears in the documents in the following form: *Parent Element*.

147 ***Probe Request***

148     A *Probe Request* is a *Request* to an *Agent* to produce an *MTConnectDevices Re-*  
149     *sponse Document* containing the *Devices Information Model*.

150 ***Request***

151     A communications method where a client software application transmits a message  
152     to an *Agent*. That message instructs the *Agent* to respond with specific information.

153     Appears in the documents in the following form: *Request*.

154 ***Response Document***

155     An electronic document published by an *MTConnect Agent* in response to a *Probe*  
156     *Request*, *Current Request*, *Sample Request* or *Asset Request*.

157 ***Sample Request***

158     A *Sample Request* is a *Request* to an *Agent* to produce an *MTConnectStreams Re-*  
159     *sponse Document* containing the *Observations Information Model* for a set of time-  
160     stamped *observations* made by *Components*.

161 ***semantic data model***

162     A methodology for defining the structure and meaning for data in a specific logical  
163     way.

164     It provides the rules for encoding electronic information such that it can be inter-  
165     preted by a software system.

166     Appears in the documents in the following form: *semantic data model*.

167 ***sequence number***

168     The primary key identifier used to manage and locate a specific piece of *Streaming*  
169     *Data* in an *Agent*.

170     *sequence number* is a monotonically increasing number within an instance of an  
171     *Agent*.

172     Appears in the documents in the following form: *sequence number*.

173 ***Spindle***

174     A mechanism that provides rotational capabilities to a piece of equipment.

175     Typically used for either work holding, materials or cutting tools.

176 ***Streaming Data***

177     The values published by a piece of equipment for the *Data Entities* defined by the  
178     *Equipment Metadata*.

179     Appears in the documents in the following form: *Streaming Data*.

180 ***Structural Element***

181     General meaning:

182     An XML element that organizes information that represents the physical and logical  
183     parts and sub-parts of a piece of equipment.

184     Appears in the documents in the following form: *Structural Element*.

185     Used to indicate hierarchy of Components:

186     When used to describe a primary physical or logical construct within a piece of  
187     equipment.

188     Appears in the documents in the following form: *Top Level Structural Element*.

189     When used to indicate a *Child Element* which provides additional detail describing  
190     the physical or logical structure of a *Top Level Structural Element*.

191     Appears in the documents in the following form: *Lower Level Structural Element*.

192 ***Top Level***

193     *Structural Elements* that represent the most significant physical or logical functions  
194     of a piece of equipment.

195 ***Valid Data Value***

196     One or more acceptable values or constrained values that can be reported for a *Data*  
197     *Entity*.

198     Appears in the documents in the following form: *Valid Data Value(s)*.

199 *XML Schema*

200 In the MTConnect Standard, an instantiation of a schema defining a specific docu-  
201 ment encoded in XML.

202 2.2 Acronyms

203 *AMT*

204 The Association for Manufacturing Technology

205 2.3 MTConnect References

206 [MTConnect Part 1.0] *MTConnect Standard Part 1.0 - Overview and Fundamentals*. Ver-  
207 sion 1.8.0.

[MTConnect Part 2.0] *MTConnect Standard: Part 2.0 - Devices Information Model*. Version 1.8.0.

210 [MTConnect Part 3.0] *MTConnect Standard: Part 3.0 - Streams Information Model*. Ver-  
211 sion 1.8.0.

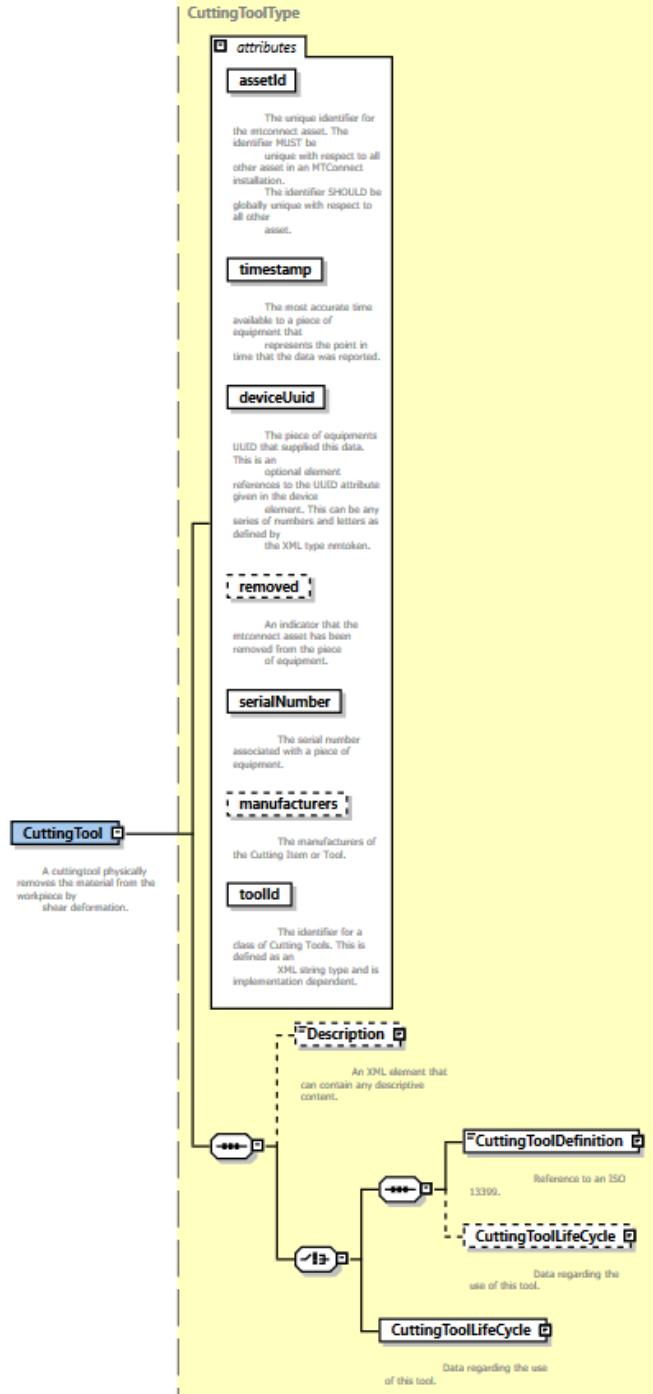
212 [MTConnect Part 4.1] *MTConnect Standard: Part 4.1 - Cutting Tools*, Version 1.8.0.

## **213 3 Cutting Tool and Cutting Tool Archetype**

214 There are two *Information Models* used to represent a cutting tool, *CuttingToolArchetype*  
215 and *CuttingTool*. The *CuttingToolArchetype* represent the static cutting tool  
216 geometries and nominal values as one would expect from a tool catalog and the *Cut-  
217 tingTool* represents the use or application of the tool on the shop floor with actual  
218 measured values and process data. In Version 1.3.0 of the MTConnect Standard it was de-  
219 cided to separate out these two concerns since not all pieces of equipment will have access  
220 to both sets of information. In this way, a generic definition of the cutting tool can coexist  
221 with a specific assembly *Information Model* with minimal redundancy of data.

### **222 3.1 XML Schema Structure for CuttingTool and CuttingToolArchetype**

223 The *Figure 1* shows the *XML Schema* that applies to both the *CuttingTool Information  
224 Model* and the *CuttingToolArchetype Information Model*.

**Figure 1:** Cutting Tool Schema

225 Note: The use of the XML element `CuttingToolDefinition` has been **DEP-**  
 226 **RECATED** in the `CuttingTool` schema, but remains in the `Cutting-`  
 227 `ToolArchetype` schema.

228 The following sections contain the definitions of `CuttingTool` and `CuttingToolArchetype`  
 229 and describe their unique components. The following are the common entities for both el-  
 230 ements.

## 231 3.2 Common Attributes for CuttingTool and CuttingToolArchetype

**Table 1:** Attributes for CuttingTool and CuttingToolArchetype

| Attribute                 | Description  | Occurrence |
|---------------------------|--|------------|
| <code>timestamp</code>    | The time this <i>MTConnect Asset</i> was last modified. Always given in UTC. The <code>timestamp</code> <b>MUST</b> be provided in UTC (Universal Time Coordinate, also known as GMT). This is the time the <i>Asset</i> data was last modified.<br><br><code>timestamp</code> is a required attribute.  | 1          |
| <code>assetId</code>      | The unique identifier of the instance of this tool. This will be the same as the <code>toolId</code> and <code>serialNumber</code> in most cases. The <code>assetId</code> <b>SHOULD</b> be the combination of the <code>toolId</code> and <code>serialNumber</code> as in <code>toolId</code> , <code>serialNumber</code> or an equivalent implementation dependent identification scheme.<br><br><code>assetId</code> is a required attribute.<br><br><code>assetId</code> is a permanent identifier that will be associated with an <i>MTConnect Asset</i> for its entire life. | 1          |
| <code>serialNumber</code> | The unique identifier for this assembly. This is defined as an XML string type and is implementation dependent.<br><br><code>serialNumber</code> is a required attribute.  | 1          |

| Continuation of Table 1 |  |            |
|-------------------------|--|------------|
| Attribute               | Description  | Occurrence |
| toolId                  | The identifier for a class of Cutting Tools. This is defined as an XML string type and is implementation dependent.<br><br>toolId is a required attribute.   | 1          |
| deviceUuid              | A reference to the Device's uuid that created the Asset information. The deviceUuid <b>MUST</b> be an NMTOKEN XML type.  | 1          |
| manufacturers           | An optional attribute referring to the manufacturer(s) of this Cutting Tool, for this element, 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.                                       | 0..1       |
| removed                 | This is an indicator that the Cutting Tool has been removed from the piece of equipment.<br><br>removed is a required attribute.<br><br>If the <i>MTConnect Asset</i> is marked as removed, it will not be visible to the client application unless the includeRemoved=true parameter is provided in the URL. If this attribute is not present it <b>MUST</b> be assumed to be false. The value is an xsi:boolean type and <b>MUST</b> be true or false. | 0..1       |

## 232 3.3 Common Elements for CuttingTool and CuttingToolArchetype

**Table 2:** Common Elements for CuttingTool and CuttingToolArchetype

| Element     | Description  | Occurrence |
|-------------|--|------------|
| Description | 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 Standard. | 0..1       |

### 233 3.3.1 Description Element for CuttingTool and CuttingToolArchetype

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

## 237 4 CuttingToolArchetype Information Model

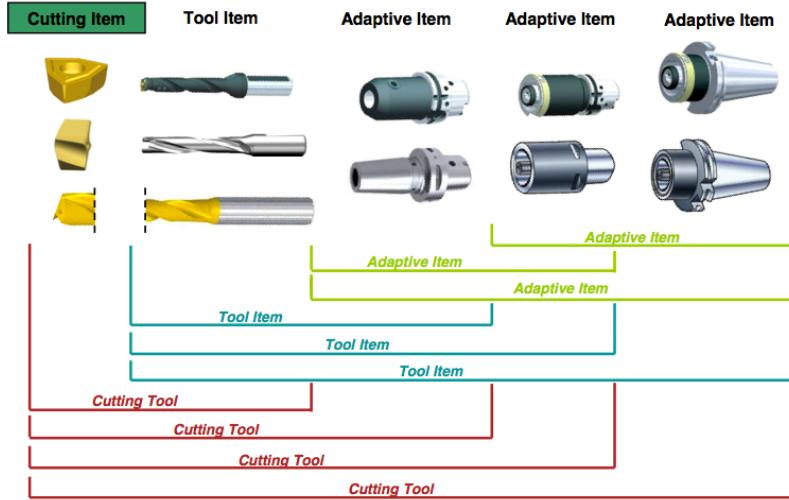
238 The CuttingToolArchetype *Information Model* will have the identical structure as  
 239 the CuttingTool *Information Model* illustrated in *Figure 1*, except for a few entities.  
 240 The CuttingTool will no longer carry the CuttingToolDefinition, this **MUST**  
 241 only appear in the CuttingToolArchetype. The CuttingToolArchetype **MUST**  
 242 **NOT** have measured values and **MUST NOT** have any of the following items: Cutter-  
 243 Status, ToolLife values, Location, or a ReconditionCount.

244 MTConnect Standard will adopt the ISO 13399 structure when formulating the vocabulary  
 245 for Cutting Tool geometries and structure to be represented in the CuttingToolArchetype.  
 246 The nominal values provided in the CuttingToolLifeCycle section are only con-  
 247 cerned with two aspects of the Cutting Tool, the Cutting Tool and the Cutting Item. The  
 248 Tool Item, Adaptive Item, and Assembly Item will only be covered in the Cutting-  
 249 ToolDefinition section of this document since this section contains the full ISO  
 250 13399 information about a Cutting Tool.



**Figure 2:** Cutting Tool Parts

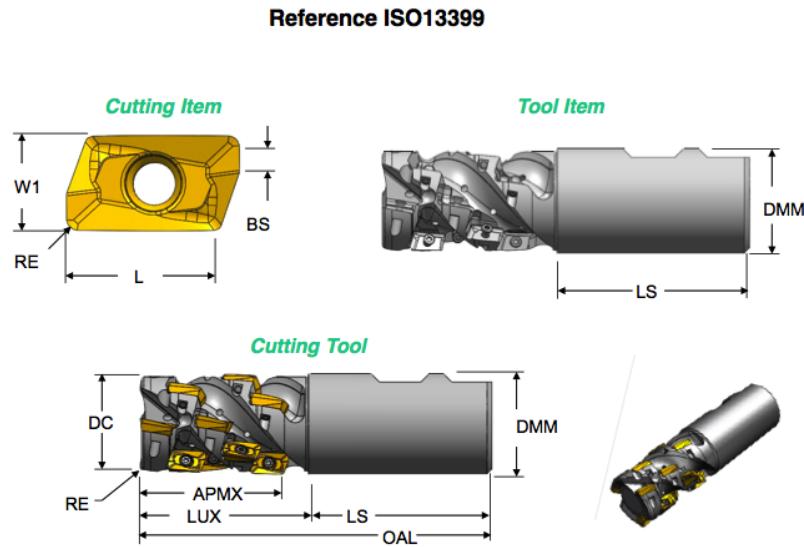
251 The *Figure 2* illustrates the parts of a Cutting Tool. The Cutting Tool is the aggregate of  
 252 all the components and the Cutting Item is the part of the tool that removes the material  
 253 from the workpiece. These are the primary focus of the MTConnect Standard.



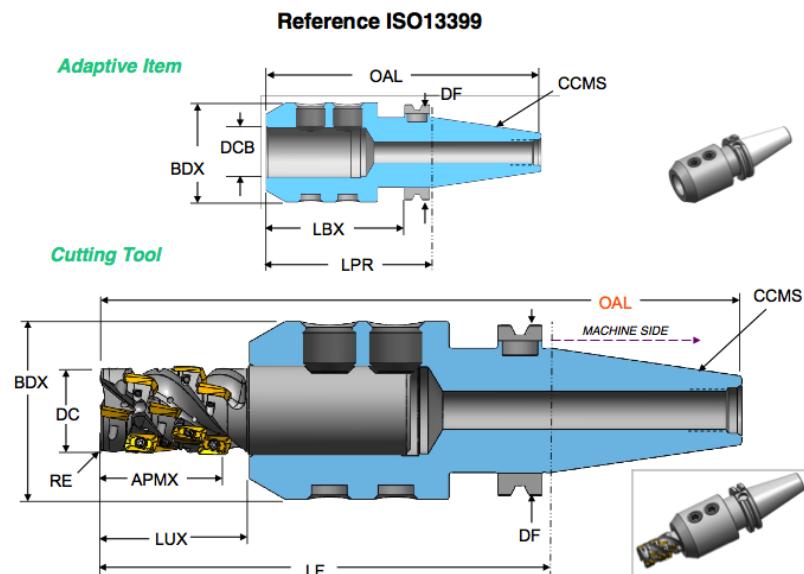
**Figure 3:** Cutting Tool Composition

254 *Figure 3* provides another view of the composition of a Cutting Tool. The Adaptive Items  
 255 and Tool Items will be used for measurements, but will not be modeled as separate entities.  
 256 When we are referencing the Cutting Tool we are referring to the entirety of the assembly  
 257 and when we provide data regarding the Cutting Item we are referencing each individual  
 258 item as illustrated on the left of the previous diagram.

259 *Figure 4* and *Figure 5* further illustrates the components of the Cutting Tool. As we  
 260 compose the Tool Item, Cutting Item, Adaptive Item, we get a Cutting Tool. The Tool Item,  
 261 Adaptive Item, and Assembly Item will only be in the CuttingToolDefinition  
 262 section that will contain the full ISO 13399 information.

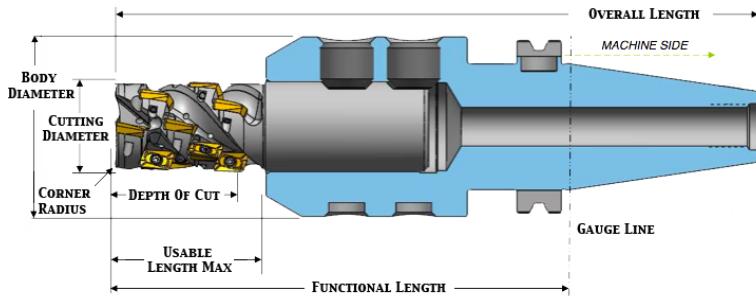


**Figure 4:** Cutting Tool, Tool Item, and Cutting Item



**Figure 5:** Cutting Tool, Tool Item, and Cutting Item 2

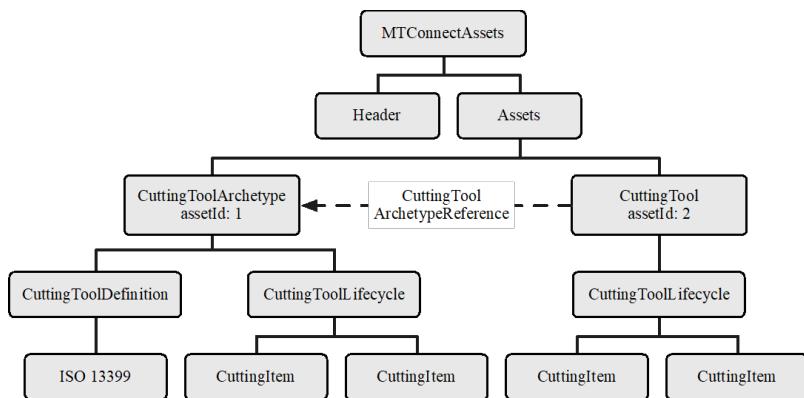
263 *Figure 4* and *Figure 5* use the ISO 13399 codes for each of the measurements. These  
 264 codes will be translated into the MTConnect Standard vocabulary as illustrated below.  
 265 The measurements will have a maximum, minimum, and nominal value representing the  
 266 tolerance of allowable values for this dimension. See below for a full discussion.



**Figure 6:** Cutting Tool Measurements

267 The MTConnect Standard will not define the entire geometry of the Cutting Tool, but will  
 268 provide the information necessary to use the tool in the manufacturing process. Additional  
 269 information can be added to the definition of the Cutting Tool by means of schema  
 270 extensions.

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



**Figure 7:** Cutting Tool Asset Structure

275 The structure of the MTConnectAssets header is defined in *MTConnect Standard Part*  
 276 *1.0 - Overview and Fundamentals* of the Standard. A finite number of *MTConnect Assets*  
 277 will be stored in the *Agent*. This finite number is implementation specific and will depend  
 278 on memory and storage constraints. The standard will not prescribe the number or capacity  
 279 requirements for an implementation.

## 280 4.1 Attributes for CuttingToolArchetype

281 Refer to *Section 3.2 - Common Attributes for CuttingTool and CuttingToolArchetype* for a  
 282 full description of the attributes for CuttingToolArchetype *Information Model*.

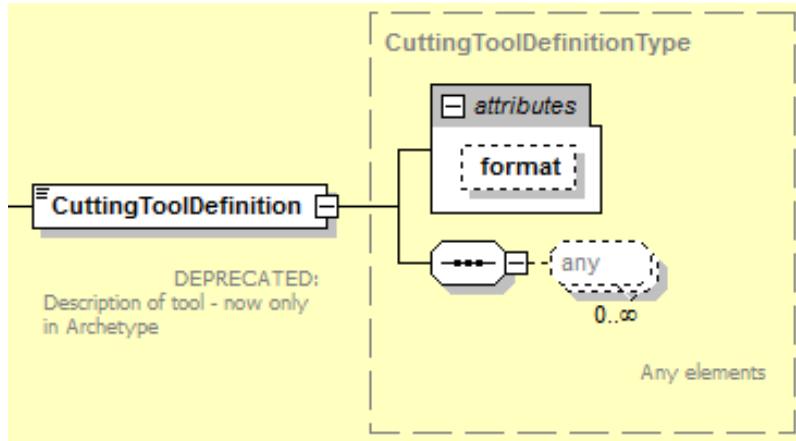
## 283 4.2 Elements for CuttingToolArchetype

284 The elements associated with CuttingToolArchetype are given in *Table 3*. Each  
 285 element will be described in more detail below and any possible values will be presented  
 286 with full definitions. The elements **MUST** be provided in the following order as prescribed  
 287 by XML. At least one of CuttingToolDefinition or CuttingToolLifeCycle  
 288 **MUST** be supplied.

**Table 3:** Elements for CuttingToolArchetype

| Element               | Description  | Occurrence |
|-----------------------|--|------------|
| Description           | 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 Standard. | 0..1       |
| CuttingToolDefinition | Reference to an ISO 13399.   | 0..1       |
| CuttingToolLifeCycle  | Data regarding the use of this tool. The archetype will only contain nominal values.   | 0..1       |

289 **4.2.1 CuttingToolDefinition Element for CuttingToolArchetype**



**Figure 8:** CuttingToolDefinition Schema

290 The `CuttingToolDefinition` contains the detailed structure of the Cutting Tool.  
 291 The information contained in this element will be static during its lifecycle. Currently we  
 292 are referring to the external ISO 13399 standard to provide the complete definition and  
 293 composition of the Cutting Tool as defined in *Section 6.1 - CuttingToolLifeCycle*.

294 **4.2.1.1 Attributes for CuttingToolDefinition**

**Table 4:** Attributes for CuttingToolDefinition

| Attribute           | Description  | Occurrence |
|---------------------|--|------------|
| <code>format</code> | <p>Identifies the expected representation of the enclosed data.</p> <p><code>format</code> is an optional attribute.</p> <p>Valid values of <code>format</code> are – XML, EXPRESS, TEXT, or UNDEFINED.</p> <p>If <code>format</code> is not specified, the assumed format is XML.</p> | 0..1       |

295 **4.2.1.1.1 format Attribute for CuttingToolDefinition**

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

**Table 5:** Values for format attribute of CuttingToolDefinition

| Value     | Description  |
|-----------|--|
| XML       | The default value for the definition. The content will be an XML document. |
| EXPRESS   | The document will conform to the ISO 10303 Part 21 standard.               |
| TEXT      | The document will be a text representation of the tool data.               |
| UNDEFINED | The document will be provided in an undefined format.                      |

298 **4.2.1.2 Elements for CuttingToolDefinition**

299 The only acceptable Cutting Tool definition at present is defined by the ISO 13399 stan-  
 300 dard. Additional formats **MAY** be considered in the future.

301 **4.2.1.3 ISO13399 Standard**

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

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

309 **4.2.2 CuttingToolLifeCycle Element for CuttingToolArchetype**

310 Refer to *Section 6 - Common Entity CuttingToolLifeCycle* for a complete description of  
 311 *CuttingToolLifeCycle* element.

## 312 5 CuttingTool Information model

313 The CuttingTool *Information Model* illustrated in *Figure 1* has the identical struc-  
 314 ture as the CuttingToolArchetype *Information Model* except for the XML ele-  
 315 ment CuttingToolDefinition that has been **DEPRECATED** in the Cutting-  
 316 Tool schema.

### 317 5.1 Attributes for CuttingTool

318 Refer to *Section 3.2 - Common Attributes for CuttingTool and CuttingToolArchetype* for a  
 319 full description of the *Attributes for CuttingTool Information Model*.

### 320 5.2 Elements for CuttingTool

321 The elements associated with CuttingTool are given below. The elements **MUST** be  
 322 provided in the order shown in *Table 6* as prescribed by XML.

**Table 6:** Elements for CuttingTool

| Element               | Description  | Occurrence |
|-----------------------|--|------------|
| Description           | 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 Standard. | 0..1       |
| CuttingToolDefinition | <b>DEPRECATED</b> for CuttingTool in Version 1.3.0.<br><br>Reference to an ISO 13399.  | 0..1       |

| Continuation of Table 6       |  |            |
|-------------------------------|--|------------|
| Element                       | Description  | Occurrence |
| CuttingToolLifeCycle          | Data regarding the use of this tool.   | 0..1       |
| CuttingToolArchetypeReference | The content of this XML element is the assetId of the CuttingToolArchetype document. It <b>MAY</b> also contain a source attribute that gives the URL of the archetype data as well. | 0..1       |

### 323 5.2.1 CuttingToolLifeCycle Elements for CuttingTool Only

324 The following CuttingToolLifeCycle elements are used only in the Cutting-  
 325 Tool *Information Model* and are not part of the CuttingToolArchetype *Information*  
 326 *Model*. Refer to *Section 6 - Common Entity CuttingToolLifeCycle* for a complete  
 327 description of the remaining elements for CuttingToolLifeCycle that are common  
 328 in both *Information Models*. Refer also to the CuttingToolLifeCycle schema illus-  
 329 trated in *Figure 14*.

#### 330 5.2.1.1 CutterStatus Element for CuttingToolLifeCycle

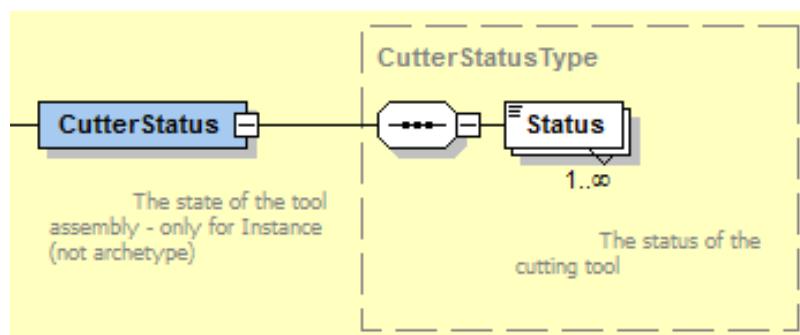


Figure 9: CutterStatus Schema

331 The elements of the CutterStatus element can be a combined set of Status ele-  
 332 ments. The *MTConnect Standard* allows any set of statuses to be combined, but only  
 333 certain combinations make sense. A CuttingTool **SHOULD** not be both NEW and

334 USED at the same time. There are no rules in the schema to enforce this, but this is left to  
 335 the implementer. The following combinations **MUST NOT** occur:

- 336     • NEW **MUST NOT** be used with USED, RECONDITIONED, or EXPIRED.
- 337     • UNKNOWN **MUST NOT** be used with any other status.
- 338     • ALLOCATED and UNALLOCATED **MUST NOT** be used together.
- 339     • AVAILABLE and UNAVAILABLE **MUST NOT** be used together.
- 340     • If the tool is EXPIRED, BROKEN, or NOT\_REGISTERED it **MUST NOT** be AVAIL-  
 341       ABLE.
- 342     • All other combinations are allowed.

**Table 7:** Elements for CutterStatus

| Element | Description  | Occurrence |
|---------|--|------------|
| Status  | The status of the Cutting Tool. There can be multiple Status elements. | 1..*       |

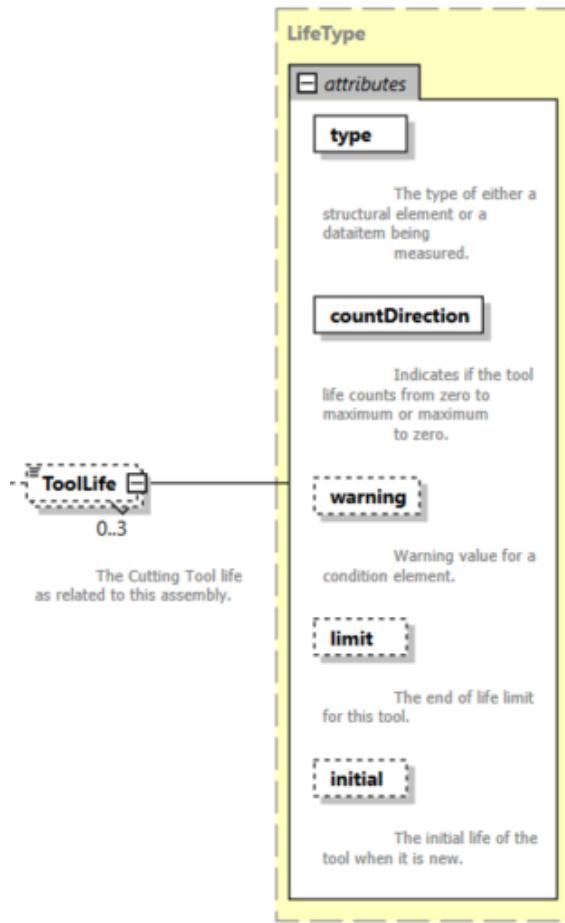
343 **5.2.1.1.1 Status Element for CutterStatus**

344 One of the values for the status of the CuttingTool.

**Table 8:** Values for Status Element of CutterStatus

| Value       | Description   |
|-------------|---|
| NEW         | A new tool that has not been used or first use. Marks the start of the tool history.  |
| AVAILABLE   | Indicates the tool is available for use. If this is not present, the tool is currently not ready to be used.                    |
| UNAVAILABLE | Indicates the tool is unavailable for use in metal removal. If this is not present, the tool is currently not ready to be used. |

| Continuation of Table 8 |  |
|-------------------------|--|
| Value                   | Description  |
| ALLOCATED               | Indicates if this tool is has been committed to a piece of equipment for use and is not available for use in any other piece of equipment. If this is not present, this tool has not been allocated for this piece of equipment and can be used by another piece of equipment. |
| UNALLOCATED             | Indicates this Cutting Tool has not been committed to a process and can be allocated.  |
| MEASURED                | The tool has been measured.  |
| RECONDITIONED           | The Cutting Tool has been reconditioned. See ReconditionCount for the number of times this cutter has been reconditioned.  |
| USED                    | The Cutting Tool is in process and has remaining tool life.  |
| EXPIRED                 | The Cutting Tool has reached the end of its useful life.   |
| BROKEN                  | Premature tool failure.  |
| NOT_REGISTERED          | This Cutting Tool cannot be used until it is entered into the system.  |
| UNKNOWN                 | The Cutting Tool is an indeterminate state. This is the default value.   |

345 **5.2.1.2 ToolLife Element for CuttingToolLifeCycle****Figure 10:** ToolLife Schema

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

351 **5.2.1.2.1 Attributes for ToolLife**

352 ToolLife has the following attributes that can be used to indicate the behavior of the  
 353 tool life management mechanism.

**Table 9:** Attributes for ToolLife

| Attribute      | Description  | Occurrence |
|----------------|--|------------|
| type           | The type of tool life being accumulated.<br>MINUTES, PART_COUNT, or WEAR.<br><br>type is a required attribute.   | 1          |
| countDirection | Indicates if the tool life counts from zero to maximum or maximum to zero. The value <b>MUST</b> be one of UP or DOWN.<br><br>countDirection is a required attribute.  | 1          |
| warning        | The point at which a tool life warning will be raised.<br><br>warning is an optional attribute.  | 0..1       |
| limit          | 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.<br><br>limit is an optional attribute. | 0..1       |
| initial        | The initial life of the tool when it is new.<br><br>initial is an optional attribute.  | 0..1       |

354 **5.2.1.2.2 type Attribute for ToolLife**

355 The value of type must be one of the following:

**Table 10:** Values for type of ToolLife

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

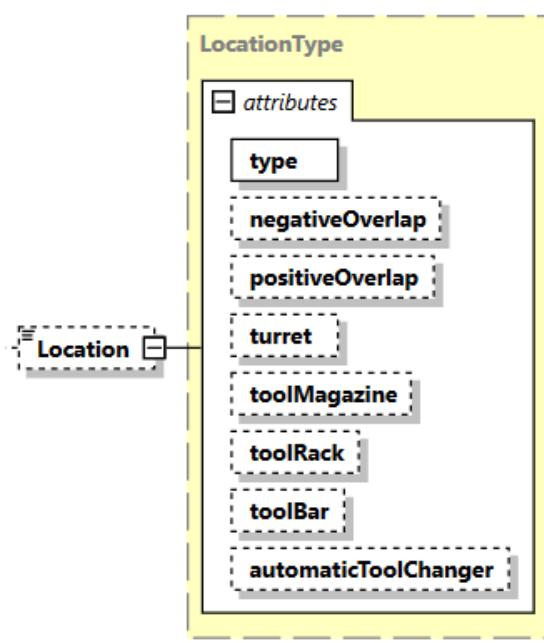
356 **5.2.1.2.3 countDirection Attribute for ToolLife**

357 The value of countDirection must be one of the following:

**Table 11:** Values for countDirection

| Value | Description   |
|-------|---|
| UP    | The tool life counts up from zero to the maximum.   |
| DOWN  | The tool life counts down from the maximum to zero. |

358 **5.2.1.3 Location Element for CuttingToolLifeCycle**

**Figure 11:** Location Schema

359 Location element identifies the specific location where a tool resides in a piece of equipment  
 360 tool storage or in a tool crib. This can be any series of numbers and letters as defined  
 361 by the XML type NMTOKEN. When a POT or STATION type is used, the value **MUST**  
 362 be a numeric value. If a negativeOverlap or the positiveOverlap is provided,  
 363 the tool reserves additional locations on either side, otherwise if they are not given, no  
 364 additional locations are required for this tool. If the pot occupies the first or last location,  
 365 a rollover to the beginning or the end of the index-able values may occur. For example, if  
 366 there are 64 pots and the tool is in pot 64 with a positiveOverlap of 1, the first pot  
 367 **MAY** be occupied as well.

#### 368 5.2.1.3.1 Attributes for Location

**Table 12:** Attributes for Location

| Attribute            | Description  | Occurrence |
|----------------------|--|------------|
| type                 | The type of location being identified.<br><br>type <b>MUST</b> be one of POT, STATION, CRIB, SPINDLE, TRANSFER_POT, RETURN_POT, STAGING_POT, REMOVAL_POT, EXPIRED_POT, or END_EFFECTOR.<br><br>type is a required attribute. | 1          |
| positiveOverlap      | The number of locations at higher index value from this location.<br><br>positiveOverlap is a optional attribute.  | 0..1       |
| negativeOverlap      | The number of location at lower index values from this location.<br><br>negativeOverlap is an optional attribute.  | 0..1       |
| turret               | The turret associated with a tool.<br><br>turret <b>MUST</b> be an XML NMTOKEN type.   | 0..1       |
| toolMagazine         | The tool magazine associated with a tool.<br><br>toolMagazine <b>MUST</b> be an XML NMTOKEN type.  | 0..1       |
| toolBar              | The tool bar associated with a tool.<br><br>toolBar <b>MUST</b> be an XML NMTOKEN type.  | 0..1       |
| toolRack             | The tool rack associated with a tool.<br><br>toolRack <b>MUST</b> be an XML NMTOKEN type.  | 0..1       |
| automaticToolChanger | The automatic tool changer associated with a tool.<br><br>automaticToolChanger <b>MUST</b> be an XML NMTOKEN type.   | 0..1       |

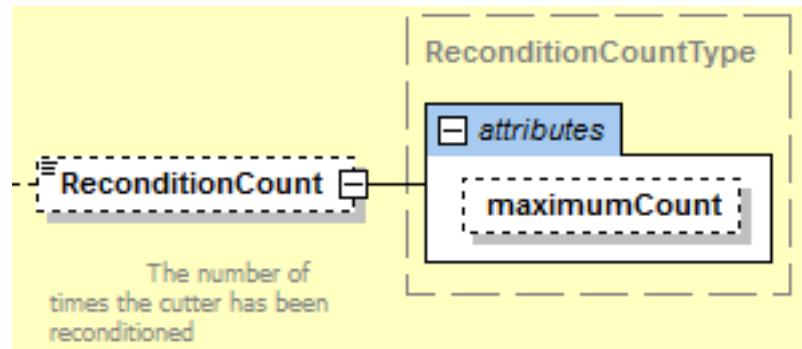
369 **5.2.1.3.2 type Attribute for Location**

370 The type of location being identified.

**Table 13:** Values for type of Location

| Value        | Description   |
|--------------|---|
| POT          | A location in a tool magazine.  |
| STATION      | A location in a turret, tool bar, or tool rack.   |
| CRIB         | A location within a tool crib.  |
| SPINDLE      | A location associated with a <i>Spindle</i> .   |
| TRANSFER_POT | A location for a tool awaiting transfer from a tool magazine to spindle or a turret.  |
| RETURN_POT   | A location for a tool removed from a <i>Spindle</i> or turret and awaiting return to a tool magazine.                           |
| STAGING_POT  | A location for a tool awaiting transfer to a tool magazine or turret from outside of the piece of equipment.                    |
| REMOVAL_POT  | A location for a tool removed from a tool magazine or turret awaiting transfer to a location outside of the piece of equipment. |
| EXPIRED_POT  | A location for a tool that is no longer useable and is awaiting removal from a tool magazine or turret.                         |
| END_EFFECTOR | A location associated with an end effector.   |

371 **5.2.1.3.3 postiveOverlap Attribute for Location**372 The number of locations at higher index values that the CuttingTool occupies due to  
373 interference. The value **MUST** be an integer. If not provided it is assumed to be 0.374 **5.2.1.3.4 negativeOverlap Attribute for Location**375 The number of locations at lower index values that the CuttingTool occupies due to  
376 interference. The value **MUST** be an integer. If not provided it is not assumed to be 0.377 The tool number assigned in the part program and is used for cross referencing this tool  
378 information with the process parameters. The value **MUST** be an integer.

379 **5.2.1.4 ReconditionCount Element for CuttingToolLifeCycle****Figure 12:** ReconditionCount Schema

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

382 **5.2.1.4.1 Attributes for ReconditionCount****Table 14:** Attributes for ReconditionCount

| Attribute    | Description  | Occurrence |
|--------------|--|------------|
| maximumCount | The maximum number of times this tool may be reconditioned.<br><br>maximumCount is a optional attribute. | 0..1       |

### 383 5.2.2 CuttingToolArchetypeReference Element for Cutting Tool

384



**Figure 13:** CuttingToolArcheTypeReference Schema

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

#### 389 5.2.2.1 source Attribute for CuttingToolArcheTypeReference

**Table 15:** Attributes for CuttingToolArchetypeReference

| Attribute | Description  | Occurrence |
|-----------|--|------------|
| source    | <p>The URL of the <i>CuttingToolArchetype Information Model</i>.</p> <p>This <b>MUST</b> be a fully qualified URL as in<br/> <a href="http://example.com/asset/A213155">http://example.com/asset/A213155</a></p> | 0..1       |

## 390 6 Common Entity CuttingToolLifeCycle

### 391 6.1 CuttingToolLifeCycle

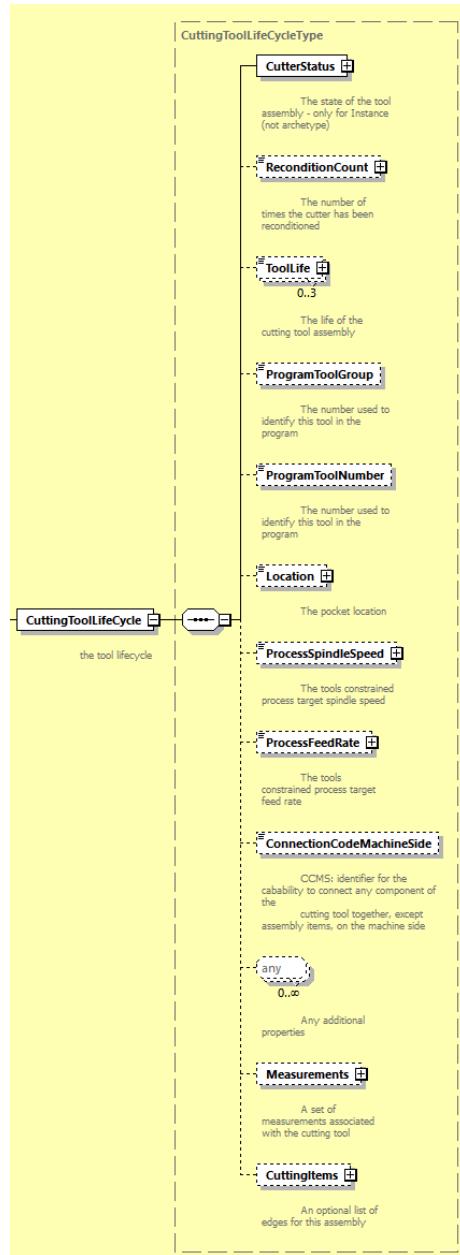
392 The life cycle refers to the data pertaining to the application or the use of the tool. This  
393 data is provided by various pieces of equipment (i.e. machine tool, presetter) and statis-  
394 tical process control applications. Life cycle data will not remain static, but will change  
395 periodically when a tool is used or measured. The life cycle has three conceptual parts;  
396 CuttingTool and CuttingItem identity, properties, and measurements. A measure-  
397 ment is defined as a constrained value that is reported in defined units and as a W3C  
398 floating point format.

399 The CuttingToolLifeCycle contains data for the entire tool assembly. The specific  
400 CuttingItems that are part of the CuttingToolLifeCycle are contained in the  
401 CuttingItems element. Each Cutting Item has similar properties as the assembly;  
402 identity, properties, and Measurements.

403 The units for all Measurements have been predefined in the *MTConnect Standard* and  
404 will be consistent with *MTConnect Standard: Part 2.0 - Devices Information Model* and  
405 *MTConnect Standard: Part 3.0 - Streams Information Model*. This means that all lengths  
406 and distances will be given in millimeters and all angular measures will be given in de-  
407 grees. Quantities like ProcessSpindleSpeed will be given in RPM, the same as the  
408 ROTARY\_VELOCITY in *MTConnect Standard: Part 3.0 - Streams Information Model*.

#### 409 6.1.1 XML Schema Structure for CuttingToolLifeCycle

410 The CuttingToolLifeCycle schema shown in *Figure 14* is used in both the Cut-  
411 tingToolArchetype and CuttingTool *Information Models*. The only difference  
412 is that the elements CutterStatus, ToolLife, Location, and Recondi-  
413 Count are used only in the CuttingTool *Information Model*.



**Figure 14:** CuttingToolLifeCycle Schema

## 414 6.2 Elements for CuttingToolLifeCycle

415 The elements associated with this Cutting Tool are given in *Table 16*. The elements **MUST**  
 416 be provided in the following order as prescribed by XML.

**Table 16:** Elements for CuttingToolLifeCycle

| Element          | Description   | Occurrence |
|------------------|---|------------|
| CutterStatus     | <p>The status of this assembly.</p> <p>CutterStatus can be one of the following values: NEW, AVAILABLE, UNAVAILABLE, ALLOCATED, UNALLOCATED, MEASURED, RECONDITIONED, NOT_REGISTERED, USED, EXPIRED, BROKEN, or UNKNOWN.</p> <p><b>MUST</b> only be used in the <i>CuttingTool Information Model</i>.</p> | 1          |
| ReconditionCount | <p>The number of times this cutter has been reconditioned.</p> <p><b>MUST</b> only be used in the <i>CuttingTool Information Model</i>.</p>   | 0..1       |
| ToolLife         | <p>The Cutting Tool life as related to this assembly.</p> <p><b>MUST</b> only be used in the <i>CuttingTool Information Model</i>.</p>  | 0..1       |
| Location         | <p>The Pot or Spindle this tool currently resides in.</p> <p><b>MUST</b> only be used in the <i>CuttingTool Information Model</i>.</p>  | 0..1       |

| Continuation of Table 16  |   |            |
|---------------------------|---|------------|
| Element                   | Description   | Occurrence |
| ProgramToolGroup          | The tool group this tool is assigned in the part program.   | 0..1       |
| ProgramToolNumber         | The number of the tool as referenced in the part program.   | 0..1       |
| ProcessSpindleSpeed       | The constrained process spindle speed for this tool.  | 0..1       |
| ProcessFeedRate           | The constrained process feed rate for this tool in mm/s.  | 0..1       |
| ConnectionCodeMachineSide | Identifier for the capability to connect any component of the Cutting Tool together, except Assembly Items, on the machine side. Code: CCMS | 0..1       |
| Measurements              | A collection of measurements for the tool assembly.   | 0..1       |
| CuttingItems              | An optional set of individual Cutting Items.  | 0..1       |
| xs:any                    | Any additional properties not in the current document model. <b>MUST</b> be in separate XML namespace.                                      | 0..n       |

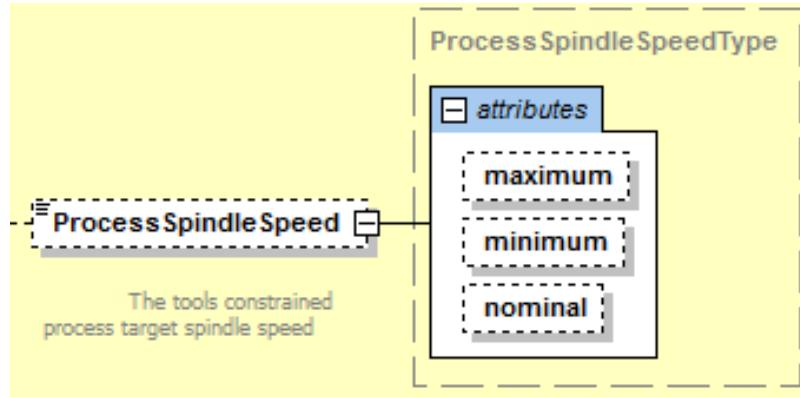
#### 417 6.2.1 ProgramToolGroup Element for CuttingToolLifeCycle

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

#### 420 6.2.2 ProgramToolNumber Element for CuttingToolLifeCycle

421 The tool number assigned in the part program and is used for cross referencing this tool  
 422 information with the process parameters. The value **MUST** be a string.

### 423 6.2.3 ProcessSpindleSpeed Element for CuttingToolLifeCycle



**Figure 15:** ProcessSpindleSpeed Schema

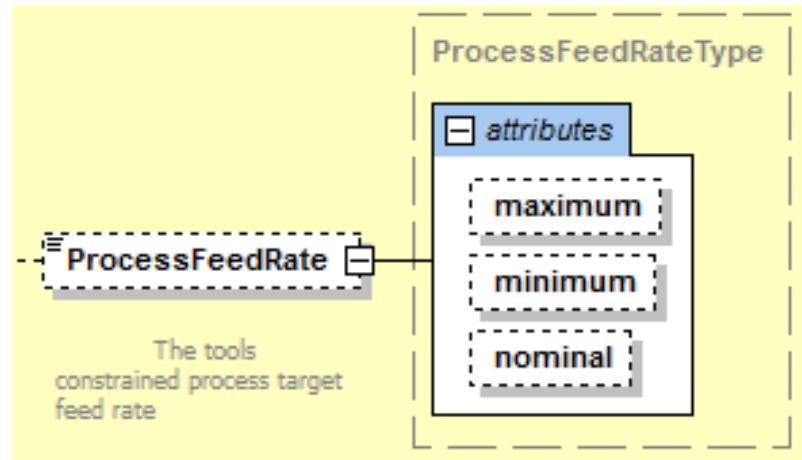
424 The `ProcessSpindleSpeed` **MUST** be specified in revolutions/minute (RPM). The  
 425 CDATA **MAY** contain the nominal process target spindle speed if available. The maximum  
 426 and minimum speeds **MAY** be provided as attributes. If `ProcessSpindleSpeed` is  
 427 provided, at least one value of maximum, nominal, or minimum **MUST** be specified.

#### 428 6.2.3.1 Attributes for ProcessSpindleSpeed

**Table 17:** Attributes for ProcessSpindleSpeed

| Attribute            | Description   | Occurrence |
|----------------------|---|------------|
| <code>maximum</code> | The upper bound for the tool's target spindle speed.<br><code>maximum</code> is an optional attribute.  | 0..1       |
| <code>minimum</code> | The lower bound for the tools spindle speed.<br><code>minimum</code> is a optional attribute.           | 0..1       |
| <code>nominal</code> | The nominal speed the tool is designed to operate at.<br><code>nominal</code> is an optional attribute. | 0..1       |

#### 429 6.2.4 ProcessFeedRate Element for CuttingToolLifeCycle



**Figure 16:** ProcessFeedRate Schema

430 The `ProcessFeedRate` **MUST** be specified in millimeters/second (mm/s). The CDATA  
 431 **MAY** contain the nominal process target feed rate if available. The maximum and mini-  
 432 mum rates **MAY** be provided as attributes. If `ProcessFeedRate` is provided, at least  
 433 one value of maximum, nominal, or minimum **MUST** be specified.

##### 434 6.2.4.1 Attributes for ProcessFeedRate

**Table 18:** Attributes for ProcessFeedRate

| Attribute            | Description  | Occurrence |
|----------------------|--|------------|
| <code>maximum</code> | The upper bound for the tool's process target feedrate.<br><code>maximum</code> is an optional attribute.  | 0..1       |
| <code>minimum</code> | The lower bound for the tools feedrate.<br><code>minimum</code> is a optional attribute.                   | 0..1       |
| <code>nominal</code> | The nominal feedrate the tool is designed to operate at.<br><code>nominal</code> is an optional attribute. | 0..1       |

435 **6.2.5 ConnectionCodeMachineSide Element for CuttingToolLifeCy-**  
436 **cle**

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

440 **6.2.6 xs:any Element for CuttingToolLifeCycle**

441 Utilizing *XML Schema* 1.1, extension points are available where an additional element  
442 can be added to the document without being part of a substitution group. The new ele-  
443 ments **MUST NOT** be part of the *MTConnect namespace* and **MUST NOT** be one of the  
444 predefined elements mentioned above.

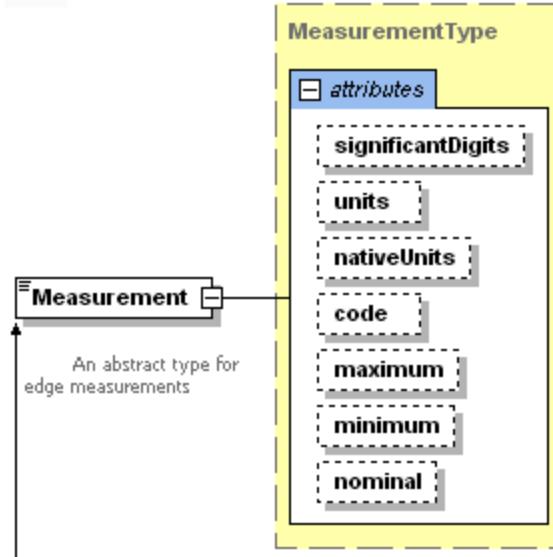
445 This allows additional properties to be defined for *CuttingTool* without having to  
446 change the definition of the definition of the *CuttingTool* or modify the standard, but  
447 requires *XML Schema* Version 1.1.

448 **6.2.7 Measurements Element for CuttingToolLifeCycle**

449 The *Measurements* element is a collection of one or more constrained scalar values  
450 associated with this *Cutting Tool*. The XML element **MUST** be a type extension of the  
451 base types *CommonMeasurement* or *AssemblyMeasurement*. The following sec-  
452 tion defines the abstract *Measurement* type used in both *CuttingToolLifeCycle*  
453 and *CuttingItem*. This subsequent sections describe the *AssemblyMeasurement*  
454 types followed by the *CuttingItemMeasurement* types.

455 A *Measurement* is specific to the tool management policy at a particular shop. The tool  
456 zero reference point or gauge line will be different depending on the particular implemen-  
457 tation and will be assumed to be consistent within the shop. *MTConnect Standard* does  
458 not standardize the manufacturing process or the definition of the zero point.

## 459 6.2.8 Measurement



**Figure 17:** Measurement Schema

460 A Measurement **MUST** be a scalar floating-point value that **MAY** be constrained to a  
 461 maximum and minimum value. Since the *CuttingToolLifeCycle*'s main responsi-  
 462 bility is to track aspects of the tool that change over its use in the shop, *MTConnect* repre-  
 463 sents the current value of the Measurement **MUST** be in the CDATA (text between the  
 464 start and end element) as the most current valid value.

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

468 There are three abstract subtypes of Measurement: CommonMeasurement, Assem-  
 469 blyMeasurement, and CuttingItemMeasurement. These abstract types **MUST**  
 470 **NOT** appear in an *MTConnectAssets* document, but are used in the schema as a way  
 471 to separate which measurements **MAY** appear in the different sections of the document.  
 472 Only subtypes that have extended these types **MAY** appear in the *MTConnectAssets*  
 473 XML.

474 Measurements in the *CuttingToolLifeCycle* section **MUST** refer to the en-  
 475 tire assembly and not to an individual *CuttingItem*. *CuttingItem* measurements  
 476 **MUST** be located in the measurements associated with the individual *CuttingItem*.

477 Measurements **MAY** provide an optional units attribute to reinforce the given units.  
 478 The units **MUST** always be given in the predefined *MTConnect* units. If units are

479 provided, they are only for documentation purposes. `nativeUnits` **MAY** optionally be  
 480 provided to indicate the original units provided for the measurements.

481 **6.2.8.1 Attributes for Measurement**

**Table 19:** Attributes for Measurement

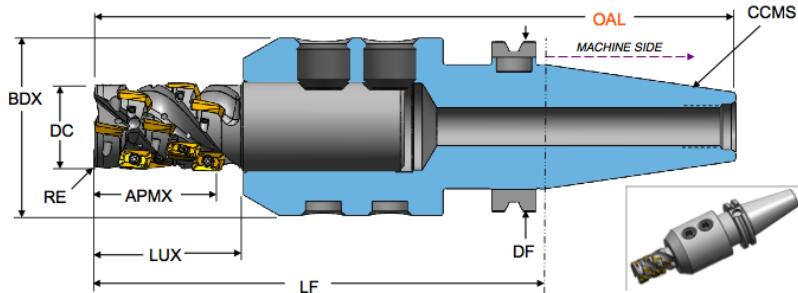
| Attribute                      | Description   | Occurrence |
|--------------------------------|---|------------|
| <code>code</code>              | A shop specific code for this measurement. ISO 13399 codes <b>MAY</b> be used for these codes as well.<br><br><code>code</code> is a optional attribute.  | 0..1       |
| <code>maximum</code>           | The maximum value for this measurement. Exceeding this value would indicate the tool is not usable.<br><br><code>maximum</code> is a optional attribute.  | 0..1       |
| <code>minimum</code>           | The minimum value for this measurement. Exceeding this value would indicate the tool is not usable.<br><br><code>minimum</code> is a optional attribute.  | 0..1       |
| <code>nominal</code>           | The as advertised value for this measurement.<br><br><code>nominal</code> is a optional attribute.  | 0..1       |
| <code>significantDigits</code> | The number of significant digits in the reported value. This is used by applications to determine accuracy of values. This <b>MAY</b> be specified for all numeric values.<br><br><code>significantDigits</code> is a optional attribute. | 0..1       |

| Continuation of Table 19 |  |            |
|--------------------------|--|------------|
| Attribute                | Description  | Occurrence |
| units                    | The units for the measurements. MTConnect Standard defines all the units for each measurement, so this is mainly for documentation sake. See <i>MTConnect Standard: Part 2.0 - Devices Information Model</i> 7.2.2.5 for the full list of units.<br><br>units is a optional attribute. | 0..1       |
| nativeUnits              | The units the measurement was originally recorded in. This is only necessary if they differ from units. See <i>MTConnect Standard: Part 2.0 - Devices Information Model</i> Section 7.2.2.6 for the full list of units.<br><br>nativeUnits is a optional attribute.                    | 0..1       |

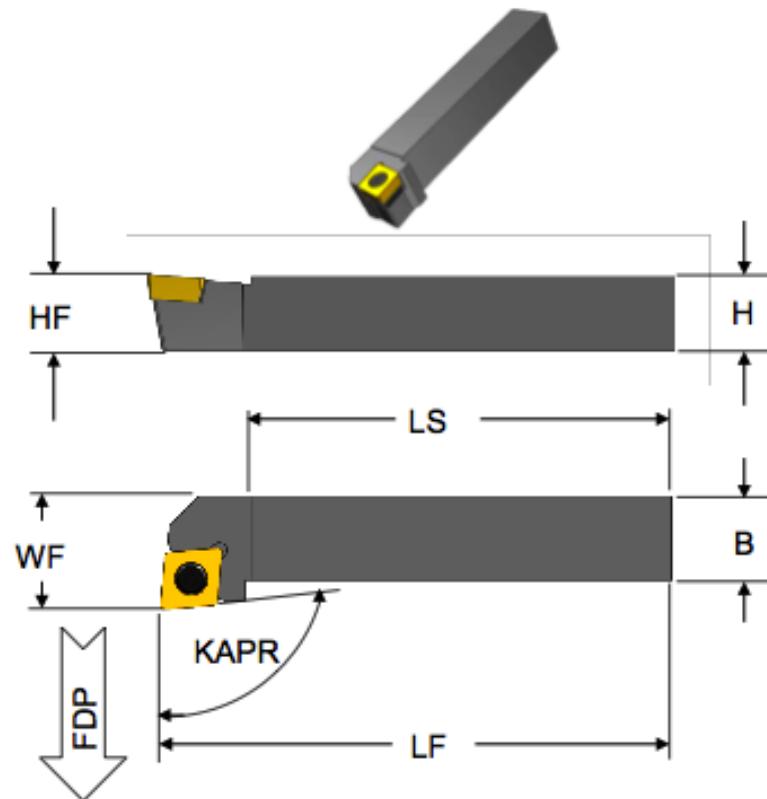
#### 482 6.2.8.2 Measurement Subtypes for CuttingToolLifeCycle

483 These Measurements for CuttingTool are specific to the entire assembly and **MUST**  
 484 **NOT** be used for the Measurement pertaining to a CuttingItem. *Figure 18* and *Fig-  
 485 ure 19* will be used to reference the assembly specific Measurements.

486 The Code in *Table 20* will refer to the acronyms in the diagrams. We will be referring to  
 487 many diagrams to disambiguate all measurements of the CuttingTool and Cuttin-  
 488 gItem.



**Figure 18:** Cutting Tool Measurement Diagram 1

**Figure 19:** Cutting Tool Measurement Diagram 2**Table 20:** Measurement Subtypes for CuttingTool

| Measurement Subtype | Code | Description                                      | Units      |
|---------------------|------|--|------------|
| BodyDiameterMax     | BDX  | The largest diameter of the body of a Tool Item. | MILLIMETER |

| Continuation of Table 20 |      |  |            |
|--------------------------|------|--|------------|
| Measurement Subtype      | Code | Description  | Units      |
| BodyLengthMax            | LBX  | 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. | MILLIMETER |
| DepthOfCutMax            | APMX | The maximum engagement of the cutting edge or edges with the workpiece measured perpendicular to the feed motion.  | MILLIMETER |
| CuttingDiameterMax       | DC   | 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.   | MILLIMETER |
| FlangeDiameterMax        | DF   | The dimension between two parallel tangents on the outside edge of a flange.   | MILLIMETER |
| OverallToolLength        | OAL  | The largest length dimension of the Cutting Tool including the master insert where applicable.   | MILLIMETER |

| Continuation of Table 20 |      |   |            |
|--------------------------|------|---|------------|
| Measurement Subtype      | Code | Description   | Units      |
| ShankDiameter            | DMM  | The dimension of the diameter of a cylindrical portion of a Tool Item or an Adaptive Item that can participate in a connection.     | MILLIMETER |
| ShankHeight              | H    | The dimension of the height of the shank.   | MILLIMETER |
| ShankLength              | LS   | The dimension of the length of the shank.   | MILLIMETER |
| UsableLengthMax          | LUX  | Maximum length of a Cutting Tool that can be used in a particular cutting operation including the non-cutting portions of the tool. | MILLIMETER |
| ProtrudingLength         | LPR  | The dimension from the yz-plane to the furthest point of the Tool Item or Adaptive Item measured in the -X direction.               | MILLIMETER |
| Weight                   | WT   | The total weight of the Cutting Tool in grams. The force exerted by the mass of the Cutting Tool.                                   | GRAM       |

| Continuation of Table 20 |      |   |            |
|--------------------------|------|---|------------|
| Measurement Subtype      | Code | Description   | Units      |
| FunctionalLength         | LF   | 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. | MILLIMETER |

#### 489 6.2.9 CuttingItems Element for CuttingToolLifeCycle

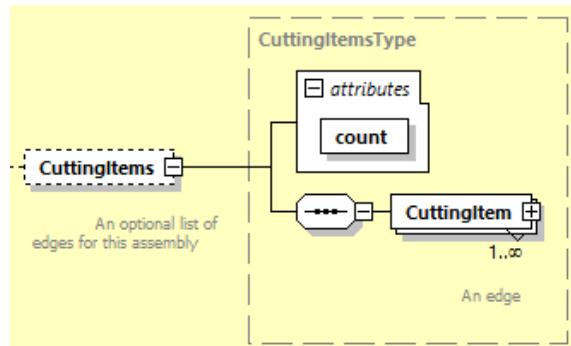


Figure 20: CuttingItems Schema

490 An optional collection of CuttingItems that **SHOULD** be provided for each indepen-  
 491 dent edge or insert. If the CuttingItems are not present; it indicates there is no specific  
 492 information with respect to each of the CuttingItems. This does not imply there are no  
 493 CuttingItems – there **MUST** be at least one CuttingItem – but there is no specific  
 494 information.

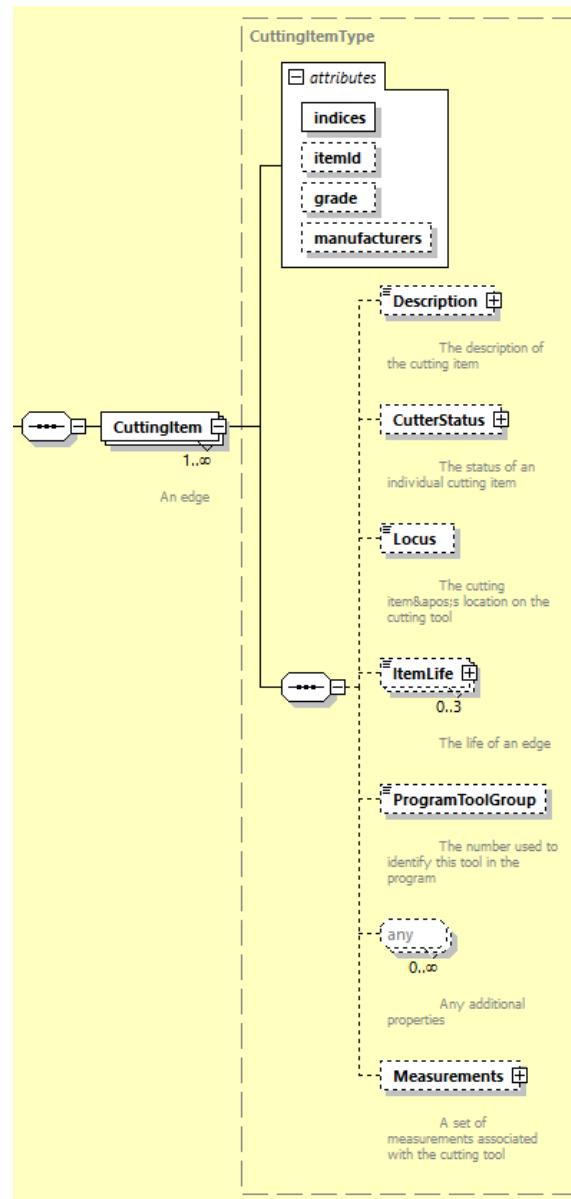
495 **6.2.9.1 Attributes for CuttingItems****Table 21:** Attributes for CuttingItems

| Attribute | Description   | Occurrence |
|-----------|---|------------|
| count     | The number of Cutting Item.<br><br>count is a required attribute. | 1          |

496 **6.2.10 CuttingItem**

497 A CuttingItem is the portion of the tool that physically removes the material from the  
 498 workpiece by shear deformation. The Cutting Item can be either a single piece of mate-  
 499 rial attached to the CuttingItem or it can be one or more separate pieces of material  
 500 attached to the CuttingItem using a permanent or removable attachment. A Cut-  
 501 tingItem can be comprised of one or more cutting edges. CuttingItems include:  
 502 replaceable inserts, brazed tips and the cutting portions of solid CuttingTools.

503 MTConnect Standard considers CuttingItems as part of the CuttingTool. A Cut-  
 504 tingItems **MUST NOT** exist in MTConnect unless it is attached to a CuttingTool.  
 505 Some of the measurements, such as FunctionalLength, **MUST** be made with refer-  
 506 ence to the entire CuttingTool to be meaningful.



**Figure 21:** CuttingItem Schema

507 **6.2.10.1 Attributes for CuttingItem****Table 22:** Attributes for CuttingItem

| Attribute     | Description  | Occurrence |
|---------------|--|------------|
| indices       | The number or numbers representing the individual Cutting Item or items on the tool.<br><br>indices is a required attribute. | 1          |
| itemId        | The manufacturer identifier of this Cutting Item.<br><br>itemId is an optional attribute.                                    | 0..1       |
| manufacturers | The manufacturers of the Cutting Item or Tool.<br><br>manufacturers is an optional attribute.                                | 0..1       |
| grade         | The material composition for this Cutting Item.<br><br>grade is an optional attribute.                                       | 0..1       |

508 **6.2.10.1.1 indices Attribute for CuttingItem**

509 An identifier that indicates the CuttingItem or CuttingItems these data are as-  
 510 sociated with. The value **MUST** be a single number ("1") or a comma separated set of  
 511 individual elements ("1,2,3,4"), or as a inclusive range of values as in ("1-10") or any  
 512 combination of ranges and numbers as in "1-4,6-10,22". There **MUST NOT** be spaces or  
 513 non-integer values in the text representation.

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

517 **6.2.10.1.2 itemId Attribute for CuttingItem**

518 The manufactures' identifier for this CuttingItem that **MAY** be its catalog or reference  
 519 number. The value **MUST** be an XML NMTOKEN value of numbers and letters.

520 **6.2.10.1.3 manufacturers Attribute for CuttingItem**

521 This optional element references the manufacturers of this tool. At this level the manufac-

522 turers will reference the CuttingItem specifically. The representation will be a comma  
 523 (,) delimited list of manufacturer names. This can be any series of numbers and letters as  
 524 defined by the XML type string.

525 **6.2.10.1.4 grade Attribute for CuttingItem**

526 This provides an implementation specific designation for the material composition of this  
 527 CuttingItem.

528 **6.2.10.2 Elements for CuttingItem**

**Table 23:** Elements for CuttingItem

| Element          | Description  | Occurrence |
|------------------|--|------------|
| Description      | A free-form description of the Cutting Item.   | 0..1       |
| Locus            | A free form description of the location on the Cutting Tool.   | 0..1       |
| ItemLife         | The life of this Cutting Item.   | 0..3       |
| Measurements     | A collection of measurements relating to this Cutting Item.  | 0..1       |
| CutterStatus     | The status of this item.<br><br>CutterStatus <b>MUST</b> one of the following values: NEW, AVAILABLE, UNAVAILABLE, ALLOCATED, UNALLOCATED, MEASURED, RECONDITIONED, NOT_REGISTERED, USED, EXPIRED, BROKEN, or UNKNOWN. | 0..1       |
| ProgramToolGroup | The tool group the part program assigned this item.  | 0..1       |

529 **6.2.10.2.1 Description Element for CuttingItem**

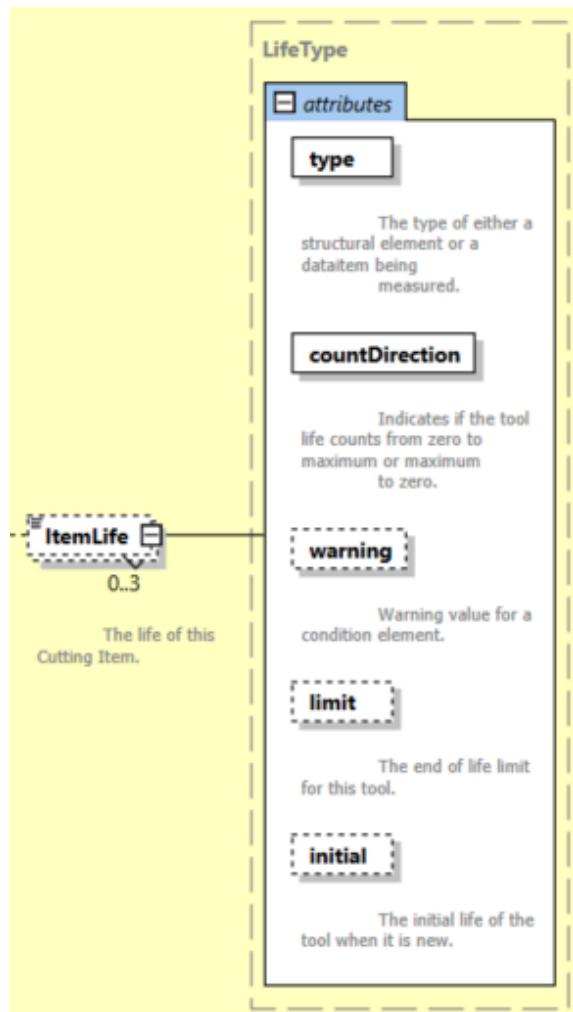
530 An optional free form text description of this CuttingItem.

531 **6.2.10.2.2 Locus Element for CuttingItem**

532 Locus represents the location of the CuttingItem with respect to the Cutting Tool.  
533 For clarity, the words FLUTE, INSERT, and CARTRIDGE **SHOULD** be used to assist in  
534 noting the location of a CuttingItem. The Locus **MAY** be any free form text, but  
535 **SHOULD** adhere to the following rules:

- 536 • The location numbering **SHOULD** start at the furthest CuttingItem (#1) and  
537 work it's way back to the Cutting Item closest to the gauge line.
- 538 • Flutes **SHOULD** be identified as such using the word FLUTE:. For example: FLUTE:  
539 1, INSERT: 2 - would indicate the first flute and the second furthest insert from the  
540 end of the tool on that flute.
- 541 • Other designations such as CARTRIDGE **MAY** be included, but should be identified  
542 using upper case and followed by a colon (:).

## 543 6.2.10.2.3 ItemLife Element for CuttingItem

**Figure 22:** ItemLife Schema

544 The value is the current value for the `ItemLife`. The value **MUST** be numeric. `Item-`  
 545 `Life` is an option element which can have three types, either minutes for time based, part  
 546 count for parts based, or wear based using a distance measure. One `ItemLife` can ap-  
 547 pear for each type, but there cannot be two entries of the same type. Additional types can  
 548 be added in the future.

549 **6.2.10.2.4 Attributes for ItemLife**

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

**Table 24:** Attributes for ItemLife

| Attribute      | Description  | Occurrence |
|----------------|--|------------|
| type           | The type of tool life being accumulated.<br><br><i>Valid Data Values:</i><br>MINUTES, PART_COUNT, or WEAR.<br><br>type is a required attribute.  | 1          |
| countDirection | Indicates if the tool life counts from zero to maximum or maximum to zero. The value <b>MUST</b> be one of UP or DOWN.<br><br>countDirection is a required attribute.  | 1          |
| warning        | The point at which a tool life warning will be raised.<br><br>warning is an optional attribute.  | 0..1       |
| limit          | The end of life limit for this tool.<br><br>If the countDirection is DOWN, the point at which this tool should be expired, usually zero.<br>If the countDirection is UP, this is the upper limit for which this tool should be expired.<br><br>limit is an optional attribute. | 0..1       |
| initial        | The initial life of the tool when it is new.<br><br>initial is an optional attribute.  | 0..1       |

551 **6.2.10.2.5 type Attribute for ItemLife**

552 The value of type must be one of the following:

**Table 25:** Values for type of ItemLife

| Value      | Description   |
|------------|---|
| MINUTES    | The tool life measured in minutes. All units for minimum, maximum, and nominal <b>MUST</b> be provided in minutes.  |
| PART_COUNT | The tool life measured in parts. All units for minimum, maximum, and nominal <b>MUST</b> be provided as the number of parts.  |
| WEAR       | The tool life measured in tool wear. Wear <b>MUST</b> be provided in millimeters as an offset to nominal. All units for minimum, maximum, and nominal <b>MUST</b> be given as millimeter offsets as well. |

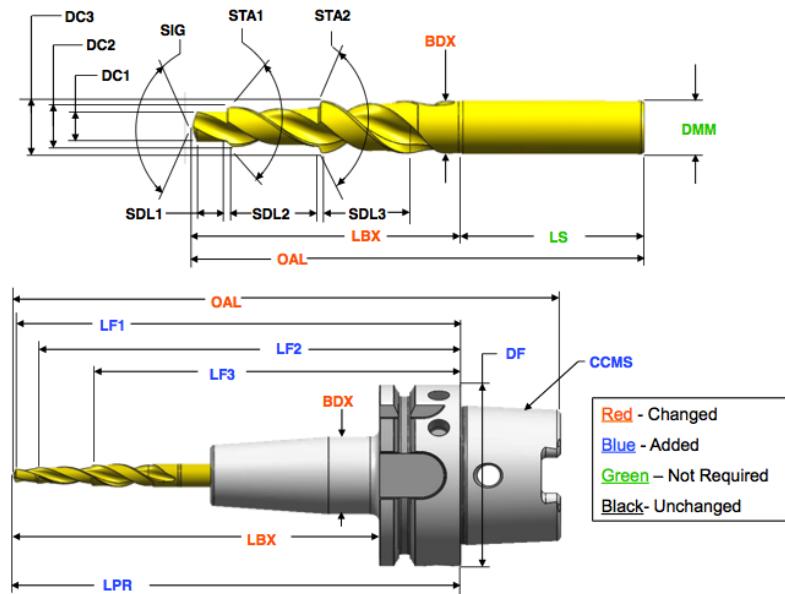
553 **6.2.10.2.6 countDirection Attribute for ItemLife**

554 The value of type must be one of the following:

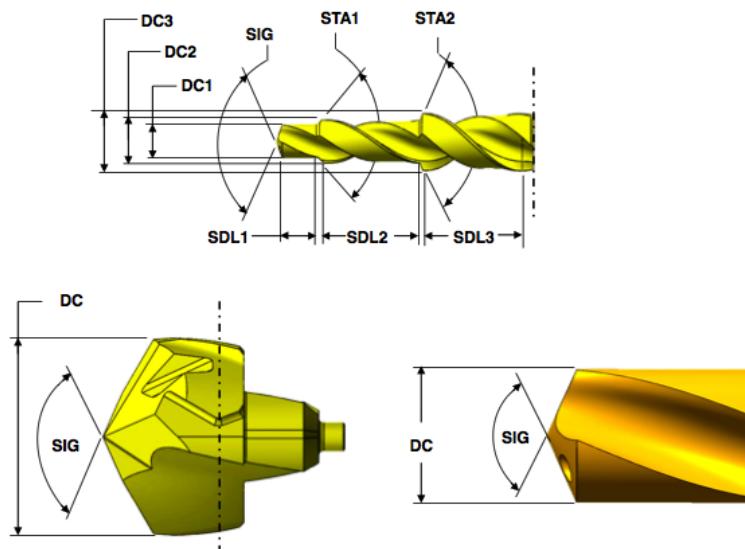
**Table 26:** Values for countDirection

| Value | Description   |
|-------|---|
| UP    | The tool life counts up from zero to the maximum.   |
| DOWN  | The tool life counts down from the maximum to zero. |

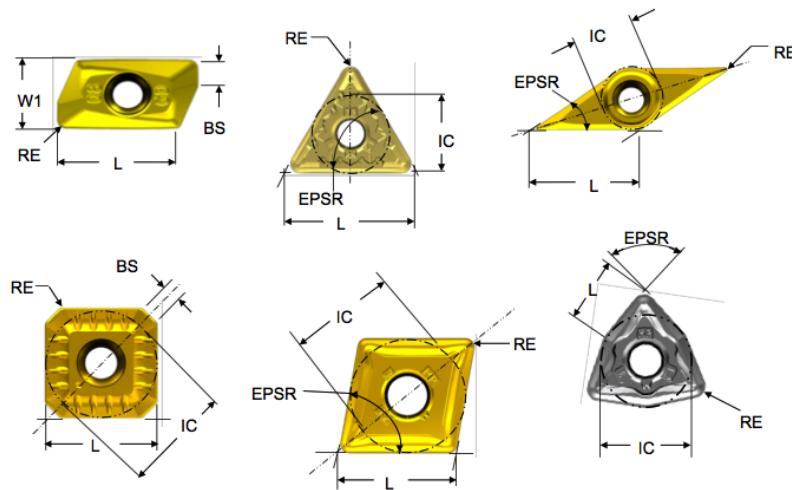
555 **6.2.10.3 Measurement Subtypes for CuttingItem**556 These Measurements for CuttingItem are specific to an individual CuttingItem  
557 and **MUST NOT** be used for the Measurements pertaining to an assembly. The *Fig-*  
558 *ure 23 , Figure 24 , Figure 25* and *Figure 26* will be used to for reference for the Cut-  
559 *tingItem specific Measurements .*560 The Code in *Table 27* will refer to the acronym in the diagram. We will be referring to  
561 many diagrams to disambiguate all Measurements of the CuttingTools and Cut-  
562 tingItems. We will present a few here; please refer to Appendix B for additional  
563 reference material.



**Figure 23:** Cutting Tool



**Figure 24:** Cutting Item

**Figure 25:** Cutting Item Measurement Diagram 3**Figure 26:** Cutting Item Drive Angle

564 The CuttingItem Measurements in *Table 27* will refer the *Figure 23* , *Figure 24* ,  
 565 *Figure 25* and *Figure 26* .

**Table 27:** Measurement Subtypes for CuttingItem

| Measurement Subtype   | Code | Description   | Units      |
|-----------------------|------|---|------------|
| CuttingReferencePoint | CRP  | The theoretical sharp point of the Cutting Tool from which the major functional dimensions are taken. | MILLIMETER |

| Continuation of Table 27 |      |  |            |
|--------------------------|------|--|------------|
| Measurement Subtype      | Code | Description  | Units      |
| CuttingEdgeLength        | L    | The theoretical length of the cutting edge of a Cutting Item over sharp corners.   | MILLIMETER |
| DriveAngle               | DRVA | Angle between the driving mechanism locator on a Tool Item and the main cutting edge.  | DEGREE     |
| FlangeDiameter           | DF   | The dimension between two parallel tangents on the outside edge of a flange.   | MILLIMETER |
| FunctionalWidth          | WF   | The distance between the cutting reference point and the rear backing surface of a turning tool or the axis of a boring bar. | MILLIMETER |
| InscribedCircleDiameter  | IC   | The diameter of a circle to which all edges of a equilateral and round regular insert are tangential.                        | MILLIMETER |
| PointAngle               | SIG  | The angle between the major cutting edge and the same cutting edge rotated by 180 degrees about the tool axis.               | DEGREE     |
| ToolCuttingEdgeAngle     | KAPR | The angle between the tool cutting edge plane and the tool feed plane measured in a plane parallel the xy-plane.             | DEGREE     |

| Continuation of Table 27 |      |  |            |
|--------------------------|------|--|------------|
| Measurement Subtype      | Code | Description  | Units      |
| ToolLeadAngle            | PSIR | 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.  | DEGREE     |
| ToolOrientation          | N/A  | The angle of the tool with respect to the workpiece for a given process. The value is application specific.  | DEGREE     |
| WiperEdgeLength          | BS   | The measure of the length of a wiper edge of a Cutting Item.   | MILLIMETER |
| StepDiameterLength       | SDLx | 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. | MILLIMETER |
| StepIncludedAngle        | STAx | 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.  | DEGREE     |

| Continuation of Table 27 |      |  |            |
|--------------------------|------|--|------------|
| Measurement Subtype      | Code | Description  | Units      |
| CuttingDiameter          | DCx  | The diameter of a circle on which the defined point Pk located on this Cutting Tool. The normal of the machined peripheral surface points towards the axis of the Cutting Tool.  | MILLIMETER |
| CuttingHeight            | HF   | The distance from the basal plane of the Tool Item to the cutting point.   | MILLIMETER |
| CornerRadius             | RE   | The nominal radius of a rounded corner measured in the X Y-plane.  | MILLIMETER |
| Weight                   | WT   | The total weight of the Cutting Tool in grams. The force exerted by the mass of the Cutting Tool.  | GRAM       |
| FunctionalLength         | LFx  | 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 <b>MUST NOT</b> exist without a Cutting Tool. | MILLIMETER |
| ChamferFlatLength        | BCH  | The flat length of a chamfer.  | MILLIMETER |
| ChamferWidth             | CHW  | The width of the chamfer.  | MILLIMETER |

| Continuation of Table 27 |      |   |            |
|--------------------------|------|---|------------|
| Measurement Subtype      | Code | Description   | Units      |
| InsertWidth              | W1   | W1 is used for the insert width when an inscribed circle diameter is not practical. | MILLIMETER |

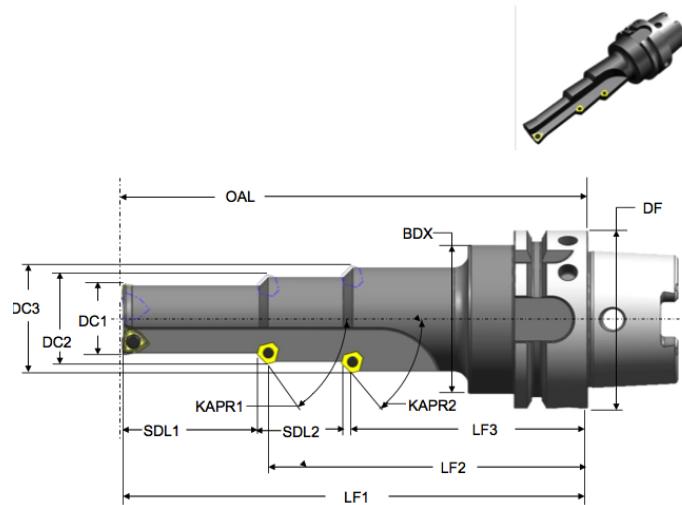
## 566 Appendices

### 567 A Bibliography

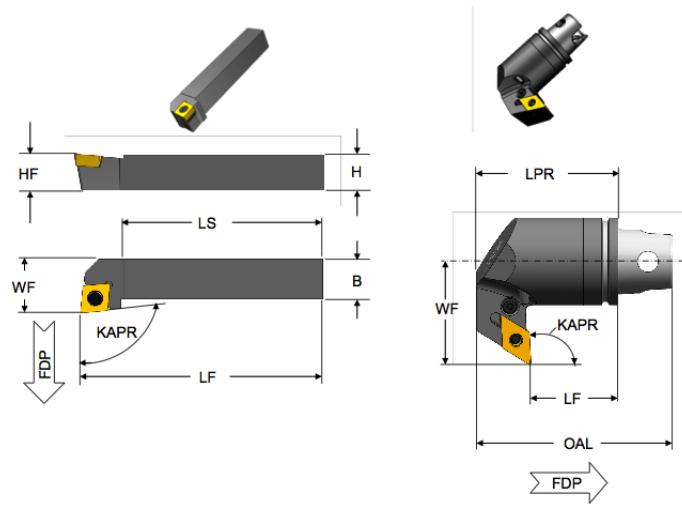
- 568 Engineering Industries Association. *EIA Standard - EIA-274-D*, Interchangeable Variable,  
569 Block Data Format for Positioning, Contouring, and Contouring/Positioning Numerically  
570 Controlled Machines. Washington, D.C. 1979.
- 571 ISO TC 184/SC4/WG3 N1089. *ISO/DIS 10303-238*: Industrial automation systems and  
572 integration Product data representation and exchange Part 238: Application Protocols: Ap-  
573 plication interpreted model for computerized numerical controllers. Geneva, Switzerland,  
574 2004.
- 575 International Organization for Standardization. *ISO 14649*: Industrial automation sys-  
576 tems and integration – Physical device control – Data model for computerized numerical  
577 controllers – Part 10: General process data. Geneva, Switzerland, 2004.
- 578 International Organization for Standardization. *ISO 14649*: Industrial automation sys-  
579 tems and integration – Physical device control – Data model for computerized numerical  
580 controllers – Part 11: Process data for milling. Geneva, Switzerland, 2000.
- 581 International Organization for Standardization. *ISO 6983/1* – Numerical Control of ma-  
582 chines – Program format and definition of address words – Part 1: Data format for posi-  
583 tioning, line and contouring control systems. Geneva, Switzerland, 1982.
- 584 Electronic Industries Association. *ANSI/EIA-494-B-1992*, 32 Bit Binary CL (BCL) and  
585 7 Bit ASCII CL (ACL) Exchange Input Format for Numerically Controlled Machines.  
586 Washington, D.C. 1992.
- 587 National Aerospace Standard. *Uniform Cutting Tests* - NAS Series: Metal Cutting Equip-  
588 ment Specifications. Washington, D.C. 1969.
- 589 International Organization for Standardization. *ISO 10303-11*: 1994, Industrial automa-  
590 tion systems and integration Product data representation and exchange Part 11: Descrip-  
591 tion methods: The EXPRESS language reference manual. Geneva, Switzerland, 1994.
- 592 International Organization for Standardization. *ISO 10303-21*: 1996, Industrial automa-  
593 tion systems and integration – Product data representation and exchange – Part 21: Imple-  
594 mentation methods: Clear text encoding of the exchange structure. Geneva, Switzerland,  
595 1996.
- 596 H.L. Horton, F.D. Jones, and E. Oberg. *Machinery's Handbook*. Industrial Press, Inc.

- 597 New York, 1984.
- 598 International Organization for Standardization. *ISO 841-2001: Industrial automation sys-*  
599 *tems and integration - Numerical control of machines - Coordinate systems and motion*  
600 *nomenclature.* Geneva, Switzerland, 2001.
- 601 ASME B5.59-2 Version 9c: *Data Specification for Properties of Machine Tools for Milling*  
602 *and Turning.* 2005.
- 603 ASME/ANSI B5.54: *Methods for Performance Evaluation of Computer Numerically Con-*  
604 *trolled Machining Centers.* 2005.
- 605 OPC Foundation. *OPC Unified Architecture Specification, Part 1: Concepts Version 1.00.*  
606 July 28, 2006.
- 607 International Organization for Standardization. *ISO 13399: Cutting tool data representa-*  
608 *tion and exchange.* Geneva, Switzerland, 2000.

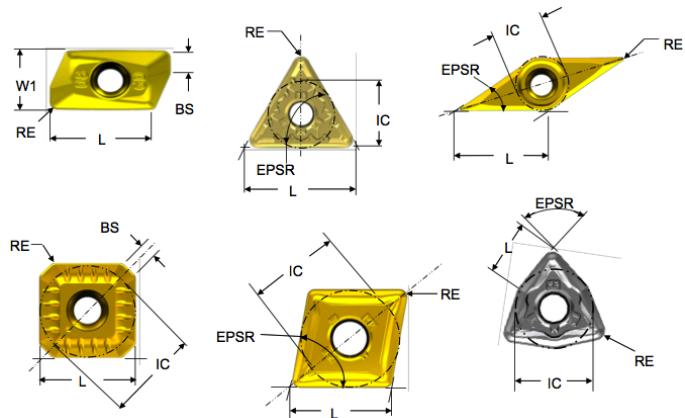
## 609 B Additional Illustrations



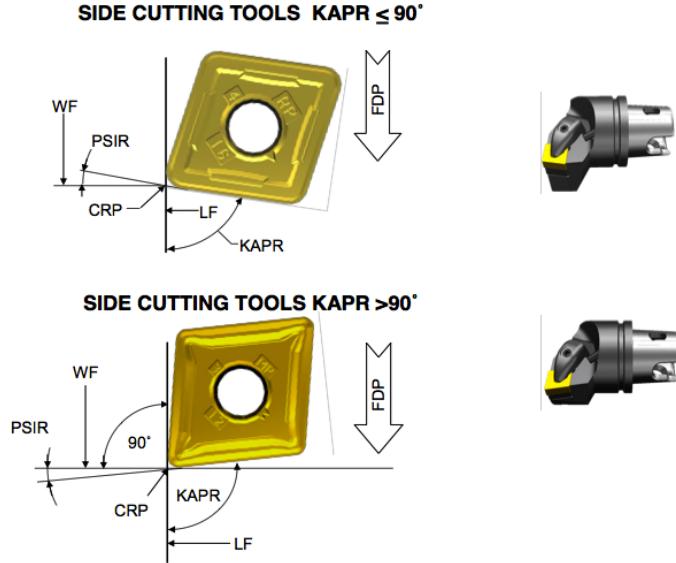
**Figure 27:** Cutting Tool Measurement Diagram 1  
(Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)



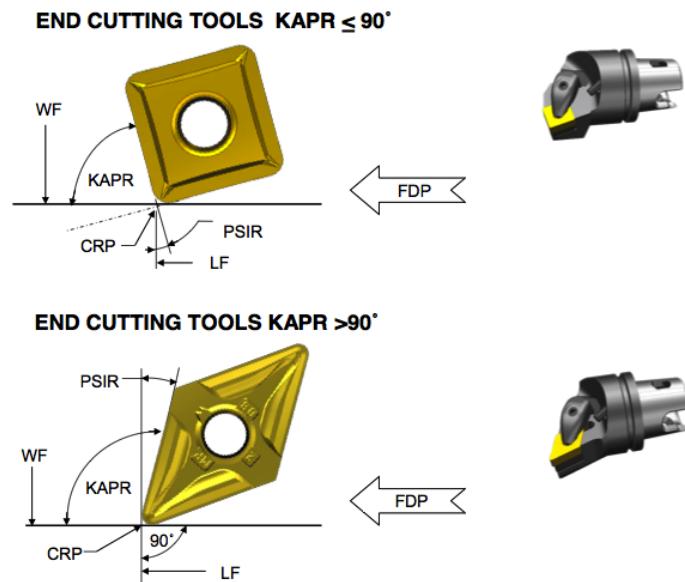
**Figure 28:** Cutting Tool Measurement Diagram 2  
(Cutting Tool, Cutting Item, and Assembly Item – ISO 13399)



**Figure 29:** Cutting Tool Measurement Diagram 3  
(Cutting Item – ISO 13399)

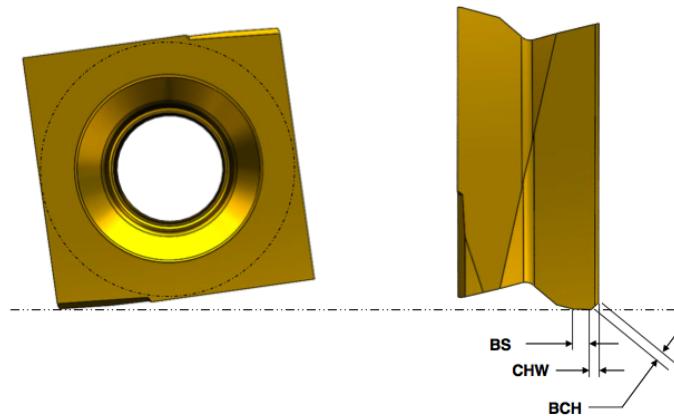


**Figure 30:** Cutting Tool Measurement Diagram 4  
(Cutting Item – ISO 13399)



**Figure 31:** Cutting Tool Measurement Diagram 5  
(Cutting Item – ISO 13399)

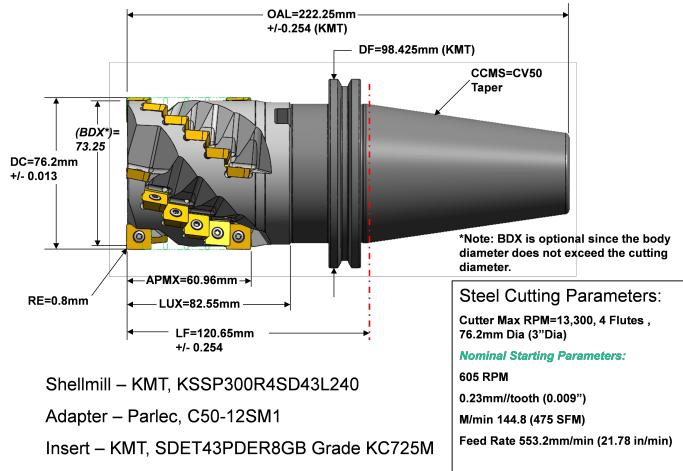
BCH = CHAMFER FLAT LENGTH  
CHW = CHAMFER WIDTH



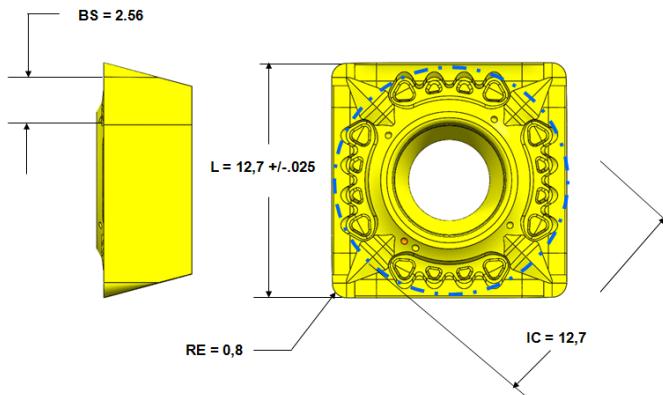
**Figure 32:** Cutting Tool Measurement Diagram 6  
(Cutting Item – ISO 13399)

## 610 C Cutting Tool Example

### 611 C.1 Shell Mill



**Figure 33:** Shell Mill Side View



**Figure 34:** Indexable Insert Measurements

#### Example 1: Example for Indexable Insert Measurements

```

612 1 <?xml version="1.0" encoding="UTF-8"?>
613 2 <MTConnectAssets
614 3 xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
615 4 xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
616 5 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
617 6 xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
618 7 http://mtconnect.org/schemas/MTConnectAssets\_1.2.xsd">
619 8   <Header creationTime="2011-05-11T13:55:22"
620 9     assetBufferSize="1024" sender="localhost"
```

```

621 10    assetCount="2" version="1.2" instanceId="1234"/>
622 11    <Assets>
623 12      <CuttingTool serialNumber="1" toolId="KSSP300R4SD43L240"
624 13          timestamp="2011-05-11T13:55:22" assetId="KSSP300R4SD43L240.1"
625 14          manufacturers="KMT, Parlec">
626 15            <CuttingToolLifeCycle>
627 16              <CutterStatus><Status>NEW</Status></CutterStatus>
628 17              <ProcessSpindleSpeed maximum="13300"
629 18                  nominal="605">10000</ProcessSpindleSpeed>
630 19              <ProcessFeedRate
631 20                  nominal="9.22">9.22</ProcessSpindleSpeed>
632 21              <ConnectionCodeMachineSide>CV50
633 22              </ConnectionCodeMachineSide>
634 23      <Measurements>
635 24          <BodyDiameterMax code="BDX">73.25
636 25          </BodyDiameterMax>
637 26          <OverallToolLength nominal="222.25"
638 27              minimum="221.996" maximum="222.504"
639 28                  code="OAL">222.25</OverallToolLength>
640 29          <UsableLengthMax code="LUX" nominal="82.55">82.55
641 30          </UsableLengthMax>
642 31          <CuttingDiameterMax code="DC" nominal="76.2"
643 32              maximum="76.213" minimum="76.187">76.2
644 33          </CuttingDiameterMax>
645 34          <BodyLengthMax code="LF" nominal="120.65"
646 35              maximum="120.904" minimum="120.404">120.65
647 36          </BodyLengthMax>
648 37          <DepthOfCutMax code="APMX"
649 38              nominal="60.96">60.95</DepthOfCutMax>
650 39          <FlangeDiameterMax code="DF"
651 40              nominal="98.425">98.425</FlangeDiameterMax>
652 41      </Measurements>
653 42      <CuttingItems count="24">
654 43          <CuttingItem indices="1-24" itemId="SDET43PDER8GB"
655 44              manufacturers="KMT" grade="KC725M">
656 45              <Measurements>
657 46                  <CuttingEdgeLength code="L" nominal="12.7"
658 47                      minimum="12.675" maximum="12.725">12.7
659 48                  </CuttingEdgeLength>
660 49                  <WiperEdgeLength code="BS" nominal=
661 50                      "2.56">2.56</WiperEdgeLength>
662 51                  <InscribedCircleDiameter code="IC"
663 52                      nominal="12.7">12.7
664 53                  </InscribedCircleDiameter>
665 54                  <CornerRadius code="RE" nominal="0.8">
666 55                      0.8</CornerRadius>
667 56                  </Measurements>
668 57                  </CuttingItem>
669 58          </CuttingItems>
670 59      </CuttingToolLifeCycle>
671 60  </CuttingTool>
```

```
672 61    </Assets>
673 62  </MTConnectAssets>
```

## 674 C.2 Step Drill

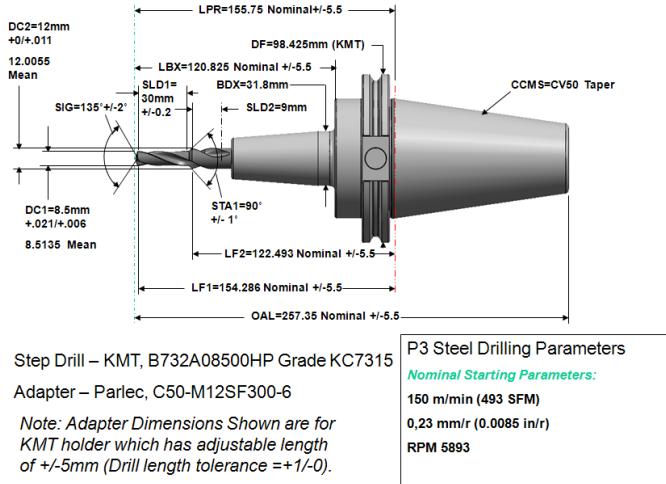


Figure 35: Step Mill Side View

### Example 2: Example for Step Mill Side View

```

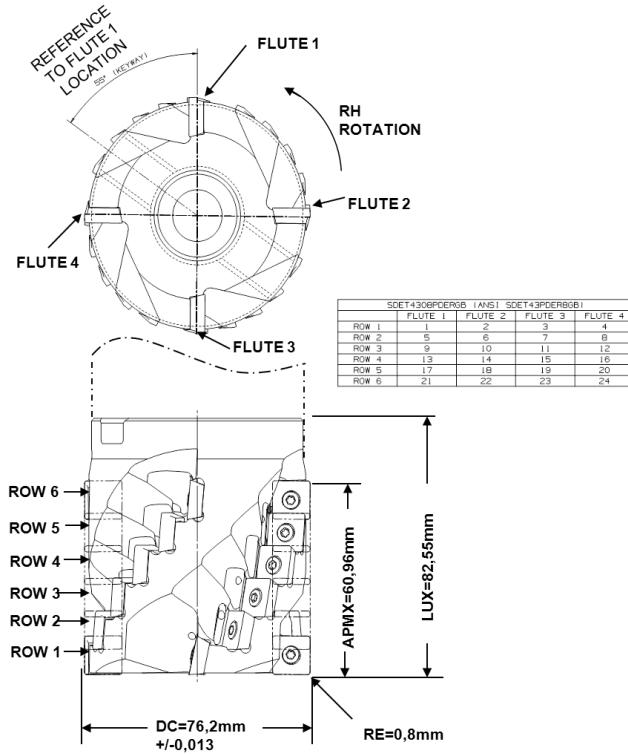
675 1 <?xml version="1.0" encoding="UTF-8"?>
676 2 <MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
677 3 xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
678 4 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
679 5 xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
680 6 http://mtconnect.org/schemas/MTConnectAssets\1.2.xsd">
681 7   <Header creationTime="2011-05-
682 8     _11T13:55:22" assetBufferSize="1024"
683 9     sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
684 10  <Assets>
685 11    <CuttingTool serialNumber="1" toolId="B732A08500HP"
686 12      timestamp="2011-05-11T13:55:22" assetId="B732A08500HP_"
687 13      manufacturers="KMT, Parlec">
688 14      <Description>
689 15        Step Drill - KMT, B732A08500HP Grade KC7315
690 16        Adapter - Parlec, C50-M12SF300-6
691 17      </Description>
692 18      <CuttingToolLifeCycle>
693 19        <CutterStatus><Status>NEW</Status></CutterStatus>
694 20        <ProcessSpindleSpeed nominal="5893">5893</ProcessSpindleSpeed>
695 21        <ProcessFeedRate nominal="2.5">2.5</ProcessFeedRate>
696 22        <ConnectionCodeMachineSide>CV50 Taper</ConnectionCodeMachineSide>
697 23      <Measurements>
698 24        <BodyDiameterMax code="BDX">31.8</BodyDiameterMax>
699 25        <BodyLengthMax code="LBX" nominal="120.825" maximum="126.325"
700 26          minimum="115.325">120.825</BodyLengthMax>
701 27        <ProtrudingLength code="LPR" nominal="155.75" maximum="161.25"
702 28          minimum="150.26">155.75</ProtrudingLength>
```

```

703 29      <FlangeDiameterMax code="DF"
704 30          nominal="98.425">98.425</FlangeDiameterMax>
705 31      <OverallToolLength nominal="257.35" minimum="251.85"
706 32          maximum="262.85" code="OAL">257.35</OverallToolLength>
707 33  </Measurements>
708 34  <CuttingItems count="2">
709 35      <CuttingItem indices="1" manufacturers="KMT" grade="KC7315">>
710 36          <Measurements>
711 37              <CuttingDiameter code="DC1" nominal="8.5" maximum="8.521"
712 38                  minimum="8.506">8.5135</CuttingDiameter>
713 39              <StepIncludedAngle code="STA1" nominal="90" maximum="91"
714 40                  minimum="89">90</StepIncludedAngle>
715 41              <FunctionalLength code="LF1" nominal="154.286"
716 42                  minimum="148.786"
717 43                  maximum="159.786">154.286</FunctionalLength>
718 44              <StepDiameterLength code="SDL1"
719 45                  nominal="9">9</StepDiameterLength>
720 46              <PointAngle code="SIG" nominal="135" minimum="133"
721 47                  maximum="137">135</PointAngle>
722 48          </Measurements>
723 49      </CuttingItem>
724 50      <CuttingItem indices="2" manufacturers="KMT" grade="KC7315">>
725 51          <Measurements>
726 52              <CuttingDiameter code="DC2" nominal="12" maximum="12.011"
727 53                  minimum="12">12</CuttingDiameter>
728 54              <FunctionalLength code="LF2" nominal="122.493"
729 55                  maximum="127.993"
730 56                  minimum="116.993">122.493</FunctionalLength>
731 57              <StepDiameterLength code="SDL2"
732 58                  nominal="9">9</StepDiameterLength>
733 59          </Measurements>
734 60      </CuttingItem>
735 61  </CuttingItems>
736 62  </CuttingToolLifeCycle>
737 63  </CuttingTool>
738 64  </Assets>
739 65 </MTConnectAssets>

```

### 740 C.3 Shell Mill with Individual Loci



**Figure 36:** Shell Mill with Explicate Loci

#### Example 3: Example for Shell Mill with Explicate Loci

```

741 1 <?xml version="1.0" encoding="UTF-8"?>
742 2 <MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
743 3 xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
744 4 xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
745 5 xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
746 6 http://mtconnect.org/schemas/MTConnectAssets\_1.2.xsd">
747 7 <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
748 8 sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
749 9 <Assets>
750 10 <CuttingTool serialNumber="1" toolID="KSSP300R4SD43L240"
751 11 timestamp="2011-05-11T13:55:22" assetId="KSSP300R4SD43L240.1"
752 12 manufacturers="KMT, Parlec">
753 13 <Description>Keyway: 55 degrees</Description>
754 14 <CuttingToolLifeCycle>
755 15 <CutterStatus><Status>NEW</Status></CutterStatus>
756 16 <Measurements>
757 17 <UsableLengthMax code="LUX"
758 18 nominal="82.55">82.55</UsableLengthMax>
759 19 <CuttingDiameterMax code="DC" nominal="76.2" maximum="76.213"
```

```
760 20      minimum="76.187">76.2</CuttingDiameterMax>
761 21      <DepthOfCutMax code="APMX" nominal="60.96">60.95</DepthOfCutMax>
762 22  </Measurements>
763 23  <CuttingItems count="24">
764 24      <CuttingItem indices="1" itemId="SDET43PDER8GB"
765 25      manufacturers="KMT">
766 26          <Locus>FLUTE: 1, ROW: 1</Locus>
767 27          <Measurements>
768 28              <DriveAngle code="DRVA" nominal="55">55</DriveAngle>
769 29          </Measurements>
770 30      </CuttingItem>
771 31      <CuttingItem indices="2-24" itemId="SDET43PDER8GB"
772 32      manufacturers="KMT">
773 33          <Locus>FLUTE: 2-4, ROW: 1; FLUTE: 1-4, ROW 2-6</Locus>
774 34          </CuttingItem>
775 35      </CuttingItems>
776 36      </CuttingToolLifeCycle>
777 37      </CuttingTool>
778 38  </Assets>
779 39 </MTConnectAssets>
```

## 780 C.4 Drill with Individual Loci

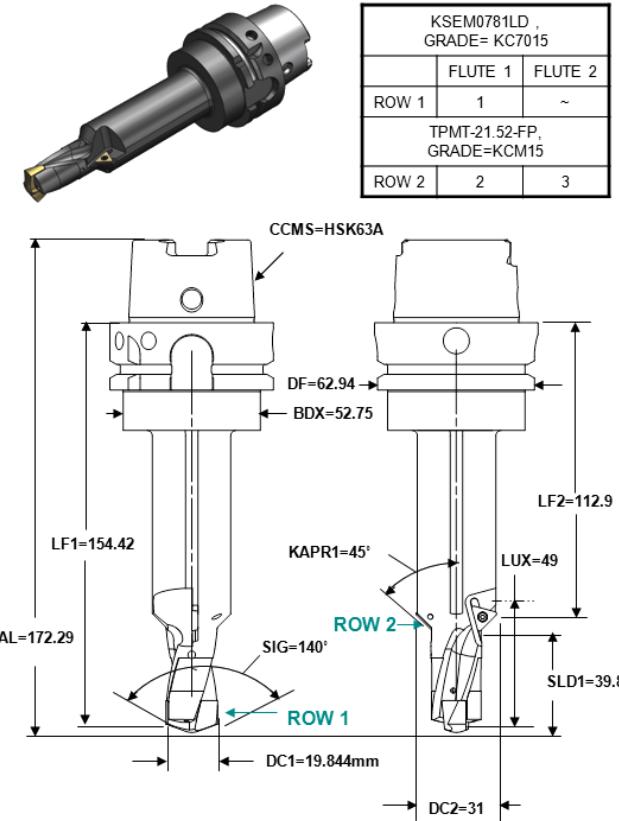


Figure 37: Step Drill with Explicate Loci

## Example 4: Example for Step Drill with Explicate Loci

```

781 1 <?xml version="1.0" encoding="UTF-8"?>
782 2 <MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
783 3   xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
784 4   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
785 5   xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
786 6   http://mtconnect.org/schemas/MTConnectAssets\1.2.xsd">
787 7   <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
788 8     sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
789 9   <Assets>
790 10     <CuttingTool serialNumber="1" toolId="KSEM0781LD"
791 11       timestamp="2011-05-11T13:55:22" assetId="KSEM0781LD.1" manufacturers="KMT">
792 12       <CuttingToolLifeCycle>
793 13         <CutterStatus><Status>NEW</Status></CutterStatus>
794 14         <ConnectionCodeMachineSide>HSK63A</ConnectionCodeMachineSide>
795 15         <Measurements>
796 16           <BodyDiameterMax code="BDX">52.75</BodyDiameterMax>
797 17           <OverallToolLength nominal="172.29"

```

```

798 18      code="OAL">172.29</OverallToolLength>
799 19      <UsableLengthMax code="LUX" nominal="49">49</UsableLengthMax>
800 20      <FlangeDiameterMax code="DF"
801 21          nominal="62.94">62.94</FlangeDiameterMax>
802 22      </Measurements>
803 23      <CuttingItems count="3">
804 24          <CuttingItem indices="1" itemId="KSEM0781LD" manufacturers="KMT"
805 25              grade="KC7015">
806 26              <Locus>FLUTE: 1, ROW: 1</Locus>
807 27              <Measurements>
808 28                  <FunctionalLength code="LF1" nominal="154.42">154.42</FunctionalLength>
809 29                  <CuttingDiameter code="DC1" nominal="19.844">19.844</CuttingDiameter>
810 30                  <PointAngle code="SIG" nominal="140">140</PointAngle>
811 31                  <ToolCuttingEdgeAngle code="KAPR1" nominal="45">45</ToolCuttingEdgeAngle>
812 32                  <StepDiameterLength code="SLD1" nominal="39.8">39.8</StepDiameterLength>
813 33          </Measurements>
814 34      </CuttingItem>
815 35      <CuttingItem indices="2-3" itemId="TPMT-21.52-FP"
816 36          manufacturers="KMT" grade="KCM15">
817 37          <Locus>FLUTE: 1-2, ROW: 2</Locus>
818 38          <Measurements>
819 39              <FunctionalLength code="LF2" nominal="112.9">119.2</FunctionalLength>
820 40              <CuttingDiameter code="DC2" nominal="31">31</CuttingDiameter>
821 41          </Measurements>
822 42      </CuttingItem>
823 43  </CuttingItems>
824 44      </CuttingToolLifeCycle>
825 45  </CuttingTool>
826 46  </Assets>
827 47 </MTConnectAssets>

```

## 828 C.5 Shell Mill with Different Inserts on First Row

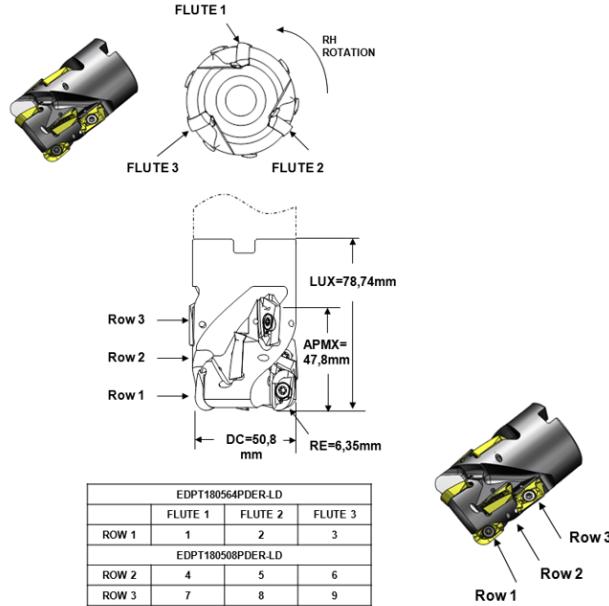


Figure 38: Shell Mill with Different Inserts on First Row

**Example 5:** Example for Shell Mill with Different Inserts on First Row

```

829 1 <?xml version="1.0" encoding="UTF-8"?>
830 2 <MTConnectAssets xmlns:m="urn:mtconnect.org:MTConnectAssets:1.2"
831 3   xmlns="urn:mtconnect.org:MTConnectAssets:1.2"
832 4   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
833 5   xsi:schemaLocation="urn:mtconnect.org:MTConnectAssets:1.2
834 6   http://mtconnect.org/schemas/MTConnectAssets\1.2.xsd">
835 7     <Header creationTime="2011-05-11T13:55:22" assetBufferSize="1024"
836 8       sender="localhost" assetCount="2" version="1.2" instanceId="1234"/>
837 9     <Assets>
838 10       <CuttingTool serialNumber="1" toolId="XXX" timestamp="2011-05-11T13:55:22"
839 11         assetId="XXX.1" manufacturers="KMT">
840 12           <CuttingToolLifeCycle>
841 13             <CutterStatus><Status>NEW</Status></CutterStatus>
842 14             <Measurements>
843 15               <DepthOfCutMax code="APMX" nominal="47.8">47.8</DepthOfCutMax>
844 16               <CuttingDiameterMax code="DC"
845 17                 nominal="50.8">50.8</CuttingDiameterMax>
846 18               <UsableLengthMax code="LUX"
847 19                 nominal="78.74">78.74</UsableLengthMax>
848 20             </Measurements>
849 21             <CuttingItems count="9">
850 22               <CuttingItem indices="1-3" itemId="EDPT180564PDER-LD"
851 23                 manufacturers="KMT">
852 24                 <Locus>FLUTE: 1-3, ROW: 1</Locus>

```

```
853 25      <Measurements>
854 26          <CornerRadius code="RE" nominal="6.25">6.35</CornerRadius>
855 27      </Measurements>
856 28  </CuttingItem>
857 29      <CuttingItem indices="4-9" itemId="EDPT180508PDER-LD"
858 30          manufacturers="KMT">
859 31          <Locus>FLANGE: 1-4, ROW: 2-3</Locus>
860 32      </CuttingItem>
861 33      </CuttingItems>
862 34  </CuttingToolLifeCycle>
863 35      </CuttingTool>
864 36  </Assets>
865 37  </MTConnectAssets>
```